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23. Aeolus; or, the future of the flying machine — Major Oliver Stewart [2025]

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Scientific feeding

Dora C. C. L. Roper

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SCIENTIFIC FEEDING

_By_ MRS. DORA C. C. L. ROPER D.O.

SECOND EDITION

OAKLAND, CALIFORNIA R. S. KITCHENER, Printer 1914

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·DEDICATION·

THESE PAGES ARE DEDICATED TO ALL WHO READ THEM, WITH THE EARNEST DESIRE TO MAINTAIN HEALTH AND PREVENT DISEASES WHICH ARE CREATED BY WRONG AND INTEMPERATE EATING AND DRINKING

■

Eat not to dullness; Drink not to elevation.

--Benjamin Franklin

[Illustration]

Man is composed of what he has assimilated from his spiritual mental and physical food

[Illustration: CONTENTS]

Page

Introduction 7

Preface 9

PART I.

Chapter I. Food. Classification and Function of Foods 13

Chapter II. Study of Foods 16

PART II.

Preparation of Foods.

Table of Measures and Weights 43

Chapter I. Green Vegetables 43

Chapter II. Legumes and Meats 43

Chapter III. Fish, Cheese and Eggs 57-64

Chapter IV. Soups 67

Chapter V. Cereals, Noodles and Dumplings 76

Chapter VI. Breads, Cakes and Puddings 84

Chapter VII. Sauces and Salad Dressings 98

Chapter VIII. Salads 104

Chapter IX. Gelatines and Toasts 111

Chapter X. Fruits, Puddings and Gruels 119

Chapter XI. Fluids 129

PART III.

Chapter I. Food Requirements.

Table of Food Requirements 139

Chapter I. 15 Sample Menus with caloric value for the average adult.--Food for the Aged, giving 12 Sample Menus with caloric value 140-146

Chapter II. Diet during Pregnancy 150

Chapter III. Care and Feeding of Children, including Recipes and Menus for Infants; Menus for the Second Period; Menus for the Third Period; Wrong and Right Management 153

[Illustration]

[Illustration]

Chapter IV. Light Lunches for School Children. Nut Foods and Sandwiches 168

Chapter V. Table of Food Combinations. 143 Menus for Breakfast. What shall we Drink for our Meals? 172

Chapter VI. 168 Menus for Dinner 177

Chapter VII. 76 Menus for Supper 185

Chapter VIII. Poor Man's Bill of Fare, including: Sample Menus for one day. Bookkeeping. Menus for 56 days, with calculations as how to feed a Family of Five (2 adults and 3 children) on $3.50 per week and on $5.00 per week 189

Menus for Thanksgiving week 213

Mixed Boiled Dinners 214

PART IV.

Disease: Prevention and Treatment.

Chapter I. Constipation. Malaria. Suggestions for Chronic Invalids. Tuberculosis. Prevention of Tuberculosis. The House we live in. Treatment of Tuberculosis. Rickets. Obesity 218

Chapter II. Care and Feeding of Convalescents. Vomiting. Diet. Suggestive Menus. Additional Menus with caloric value 228

Table of Foods with caloric value 242

APPENDIX.

Chapter I. Mental Hygiene and Diet. The Immigrant. Health Hints for Busy People 245

Chapter II. Hygiene Economy and Sanitation. Preservation of Eggs. Dishwashing. Disinfection 251

Table

Giving average composition of common American food products 262

[Illustration]

INTRODUCTORY NOTE TO SECOND EDITION

Before the manuscript for the first edition of "Scientific Feeding" went to the press, it was reviewed by several presidents of Mothers' Clubs and other women organizations; they realized that it would fill a long-felt want in the home and a large number of advance subscriptions were sent in.

After publication the gratifying demand for this work necessitated the preparation of a second edition within a month.

DORA C. C. L. ROPER, D. O.

INTRODUCTION

This is a practical and hygienic cook book for all who consider life and health valuable. Intelligent homekeepers, nurses, managers of institutions and factories, all who are interested in furnishing the most nutritious food at the least cost, or wish to distribute such a work, will find this book worth its weight in gold.

After twenty years of persistent study, combined with praccal work as nurse and physician in private and in institutions, beginning in Germany, I am able to-day to present this valuable work, and hope that it may be placed in the hands of every home-maker in the country. It is designed for the purpose of modifying the cost of living and of eliminating, to some degree, the hardships and drudgeries of our women. It is excellent for school feeding, and presents the keynote to health and longevity, helping to prevent mental, physical, and moral diseases.

The great facilities for research work in the modern laboratory offer a wide field for the study of preventive medicine and hygiene. The world is beginning to recognize the fact that a large number of diseases are the result of wrong conditions. Improper eating, drinking, sleeping, unsuitable work, excess of amusement, and wrong educational systems are to blame for a large number of germ diseases and chronic ailments.

The body is the temple of the soul, therefore the laws of hygiene (concerning our internal and external body) are divine. Many of the orthodox teachings and divine laws in reference to hygiene, fasting, and feeding are a safe guide for the prevention of disease.

It has been my object to present a practical and sane method of living, free from fads and the teachings of one-sided extremists. All natural foods are wholesome, if properly combined, prepared, proportioned, and selected with care to agree with the temperament, environment, age and climatic conditions. I have devoted a special chapter to economical menus for people of moderate means, and have endeavored to show how it is possible to feed a family of five on a moderate sum, without injury to health. The amount of food and the proportions agree with what is demanded by modern standard dietaries.

A large number of cook books have been written during the last one hundred years to tickle the palate. Much valuable time has been wasted and many innocent victims have paid the price for the sins of gluttony, caused by modern methods of living.

The most learned and advanced thinkers are turning their attention more and more to scientific dietetics. The question of feeding is one of the most important subjects our present generation has to deal with. It is my desire that this book may contribute to this cause, and that it may awaken thousands of mothers and daughters to appreciation of the dignity and importance of their life work.

PREFACE

The human body is a wonderfully complex and mysterious establishment, presided over by life. It is composed of the dust of the earth, organized by creative power.

The elements composing the human body are: Oxygen, hydrogen, carbon, nitrogen, chlorine, sulphur, phosphorus, fluorine, calcium, natrium, magnesium, silicon, iron and potassium.

Our bodies are maintained by food, air, light, activity, rest and sleep.

The union of oxygen with one or more of these elements is called oxidation. If the process of oxidation within our bodies goes on rapidly we feel warm and energetic; if it goes on slowly, the degree of heat and energy is less; in fever there is rapid oxidation; in people who suffer with chronic diseases there is incomplete and slow oxidation.

In order to produce harmony between the elements in the body, it is not only necessary to breathe pure air, and eat wholesome foods, but it is equally important to have those food elements, which are taken into our body, selected in the right quantity, quality and combination. It is further necessary to have them prepared in the mouth by mastication and insalivation. If this is done, the chemical affinity or combining power of the foods is satisfied, and digestion, absorption, sanguification, circulation, oxidation, assimilation, excretion and clorification will go on perfectly.

In order to keep our bodies in perfect health, we must understand their laws. The structures and functions of the body are intimately connected, and one is dependent upon the other.

Life at the beginning is a tiny cell; as it multiplies into other cells, it forms blood vessels, nerves, muscles, bones, lungs, liver, brain, heart, and stomach, until the body is completed. The growth of the body is from within, before and after birth. The natural food for the infant is mother's milk, the next best is the milk of a wet-nurse, whose child is about the same age as the one to be nursed. Artificial preparations of milk from a cow, goat or donkey is the next best.

The appearance of the teeth indicates that the feeding of solid food can be begun. The kind of food required for the child as well as for the adult differs with different individuals. A normal and healthy mother will be directed by her instincts, reason and judgment to choose the right food for herself as well as for her infant.

An old saying goes, "God created foods, the devil created the cooks." A few thousand years ago, when the art of cooking was in its infancy, physicians and surgeons were not in such demand as to-day. The preparation of foods for the average household in those days consisted mainly of boiled cereals prepared with salt and water, boiled and roasted meats, and baked breads. Such articles, if eaten in proper combination with raw fruits, greens, and nuts, will keep the appetite at the normal state. The principal victims of disease in those days were the kings, the idle rich and the very poor. Since civilization has progressed, and the rights of man are more equalized, the whole race is in danger of degeneration through the invention of fashionable and artificially prepared foods.

In this age of refinement, our teeth, which were made to last as long as our bodies, begin to decay before we are matured. Foods are ingested into our bodies instead of being digested. Public hygienists and technical bacteriologists work hard, trying to prevent such diseases as diphtheria, scarlet fever, tuberculosis, typhoid fever, and many other infectious and epidemic diseases, resulting from unclean food and water, and imperfect sewage systems.

Even with the purest of milk, meat, and water, we can make a filthy garbage can of our intestinal tract by the ingestion of foods which do not harmonize chemically, the result being decomposition. Right here we have all the dangers of modern diseases and pus formation, resulting in appendicitis, phlebitis, ovaritis, cancer, Bright's disease, and all the above mentioned diseases, without having to look further for the garbage can on the back porch or the sewage system in the yard. The waste products from our tables, and the excretions from our bodies would be less dangerous to health if the selection, combination, and preparation of our food were more natural. The excretions of properly fed animals are not so dangerous to our health; why should ours be?

The hygienic rules as taught by the orthodox Jew in reference to the combination and preparation of foods are wise. He is not allowed to mix milk and meat, meat and fish, and many other articles of food which do not combine well chemically. The Jewish methods of killing animals and the preliminary preparations--such as the watering and salting of meats before cooking--are also more hygienic. They eliminate part of the toxins of the meat, which have been in close contact with the air.

Since life and personal health are generally in charge of woman, the right place for every girl under eighteen or twenty years is at home or in school. No young girl under this age should be allowed to enter a profession, workshop, or business college. An occupation which by long hours of work over-develops a certain set of muscles and nerves before maturity, will produce an abnormal development and an unstable temperament. Co-education at this age is also harmful, the result being premature development, and elopement marriages, or arrested sexual development and extreme independence, or marriage and continual suffering, owing to physical defects and lack of knowledge of the care of the human body, and of domestic science.

Every woman is a born nurse. How valuable would it be, then, to give every young girl, beginning at the age of twelve, a rudimentary course in nursing and in the care of children; in the art of selecting, combining, and preparing foods; and in the art of housekeeping. An industrial high school course with such technical work as is suitable for woman's sensitive brain would develop her brain and body in every direction and make the future woman a healthy mother of healthy offspring. Those muscles and nerve centers which have been well developed during puberty will be the strongest throughout life.

The store, the factory, the office, and the business college are no places for a girl under twenty years of age. If for some reason she has no desire to follow her natural calling in life, there will be plenty of time to prepare herself for other work after the age of twenty.

If a law could be enforced to compel every woman to present a certificate of health and maturity, and a diploma of qualification when applying for a marriage license, much unnecessary misery, disease, and many untimely deaths could be avoided.

The feeding as well as the mental, moral and physical training of children is the natural profession for women. Children have in them all the possibilities for good and evil. Mistakes during this period will affect the child throughout its life. Thousands of infants and young children are killed every year by wrong feeding and environment. A large percentage of brilliant and exceptional children fill the jails and insane asylums. Idleness, stupidity, and criminal tendencies are =diseases=, and =diseases can be avoided by right living=. Children with hereditary weaknesses require double care and attention; but remember the wonderful law of nature works always toward the normal; the good tends to overcome the bad.

If the brain of a child becomes starved by the use of sweet-meats, and clogged by the use of rich condiments and highly seasoned food, or by an excess of starchy foods, there is always great danger, and more so, if the child is exceptionally bright and active. A large amount of arterial blood is sent to the brain, and if this blood contains much waste matter, the eliminating organs will soon be overworked and all kinds of diseases are liable to follow, such as brain fever, softening and subluxation of bones, epilepsy, chorea, meningitis, paralysis, tuberculosis of the lungs, bones, and mesentery.

Many young women who, through wrong food, environment and unsuitable educational systems, have dwarfed their bodies, find motherhood a great burden. They have to pay the penalty for the sin that is committed on them. Their children will not be so strong, and will have less resisting power, and their grandchildren, if there be any, will land in the institutions for the incurable, if the careless feeding and wrong habits are kept up by each succeeding generation. On the other hand, if the progress of degeneration is checked by right living, the work and time invested will be well repaid during one generation.

PART ONE

CHAPTER I.

"THE BLOOD IS THE LIFE."

Its Structure and Function Depend on the Building Material.

Foods are substances which, when introduced into the system, supply the necessary material for growth, renewal and maintenance of the vital structures. Food is anything that nourishes.

Foods must contain the same elements found in our bodies. The body requires a combination of different food elements in proper proportion to produce a suitable diet. Foods are divided into five classes: water, protein, fats, carbohydrates and mineral matters.

Air and sun are also foods, but are not generally spoken of as nutrient.

WATER.

Our bodies consist of about two-thirds water. It helps to regulate the body processes, and supplies building material. Watery fruits and vegetables contain pure distilled water. The amount of water required for the average individual differs greatly. If water is added to our foods in the cooking process, a lesser amount is required for drinking. Wholesome, non-stimulating food will call for a normal supply of water between meals.

PROTEINS.

These are sometimes called albumen, and they supply the body with nitrogen, sulphur and phosphorus. They are great tissue builders; they also furnish energy and heat, in combination with fats and carbohydrates.

Sources of Proteins:

Legumes, lean meats, nuts, cheese, whites of eggs, fish, and the glutens of the grains. Milk contains proteins in the right proportion with fats and sugars to make it suitable as a food for infants. Oats, wheat, and rye contain more protein than other grains, and if no other protein foods are on hand, these can maintain health for a long time without harm. (For combinations, see introduction of "Poor Man's Bill of Fare.")

FATS.

They are obtained from the vegetable and animal kingdoms. They supply heat and energy in the most concentrated form, and are also flesh-builders. In diseased conditions, where economy of nerve force is required, fats in combination with acids, minerals and gelatine can form a substitute for part of the protein foods.

CARBOHYDRATES.

These are found in large percentage in cereals and in fruits which contain stones and seeds, and in underground vegetables, including the lighter starches, such as sago, agar agar, sea moss and gum. Milk can serve as a carbohydrate for special conditions; being evenly proportioned with fats and protein it contains little waste. A certain amount of carbohydrate foods in the form of cereals is necessary in our daily diet, as they are rich in lime and fat--yielding material which is required for ligamentous and other elastic tissue. People who live on fruits, greens and nuts, or on fruits, greens and meats only, require a larger amount of protein food, in order to make up for the loss of cereals.

MINERAL MATTER.

In an organic form, we find mineral matter in large proportions in green leaf vegetables, small fruits and berries, bran, rye, green peas, string beans, tomatoes, yolks of eggs and in all the outer skins of legumes, grains and fruits. The importance of the mineral elements in our foods has been little understood, so far. Of late, health reformers are beginning to realize that many serious diseases, such as tuberculosis, insanity and malnutrition, are the result of mineral starvation. Three-fourths of these valuable minerals are removed from our foods daily by modern milling, bleaching, and polishing of rice, wheat, corn and all the other grains. Not alone the minerals, but necessary volatile oils, acids, and ferments are removed by these processes. Refined white flour and sugar have been on the market for the last hundred years; and much time and health have been wasted with the writing of fashionable cook books, and the manufacture of anemic snow white cakes, crackers, biscuits and soft putrefying puddings and desserts, prepared with skim milk, sugar and eggs. The deficiency of minerals in these products has created an abnormal desire for salts, spices, and chemically pure sugar, followed by an additional craving for intoxicating beverages and liquors. The latter articles cannot enter into the composition of perfect teeth and bone, or gray nervous tissue; therefore, the result is premature death and many new diseases.

It is my desire to present in this book such food combinations as perfect as can be produced from food material with our present methods of milling and preliminary treatment. Many people have become so delicate in structure that they cannot use coarse breads and cereals; therefore, a variety of different cereal foods have been included. Vegetable foods, such as are rich in minerals, have been added to the breakfast foods in place of sugar and beverages. In order to supply the body with the necessary amount of minerals, we must learn, to eat greens for breakfast, until our so-called breakfast foods have improved in quality.

All foods possess potential or latent energy. The sun is the great positive element, and plants store up the sun's energy. It is transferred to us through the eating of plants and animal foods. Through the process of oxidation this energy is set free in our bodies, and appears as heat and muscular power. This energy contained in foods is known as heat or fuel value, and is expressed in terms of a heat unit or calorie. A calorie is the amount of heat necessary to raise one kilogram of water, one degree centigrade. This is spoken of as a large calorie, which is used in determining the energy value of food. The small calorie is ¹⁄■■■■ of a large calorie.

The physiological fuel and energy value of the different foods is as follows:

1 gram of Protein yields 4 Calories 1 gram of Fat yields 9 Calories 1 gram of Carbohydrates yields 4 Calories

To determine the energy value of a food or combination of foods it is necessary to know first its composition. Then determine the weight of protein, fat, and carbohydrate in grams and multiply these weights accordingly.

CHAPTER II.

STUDY OF FOODS.

The average homekeeper knows little of the nutritive value and chemical composition of the food she buys. The desire to tickle the palate enters more into the selection of food than reason or judgment. Others, who have studied along certain lines without the fundamental training for this work, often make greater mistakes in the selection and combination of foods than if they had not studied the subject at all.

It is not sufficient to know just which foods are suitable to the individual and which are harmful; it is necessary to have a fairly well balanced diet which contains the correct proportions of protein and non-protein elements.

The following pages present briefs on the value and chemical nature of different foods not mentioned in recipes:

VEGETABLE FOODS.

These are divided into several classes. They are: Legumes, cereals, roots, bulbs, tubers, leaf, flower and fruit vegetables. All plants are made up of a mass of cells, each consisting of a membranous wall, enclosing a gelatinous mass, in which lie imbedded the nucleus or center of cell activity and minute grains of starch or other material which the plant has manufactured.

In young plants these cell walls are called cellulose; later wood cells begin to develop. The wood cells grow into fibrous material, called woody fibre. In poorly grown or stale vegetables this woody tissue becomes very hard and thick, and therefore is indigestible. For this reason it is best that all green vegetables are grown quickly and eaten while they are fresh. When fresh they will snap crisply. Peas, green corn and string beans will cook in one-third of the time if used directly after gathering, instead of being kept for several days before using.

THE LEGUMES.

The legumes are rich in vegetable protein, and differ from flesh foods on account of being richer in protein and minerals and less stimulating. They are free from animal intoxication.

DRIED PEAS.

Green peas are richer in minerals than yellow peas, beans or lentils, the protein being in the form of legumin and easier to digest. They are very purifying and should be eaten freely, especially during the cold winter or rainy season. They are a suitable food for the brain-worker as well as for the muscular-worker, and can be prepared in many different ways. Yellow peas are an excellent food for muscular-workers.

DRIED BEANS.

They contain more of the protein than peas, lentils or beef. They are therefore a very rich food and should not be consumed in large quantities. The brown, red, and black beans are richer in iron and minerals, and are therefore more suitable in cold weather. The hulls of all legumes are difficult to digest, therefore it is important to soak legumes before cooking. In countries where the water is hard, it is well to have soft water on hand for the cooking of legumes. If rain water cannot be obtained, boil a kettle of water each day and set aside to cool for cooking purposes. Legumes may be soaked with hot or cold water. Green lima beans should be put to cook in boiling water without soaking, like all green vegetables.

LENTILS.

They are rich in iron and should be used freely in cold weather. Boiled onions are a good addition, in place of fat meat.

GREEN PEAS AND BEANS.

Green peas differ from other green vegetables. They are richer in protein and can serve as a meat substitute during the summer. String-beans resemble the green leaf vegetables in their composition, but do not contain sufficient protein to serve as a meat substitute. They are very purifying to the liver and intestines, and should be eaten freely by people of a bilious temperament.

CABBAGE.

Cabbage is rich in minerals. It can be made very indigestible by careless preparation. Raw cabbage is easily digested if chopped very fine and mixed with grated potato and mayonnaise dressing. Cooked cabbage should be treated with acid and mixed with the yolk of an egg if it disagrees. Some people prefer sprouts to cabbage. They resemble each other very much in composition. Cabbage contains more water and cellulose. It is best to use only the innermost part of cabbage, if it disagrees.

CAULIFLOWER.

This belongs to the cabbage family. It is rich in sulphur and is one of the most easily digested vegetables, if properly prepared. If it disagrees, treat it with acid or serve it for breakfast instead of for dinner.

CELERY.

Celery contains valuable minerals and is soothing to the nervous system. Celery roots are rich in fat and a healing food for people with kidney, liver, and intestinal trouble. The green stalks of celery root should never be thrown away. They can be tied into a bunch and cooked with soups of meat or legumes. Celery is a very valuable food for people with a bilious temperament.

ASPARAGUS.

This is an easily digested vegetable and resembles celery. As a food for medicinal purposes it may be eaten raw or cooked.

CARROTS AND PARSNIPS.

They resemble each other, carrots being richer in sugar; the parsnip contains a little gluten. They may be eaten in the raw state with good effect.

TURNIPS.

Turnips contain some valuable minerals, but being rich in sugar and water, they are liable to ferment in weak stomachs, especially if eaten with lean meats, white breads or other foods, which are poor in fat. They should not be eaten in the middle of the day by people who do active work. If they disagree at night, they may be eaten for breakfast in combination with fat meats or stale bread and butter. Yellow turnips are richer in nutriment than white turnips. Raw turnips are wholesome if they agree. Never combine turnips with other starchy foods at the same meal, such as potatoes, rice, white flour preparations, apples or cucumbers.

CORN.

Green corn is rich in fat and protein, and can form a perfect meal during the summer if combined with tomatoes. Do not cook the corn if it is agreeable raw. Canned corn should be used with care for people with intestinal weaknesses. If used for soups it should be strained and diluted with an equal amount of hot water before thickening.

TOMATO.

The tomato stimulates peristalsis and is a wonderful tonic for the liver. It is one of the most perfect fruits, rich in oxalic acid and iron, and unsurpassed as a medicinal food. It contains a vegetable calomel and serves as a purifier for the liver in bilious conditions. It can be prepared and combined in many different ways. It may be one of the first articles given to a patient after an operation, serving as a food and tonic; it counteracts the sweetish taste of the chloroform and prevents fatty degeneration of the liver.

Whether a food is eaten raw or cooked it is important that it be ripe. (Not ripened on the market.) For people with weak digestive organs, the best way to serve tomatoes is in the form of sterilized strained juice over toast in combination with milk or in the form of soup from canned strained tomatoes. The theory that tomatoes are liable to produce cancer is entirely unfounded. Any kind of food if eaten in excess and wrongly combined will aid in the progress of disease, but all natural foods rightly combined are wholesome if eaten according to needs of the individual.

Tomatoes combine well with fatty foods,--eggs, cheese, meats and fish.

LETTUCE.

This is the most desirable greens on our tables and combines well with almost any kind of food. Being rich in minerals and alkaloidal extracts, it tends to render the digestive fluids alkaline and promotes oxidation and nutrition. If lettuce is eaten in proper proportion with other foods at the morning or noon meal, it has a sedative effect and keeps an excitable constitution better balanced throughout the day. People with delicate stomachs should not eat lettuce at the evening meal. All raw salads prepared from greens and super-acid fruits are best eaten at the beginning of the meal, or with the meat dish at the morning or noon meal.

CUCUMBERS.

They are a valuable food and should be eaten almost daily by growing children and anemic people, especially if much muscular work is required. The cucumber is considered an indigestible article of food by people with perverted appetites. The way in which the cucumber is usually prepared in the average household renders it unfit to eat. The extraction of the natural juice and the treatment with salt make the cucumber tough and indigestible, and, if eaten in combination with half a dozen other articles, it produces indigestion. Cucumbers should never be eaten at night.

NUTS.

Nuts are high in nutritive value, and are better evenly combined with non-protein elements than flesh foods are. They are rich in fat and minerals, and form an ideal diet in combination with raw fruits and greens. They are not sufficiently appreciated as a food, and receive much unjust criticism as to their digestibility. All nuts are wholesome. The right combination and proportion, and the time of day when eaten, are of great importance. The kind of activity as well as individual peculiarities have much to do with likes and dislikes or requirements of certain foods.

ALMONDS AND BRAZIL NUTS.

These nuts feed the higher nerve centers and generate a high quality of intelligence.

WALNUTS, PINE KERNELS AND CHESTNUTS.

These are excellent for those who wish to put on flesh. Care must be taken not to overtax the liver. People who have been accustomed to a large amount of bread or other starchy foods should begin with a small amount, and substitute them for bread. If they disagree, use lemon, cranberries, oranges or fruit salads with them. Walnuts supply the larger nerve structures. They are well balanced in all the elements and are excellent for people doing hard, muscular work. Sweet dried fruits also form a good combination with nuts. Chestnuts resemble cereals on account of being rich in starch. They contain less protein, fat and minerals than other nuts, and therefore combine well with such foods as supply these elements. Baked and boiled chestnuts are generally more agreeable than raw ones. Pine nuts are rich in both protein and fat.

COCOANUTS.

They are rich in starch and fat and resemble the cereals closely.

HAZELNUTS.

They are a valuable food, but require thorough mastication.

THE PEANUT.

The peanut is a very nutritious nut, but rather difficult of digestion for some people. It resembles beans and peas, and is sometimes classed as a legume. Excess of nuts at one meal, or nuts which have been poorly masticated, may cause severe disturbances of the liver and stomach. If the teeth are poor, the nuts may be ground, but even then great care must be exercised to insure their proper insalivation. Cooked nut foods and all vegetarian dishes to which strained legumes, nut-butter, eggs and other rich foods are added, should not be indulged in by people with weak stomachs.

NUT-BUTTER.

Great care should be exercised in the preparation of foods with nut-butter. Never spread it on bread without first diluting it with an equal amount of water. Do not keep it on the shelf like ordinary butter after it has been mixed with water; prepare only sufficient to last for twenty-four hours, and keep it on ice.

FRUITS.

There are three classes of fruit: acid, sub-acid, and sweet fruits.

Fresh raw fruits, if eaten in the right proportion with other articles, are wholesome. The habit of eating a large amount of acid fruits at the beginning of the morning meal is not necessary. If a heavy meal is eaten in the evening, remaining half digested in the stomach over night and putrefying, then acid fruits will cleanse the stomach in the morning. The better way is to go to bed with an empty stomach and there will be no need of cleansing in the morning. People of a highly nervous temperament should not eat the very sweet fruits at the morning or noon meal, as at this time they are too stimulating.

Hot house fruits out of season are health destroying. Certain fruits, such as apples, plums, tomatoes, apricots, grapes, figs, bananas and cranberries, will keep for a long time in the natural state, if properly preserved. Some of them can be dried and used in the winter. Fresh fancy summer fruits are not required during the winter by healthy individuals, neither are canned fruits, jams or jellies.

The canning of fruits during hot summer days is a health destroying occupation and a waste of time and money. Fresh fruits prepared with a large amount of water and sugar are little better than beer, wine and whiskey. If such fruits are eaten with yeast bread, potatoes and a variety of other foodstuffs, they set up fermentation and burden the eliminating organs. A few jars of sterilized fruit juice should be prepared and kept on hand for medicinal purposes only.

Fruits are an important article of diet, but few people know how to use them wisely. A large percentage of deaths in young children is due directly to the wrong use of fruits. Many forms of infantile paralysis, intestinal disease and malnutrition in general are due to the lack of knowledge of the scientific combination of fruits with other articles of food, so as to furnish a wholesome meal.

Many teachers of Domestic Science and writers in monthly magazines seem to have forgotten, entirely of what an ordinary mixed diet should consist. Their bills-of-fare are becoming more complex all the time. We find combinations, such as banana fritters, custard, meat, potatoes, nuts, milk, biscuits, dates, several kinds of vegetables, puddings, cheese, coffee, cake and ice cream, suggested for =one meal= (sometimes less, other times more than this). Any intelligent, thinking person must realize that such a mixture, besides being a great waste, will turn the stomach of the strongest individual into a yeast pot. Those with strong eliminating organs, who take plenty of out-door exercise and recreation of some kind, may be able to throw off the excess of poison for a long period, while others endowed with less vigor will suffer from the effects within a short time.

People who live on cooked foods consisting mainly of meat, bread, sugar, soups, puddings, cooked cereals, milk, etc., should realize that they have already filled their systems with foods which contain a large amount of water, and therefore will overburden their intestines and kidneys by adding a liberal amount of fruits to such a dietary. There is always great danger of fermentation and putrefaction, especially if constipation sets in, and here we have all the dangers of modern diseases, which begin with mal-nutrition, be it from under-or over-feeding. Only the most perfect specimens of men and women are safe from danger. Why? Because their instincts lead them to choose the right articles in the right combination, and at the table they know “when to stop,” while an individual with weak sensory nerves does not feel the effects of satisfaction from the food until dullness, pain or discomfort appear. It is from this latter class mostly, that we have our health reformers, while the former class with their perfect battery, which can turn the poorest food materials into first grade tissue, look on us as diet cranks and faddists.

The man who ate three square meals all his life, indulged in tea, coffee, liquor and tobacco, was never sick and lived to be 100 years old, probably could have lengthened his years to 300, had he not been so dangerously strong.

The menus suggested in this book are made up carefully and scientifically, so that each individual can easily find a diet suited to his temperament, environment, age and occupation. Nuts contain a high percentage of protein, and therefore form an ideal dietary in combination with fruits. Meats, eggs, cheese, cream and fish are the next best articles suitable to combine with fruits; raw greens are an excellent addition, but breads, puddings, sugars, beverages, mushes and cooked vegetables are better left out at a meal if an abundance of fruits are taken, especially at dinner, or the amount of watery foods taken into the body during twenty-four hours will not be in the proper proportion to the solids. Dry legumes are very rich in protein, but being dissolved with water during the

cooking process are less suited to combine with raw fruits, especially for those suffering with flatulence or kidney disorders. Apples, tomatoes and vegetables combine best with legumes. Apples and tomatoes, being of the most perfect type of foods, combine well with all classes of protein foods, including cereals. They should be staple articles in every household. As to other fruit combinations, study recipes and menus, and keep in mind that no matter how valuable an article may be, excess is a poison.

Those who live mainly upon dry foods, such as uncooked cereals and nuts, can safely make their morning and evening meal of fruits alone, while others who live like the average, if they attempt to make a meal of fruits alone, and continue to do active work, will soon fail in health.

BERRIES.

All berries are rich in minerals and feed the brain cells. They contain traces of protein. Blackberries and huckleberries are rich in volatile oils and iron, and are of great medicinal value. They are excellent for the evening meal in the form of gruels and drinks.

People with digestive troubles should be careful in combining raw blackberries with other foods. They are rich in protein and may take the place of part of the meat dish on hot summer days. They should never be used as a dessert after a heavy meal.

STRAWBERRIES.

Strawberries are the first fruit to make their appearance in the spring. They are rich in iron and valuable acids. As they are in season for a long time they should not be eaten to excess, never more than once per day. From three to eight ounces, according to age, is sufficient for one meal. If perfectly fresh, they combine well with fresh cream or milk. Yeast bread, red meats or legumes should not be eaten at the same meal with strawberries. Berries which have undergone slight decomposition should be placed in a mason fruit jar with a little water and be sterilized. This juice will keep for several days in a cold place and can be used for the flavoring of milk, or for softening zwieback which is to be served with cream or milk. If the juice has undergone fermentation reboil it before using. It may be used for fruit puddings or fruit gruels or be mixed with other fruit juices. In this way everything is utilized and nothing wasted.

CHERRIES.

The cherry season is short. Therefore, they should be eaten almost daily. All varieties are wholesome. If desired, several kinds may be mixed at one meal. They combine well with egg foods, whole wheat, cornmeal and fish. They may be eaten at the beginning or at the end of a meal or by themselves. People with weak stomachs should not eat them at night.

BLACKBERRIES.

They are a valuable and nutritious fruit and can form a perfect meal in combination with light cereal foods. They have little preservative properties and therefore should be eaten only when perfectly fresh. For young children or people with intestinal weakness, only the juice should be used in the form of wine or gruels.

RASPBERRIES.

They are a light and delicious fruit. They combine well with milk, egg foods, or nuts, and can be served morning, noon or night.

PEACHES, PEARS AND APRICOTS.

They are all three rich in sugar and cellulose, and can form a substitute for part of the cereal foods during hot summer days. (See recipes for Salads.)

THE PINEAPPLE.

The pineapple contains bromaline and is of medicinal value in the treatment of certain stomach disorders. It is not a necessary article for the table of people of moderate means.

BANANAS.

They are a very nutritious fruit and can partially replace the cereals. If combined with green leaves, and lemon, they can form a perfect meal. The bitter substance which is contained in the inner skin of the banana should be scraped off with a knife and added

to the bulk, as it counteracts the sweet flavor of the banana and adds to its digestibility. Baked bananas are not necessary for a healthy stomach.

APPLES.

They are among the most perfect of fruits. People who have difficulty in digesting a sufficient amount of cereals should eat apples almost daily. If raw apples disagree, they can be made agreeable by combining them with fat meats or oil in the form of a salad. Baked apples and apple sauce are also good, provided they are not spoiled with too much sugar. Some apples are fibrous and muscle-feeding; others are richer in phosphates and valuable minerals. For salads use tart apples.

GRAPES.

Grapes are a valuable fruit for the table if eaten in the right proportion with other foods which contain fat and protein. They are rich in sugar and tartaric acid. As a medicinal fruit they may be eaten in large quantities by themselves.

NECTARINES.

Like the pineapple, they belong to the luxurious fruits and are adapted for people with a large purse. They are rich in sugar and starch, with a small amount of cellulose.

ORANGES, GRAPEFRUIT, LEMONS AND LIMES.

They all belong to the citric acid group, and are of all the fruits, the richest in valuable acids, which in the process of digestion are converted into salts, rendering the blood more alkaline. The latter three should be used in greater quantities in countries near the coast or in low and damp districts, especially during the rainy season. The outer skin is rich in volatile oils and is useful in the preparation of fruit-and-milk soups. The white rind is useful as a medicine, for patients who suffer from malaria. A small amount of it chewed while sipping a glass of fresh milk will greatly add to the digestibility of the milk and serve as a germicide to the liver. The juice of one-quarter of a lemon may be taken in connection with the skin of one-half a lemon, in combination with a glass of milk. During fever, the skin should be carefully expectorated.

FRUIT JELLIES.

If prepared from fruit juice and cane sugar only, they are powerful stimulants and have little food value, for the reason that they arouse the nerve cells to extreme activity and rapid oxidation. They furnish no food for the nerve cells, and the nutritious elements in the other food materials taken in combination with these jellies pass out of the body without being assimilated, or produce congestion and inflammatory conditions. Even natural stimulants, in the form of raw fruits, can become harmful if taken, in excess, or in the wrong combinations, unsuitable to the individual requirements. If the glycogen-making function of the liver becomes overburdened, the result will be diabetes, neuralgia or starch-poison.

COMPOTES OR STEWED FRUITS.

They are more wholesome and economical than jams and jellies, which are prepared with large amounts of sugar.

They are best served with the meat dish or with some substantial pudding. If served with sponge cake at the end of a meal, the digestive juice becomes acid, and produces fermentation and mal-nutrition.

PLUMS.

Green, red and blue plums are all valuable fruits. The blue plum is rich in iron, minerals, and sugar, and is, next to apples and tomatoes, one of the most perfect fruits. It has great preserving qualities and if picked on a dry, sunny day and placed carefully in straw in a dry, cold place, will keep until Christmas. For combination, see menus and salads.

People who have distress from eating raw plums should let them alone or eat them in the dried state only.

FIGS AND DATES.

They have an average of thirty per cent water, are rich in sugar and contain some protein and saline matter. They are an excellent food for people who are fond of sweets. They are more wholesome than canned summer fruits. However, they should not be

indulged in during hot summer days, or in the spring time when the brain needs relaxation.

THE WATERMELON.

This is the largest of the melon fruits, containing sugar, salts, cellulose and distilled water. It is an excellent food during hot weather. People who suffer from chronic kidney disorders should only indulge in it in small quantities at a time, and never combine it with mushy or other starchy foods. A few drops of lemon is a good addition, in place of free salt.

MUSKMELON.

This fruit is also rich in sugar and cellulose. What has been said of watermelon in reference to combination also applies to this fruit.

CRANBERRIES.

Cranberries, like gooseberries, currants and lemons, are purifying to the blood and very valuable as a food in malarial districts. Cranberries combine well with oatmeal, cornmeal, pork, chicken, turkey and veal. Use no more sugar for the preparation than is absolutely necessary to counteract the tart taste. Cranberry jelly prepared with pure sugar is unwholesome. Raw cranberries and raw celery are a good combination for salad.

CEREALS.

Cereals are the most perfect products of the vegetable kingdom, and make fairly well balanced foods. They are deficient in fat, with the exception of corn and oats. In the processes of milling and cooking, cereals have been more abused than any other foods, by depriving them of their valuable minerals, and by compounding them into soft putrefying puddings or rich cakes. Concentrated or predigested cereals, as advertised under the name of breakfast foods, cannot take the place of ordinary rolled, whole, or steel cut cereals; they have lost valuable salts and lime during the process of baking and they also deprive the walls of the stomach of the normal stimulus, which is necessary for thorough utilization.

Well boiled cereal foods in the form of dumplings, macaroni, noodles or whole cereals are stimulating and heating to the whole alimentary tract, they take longer to digest, and are more thoroughly utilized by the system. Predigested cereals and zwieback are more suitable for the evening meal, or at the end of the noon meal, when the body has expended energy. Shredded wheat and zwieback may be used with benefit for breakfast, if a sufficient amount of raw fruits or greens is eaten with them, but if they are used in combination with other predigested foods, such as milk or sugar, it gives the intestine nothing to do. For the evening meal, toasted breads and cereals combine well with such foods as supply the lack of lime, fats and minerals: cream, fruit-gruels, yolks of eggs, gelatine, sago, milk and green foods.

WHEAT.

Wheat can be used the year around. In cooking cereals it is very important to start with the right quantity of water, and allow each starch granule to burst by fast boiling during the first twenty or thirty minutes. After this, let it cook slowly for twenty or thirty minutes longer, or until it is done. It is not necessary to cook cereals for several hours in order to make them fit for the human stomach. If well boiled cereals disagree, they are generally poorly prepared and allowed to get pasty before the starch granules have burst, or else they are combined with raw sugar and cream, which produces fermentation.

RYE.

Rye is richer in minerals and contains less starch than wheat. It is not superior to wheat, but it is one of the oldest and most perfect foods, and is the staff of life to some of the healthiest and strongest races of the old world. It is laxative, and because of this it is more suitable for certain individuals than for others. Rye is a good winter food; during the summer we have many valuable berries which supply the system with certain minerals, therefore we require less of rye bread, or rye preparations, during this time of the year.

Rye combines well with all starchy fruits and vegetables, which are deficient in minerals, such as potatoes, pumpkins, squash, melons, turnips, carrots, beets, bananas, cucumbers, rice and corn. It also combines well with sweet fruits. Apples, pork, veal, lamb, cheese, eggs, cream, milk, bacon and oily foods are all good additions to rye. Boiled rye and starchy foods are unsuitable combinations.

Whole rye or wheat bread should never be eaten fresh. It should be kept in a bread box, with good ventilation, in a dry place, or near the stove. Sun dried bread is the best.

OATS.

Oats are rich in fat and lime, and like wheat and rye belong to the most perfect foods. A fireless cooker is a convenient apparatus for the preparation of oats and wheat. They should be thoroughly cooked for at least half an hour before setting them into the fireless cooker.

RICE.

Rice, although low in protein and fat, is one of the most easily digested of all cereals, and is especially suitable for brain workers and people of sedentary habits. This book contains a large number of different recipes for the preparation of rice.

SAGO AND TAPIOCA.

They are manufactured from certain palms and roots, and belong to the lighter forms of cereals. They are easily digested if soaked for several hours before cooking, and can be partially substituted for the heavier cereals. Cornstarch, arrowroot, potato-flour and agar agar belong to the same class. They are all valuable for the sick and for young children.

BARLEY.

Barley is also rich in lime; it should take a more prominent place among food substances than it does. Pearl barley should be soaked with soft water before cooking. If it is to be strained, mash it up thoroughly with a potato masher, and pour more boiling water over it after the first liquid is strained off.

ANIMAL FOODS.

EGGS.

Eggs contain all the elements necessary for the building up of a young animal; they also contain all the elements which can be found in the human body. The eggs of hens are used most commonly. The chemical combination of the whole egg and that of the brain and nervous system have much in common. The white of the egg contains about eighty per cent water, twelve of albumen, a small amount of fat and some salts. For medicinal purposes, eggs should be fresh, directly from the nest. Eggs are deficient in minerals and should be combined with foods which are rich in minerals.

CHEESE.

Cheese is one of the most economical and nutritious of foods, and a true meat substitute. To serve cheese after a dinner is a wasteful extravagance, and dangerous to health. Cheese combines well with bread, macaroni, potato and other cereals; raw greens are also a good addition. Cooking or baking cheese makes it indigestible. Grated or sliced is the best way to serve it. People who have difficulty in digesting cheese should always combine it with raw apples, onions, or tomatoes and lettuce, in the form of a salad. If it still disagrees, leave out the cereals entirely at the meal, or use black bread with it. A combination of cheese, eggs and milk in the form of a Welsh rarebit makes a heavy and indigestible meal, and should only be indulged in by people who are very strong, and exercise a great deal out of doors.

MEAT.

People who live almost entirely on cooked foodstuffs and white flour bread, find meat a necessary article of food, and consume it in larger quantities than would be necessary, if whole wheat bread and raw fruits and greens were used. Under the present systems of forced and improper feeding of animals, and the preservation of meats by cold storage, flesh foods are becoming more dangerous. There is no need for such an excess in the production of meat, except to satisfy our habits. If human beings and animals are fed by force, they are not healthy. Flesh, eggs and milk from animals which are fed by force, are unwholesome and inferior in quality.

Under certain conditions and in cold climates, meat is a necessity, therefore the feeding of animals should be under the observation of health officers. We need quality more than quantity.

Pork, although condemned by many people as unfit for food, is a wholesome article, if the animal is fed upon dry, substantial food. Pork requires a longer time to digest than other meat, and therefore it should not be eaten at the evening meal. Pork was considered as an unclean food by the ancient Jews; perhaps the reason for this was that the Jew's system did not require pork, because of his constitution and the climatic conditions. Fat pork is a specific food for the kidneys; it is less stimulating and easier to oxidize than any other meat.

Beef is perhaps the most economical meat for family use. A good quality of meat should contain both fat and lean. All meats should be well soaked and washed before cooking. Cold meats are sometimes more agreeable than hot meats.

Veal, lamb, chicken and game are all wholesome meats if eaten in moderation and at the right time of the year. Fresh meats should not be served oftener than once per day, or better still, three times per week. The internal organs and glands, such as the lungs, liver, kidneys, tongue and stomach, are very nutritious. Sausages, if prepared from fresh, clean meat, and not highly seasoned, are cheaper and more nourishing than canned meats, and often preferable to fresh meat, which has hung a long time in a meat shop. The internal organs contain much lime and organic salts, as they feed the glands of the body; they should be well soaked before cooking, in order to drain the thick and impure blood out of them.

Beefsteak, chops and roasts should be slightly salted before they are cooked. Free salt sprinkled on meat, or other dry foods, before serving, is injurious to the lining of the stomach and blood vessels; lemon can be used instead. Many people have an abnormal craving for salt. This is a symptom of anemia; the system lacks minerals. The only way to supply the necessary elements is by taking salt in the organized state in raw greens and fruits. Free salt can satisfy such craving temporarily, but it creates an abnormal thirst. Raw apples, tomatoes and all other acid fruits, in combination with greens, are the best additions to meats.

FISH.

Fish is a valuable article of food. It is less stimulating than lean meat, and easier to digest and oxidize; for this reason it can be recommended for brain workers. It contains a large amount of phosphorus and nitrogen, and if properly combined with foods which are rich in minerals, such as apples, tomatoes, lemons and greens, fish is quickly utilized. Fish and whole rye bread is also an excellent combination. Fish being soft, it is necessary that it be thoroughly masticated. Fish can become very dangerous as a food when not fresh.

MILK.

Milk is found indispensable in some cases of sickness, especially in fevers. The greatest care should be exercised in getting clean, fresh and perfect milk, and in keeping it in a cold, clean atmosphere after delivery. Milk may be given as a food, raw, boiled, sterilized, pasteurized, or peptonized, and can be modified with water or other foods in many different ways. The best and most suitable method of preparing it for the patient must be left to the attending physician.

The color of perfect milk is yellowish white, =not blue white=. Its odor is pleasant. A drop of milk poured into a glass of fresh water will go to the bottom if it is good milk. In order to ascertain if the milk is alkaline, neutral or acid, put a small piece of red litmus paper into it, and if it turns strongly blue the milk is alkaline. If a blue litmus paper turns strongly red, the milk is acid. Perfect milk should be neutral or slightly alkaline. After the milk has stood for several hours it gradually becomes more acid.

Milk which is acid in reaction, or blue in color, is unfit as a food for children and invalids. If a mother is uncertain as to the quality of the milk she is feeding her child, she should have it examined by the city chemist.

Milk, even if handled very carefully, contains many germs. Therefore, on hot days it is better to sterilize the milk for an infant, even if the child is in perfect health, or able to take raw milk. If the milk can be obtained directly from the cow two or three times per day, it may be given raw on those occasions. If it has stood a little while, it may be heated quickly to 155 degrees F. over a hot fire, while stirring it.

CERTIFIED MILK.

This is a high grade of sanitary milk which comes from special dairies, where great care is taken to keep everything in perfect sanitary condition. The cows are kept in perfect health and are fed upon food which produces milk perfect in composition. There are, however, milkmen who have principle enough to supply their customers with milk of good character and perhaps of as high a grade as that from inspected dairies.

I have, in my practice, often come in contact with people who were informed by their milkmen that certified milk required no boiling or sterilization. Some people are impressed with the idea that certified milk has already undergone some sort of preparation. The fact that in these days milk laboratories can be found in many large cities, may easily bring confusion of mind as to "what the milk is certified for," especially to those who are not acquainted with the preparation of milk and do not know the difference between raw and sterilized milk, if they buy it. Such instructions should be given by better authorities than those who deliver milk, or the label should state "what the milk is certified for." Certified, or any other raw milk, which is over eight hours old, is not a fit food for infants.

BOILED MILK AND CREAM FOR TABLE USE.

Put the desired amount of milk or cream, or mixed milk and cream, into a clean saucepan, stir over a hot fire until it reaches the boiling point or to about 200°F. Then pour into a pitcher and set in a pan of cold water; stir until the milk is cold. Set on ice or in a cold place for 24 hours. Milk prepared in this way is the only wholesome kind to use in addition to boiled cereals and fruit puddings. It is also often preferable to raw cream and milk, in combination with raw fruits. If the milk is to be used on cereals for the morning meal, it can be reheated or used directly after boiling. If hot milk is added to cereals, the sugar will not be missed.

If boiled milk or cream has stood for 24 hours it has become unfit for further use unless it is reboiled. If putrefaction has set in, boiled milk can become more dangerous as a food than raw milk which has stood for the same length of time; therefore careful handling of boiled milk as well as other boiled foods is of the utmost importance. (See Chapter on Hygiene and Economy, under Left-Overs.)

In many foreign countries it is a general custom in every household to boil milk directly after delivery, for the infant as well as for table use. To do differently means uncleanliness. Modern invention of coolers and ice-boxes in every house, and delivery of milk in bottles, has gradually done away with this custom. Many of our present generation of house-wives are so little acquainted with practical housekeeping that they consider food fit for use as long as it has not soured, notwithstanding the many changes it has undergone on the pantry shelf. Raw cream is fit for use only directly after it has left the separator. Raw milk should not be considered fresh and wholesome for table use longer than eight or ten hours after milking, and then only with the most careful handling. Following this precaution, morning milk, which is delivered during the day, should not be used raw later than five or six o'clock in the evening. Remember that all milk begins to turn acid as soon as it comes in contact with the air. The longer it stands the more acid it will be, besides being laden with germs. The process of cooking or scalding raw milk checks the fermenting processes and renders the food more alkaline, especially if it is to be taken with cereals or fruit puddings and gelatines.

Cooked milk is not a natural food, but neither are cooked cereals. Raw milk is quickly digested, while boiled milk takes several hours to digest, and so do boiled cereals. A combination of raw milk, or cream, and cooked cereals will force the stomach to absorb the milk immediately, while the remainder, poorly masticated and filled with germs, will tend to produce an acid process rather than an alkaline. If sugar is added to raw milk and cereals, the process of intestinal fermentation is complete. If the glandular system and the eliminating organs are strong, they will work harder in order to rid the system of this excess of acid; but if the constitution is not able to stand the strain of wasteful nervous expenditure, discomfort and disease will be the result! Enlarged tonsils are often the first sign of danger. We cannot invent customs of feeding that interfere with natural laws without paying the penalty.

MISCELLANEOUS FOODS.

FATS.

Fats are derived from the animal and vegetable kingdom; they are rich in carbon and hydrogen, but poor in oxygen. Emulsified fats are present in cream, nuts and the yolks of eggs. Oleins are mainly found in oils obtained from fruits, nuts and vegetables. Butter contains mainly palmitin. Suet, from beef and mutton, consists of stearin and palmitin. Lecithin is found in yolks of eggs and in some nuts; it is a highly complex compound, and a food for the brain and nerve substance. Suet and mutton fat contain much stearin, and are harder to digest by some people than other fats. However, the digestibility of a food depends much upon the individual requirements, and a little self study will soon convince each what forms of fat are best suited to his needs. As a rule, people of large bone structures require a greater amount of fat in their food than those not so constructed.

Fats are changed into fatty acids and glycerine by the secretion of the bile and pancreatic juice, and in combination with the intestinal juices form soluble soaps. In acute diseases fats should be taken only in the form of butter, milk, or cream, in limited quantities. Fatty foods are beneficial for children suffering with scrofula or rickets, and in all chronic, wasting diseases.

People who do much indoor work, or those who are not able to digest a sufficient amount of protein or cereals, require more fats. The latter can be made easily digestible if rightly combined and prepared in the form of soups, warm sauces, boiled custards and mayonnaise dressing. In this way the fat globules are equally divided in the food and can be better emulsified than if eaten in the solid form, or in combination with white bread or other unsuitable articles. Cream, and the lighter nuts, combine well with sweet foods, while oils, yolks of eggs, meat fats, and solid fats, combine well with foods which are rich in minerals and oxygen.

People who are unable to furnish their table with expensive fats, such as butter, olives, cream, olive oil, bacon, eggs, eel and other delicacies, should use the cheaper forms of fats, as corn, oats, herring, walnuts, cream-cheese, cottonseed oil, bran, leaf lard, vegetable butter, middle rib of beef, blood and liver sausages. Meat products, prepared from the internal organs of the animal, are rich in lime and fat, and, if prepared from fresh meats of healthy animals, they are often preferable to canned and cold storage products, or to meat which hangs in a meat-shop for a week. However, every one who buys these articles should investigate the source and manner of preparation for himself.

SUGAR.

Artificial sugar is not a necessary article of food for the healthy individual who is able to supply his body with fresh and dried fruits the year round.

True candies are: figs, dates, raisins and other tropical fruits. The delicious summer fruits are better eaten without sugar. Undoubtedly nature did not mean for us to indulge in sweets during hot days, or she would have provided us more plentifully with them. All the spring fruits are tart: people who wish to improve the taste of berries add sugar to them at the expense of health. Our forefathers, who did not enjoy such luxuries, had better health than our present generation. The sugar-cane in its natural state is a valuable food. It contains gluten and minerals, such as are found in other vegetables, and if eaten in this form it is more wholesome than refined sugar. The gluten and minerals are destroyed by chemical processes which are necessary to produce sugar from the cane and beet. Pure, crystalized sugar cannot sustain life, unless it is eaten in the proper proportion, with foods which contain gluten, minerals and fats.

Sugar which contains minerals cannot crystalize; it remains syrup, therefore the latter is more wholesome than sugar. In order to produce beets, which are richer in sugar and poorer in salts, certain methods of manuring are employed. The profit gained by this method is a financial one. The consumer is the loser.

If artificial sugar is united with cocoa or other bitter, sour, nutritious substances it will serve as a food; therefore, sugar in the form of a prepared food such as chocolate, gelatine and gruels is wholesome for those who require cooked foods. If the sugar industry were diminished, the canning and stewing of fruits would also be diminished, and we would have fewer tea and coffee drunkards. All this gluttony in stimulating beverages and sweet fruit sauces was not indulged in by the masses a hundred years ago, therefore the constitution of the average individual at that time was much stronger.

Many parents are impressed with the idea that their children require a large amount of sweets, in order to make them grow. We cannot force nature without paying the penalty. At maturity, we reap what has been sown for us, or what we have sown for ourselves.

SPICES.

Spices are a species of aromatic vegetables and fruits used for the seasoning and preservation of foods. Their flavor is pleasant and stimulating to the mucous membrane of the mouth.

The odoriferous substances yielded from these plants are: the volatile oils and ethers of peppermint, roses, orange flower, lavender, camphor, lemon, bitter almond, wintergreen, cinnamon, cloves and a number of others. They are used for perfumes, medicines, confections, and in the art of cookery. Many of the spices used for food are dried, as bay leaves, thyme, marjoram, vanilla beans, dried skins of lemons and oranges. Ground spices or liquid extracts should be used sparingly. Many of them are adulterated. Free salt and ground spices create an abnormal desire for water and food, and they injure the mucous membrane lining of the blood vessels and glandular structures, and obstruct the capillaries.

People who cannot relish their food without these artificial appetizers should fast a while, or replace them by natural stimulants, as tomatoes, apples, lemons and greens. Few people realize the harm that is done by the number of salt, sugar and pepper holders that are placed on the table at every meal, to say nothing of the dozens of boxes of ground spices that fill the kitchen shelf. A pinch

of pepper on gravies, milk soups, or other nutritious dishes, if mixed thoroughly with the food, assists in the coagulation of soft nitrogenous foods and prevents putrefaction, but excess of it, or if sprinkled on dry food, is very harmful.

The best way to use spices is to buy them whole, in the fresh or dried state, and chop, grate, or grind them when needed. Vanilla beans, bitter almonds, bay leaves, cinnamon bark and many others may be used whole and removed before serving.

Children's food should never be covered with pepper or other stimulating spices. Under our present system of living salt has become a necessary adjunct to our food. Legumes, cereals or any other foods which require a large amount of water for cooking need an additional amount of salt. It should be added before the food is removed from the fire, so that the salt will be properly dissolved and combined with the food. Moderate amounts of preserved, salted meats and fish are valuable as antiseptics, if combined with soft, cooked, nutritious foods in the form of soups and gravies, or with milk foods, eggs, cereals or legumes. Salt used in this way will not hurt the lining of the alimentary tract and other tissues, as free salt does when it is sprinkled on lettuce, meat, potatoes or other dry food. Never use salted, smoked or preserved meats or fish in excess. If possible, investigate the source and manner of preparation of preserved foods.

DESSERTS.

Desserts have only been mentioned in the form of steamed puddings, gelatines, oranges, grapes or bread and butter in combination with black unsweetened coffee. Artificially prepared desserts in the form of attractive, soft puddings and other rich mixtures flatter the palate and renew the appetite. The true enjoyment of eating is in the satisfaction of hunger. The craving for desserts indicates a desire to stimulate certain nerves, which force the contents of the stomach into the intestine and destroy the digestive processes or produce decomposition, hasten absorption, and exhilarate the brain with the toxins hereby produced.

Those who desire to correct the habits of intoxication in themselves or in others should consider whether the abnormal craving is for merely physical pleasure or for the satisfaction of starved and overworked brains and bodies, and the change should be brought about accordingly. To drop a long acquired habit at once may prove harmless to one person and very fatal to another.

The worn-out digestive organs need to be toned up and developed gradually, either by stimulating fruits or fruit juices or by tonics in the form of bran-tea and malt-coffee.

People who have vigorous appetites and strong digestive organs may eat a few nuts at the end of the meal until the appetite has been restored to normal. For those who like sweets, a large number of recipes have been given for fruit salads and light cooked dishes. Many can be served as whole meals for the evening, or in combination with milk broths or soups.

MUFFINS AND PANCAKES.

Many people who find pancakes indigestible will do well to observe the time when they are most agreeable. If they are made with eggs, cream, and water, or with rich milk, and properly prepared and combined with suitable articles, they are generally agreeable to the most sensitive stomach.

People of sedentary habits, or those who do brain work mainly, should not eat pancakes or muffins for breakfast.

All ingredients, as well as the vessel, should be cold. The batter should also be made in a cold place or out of doors. The oven, the baking pans and the oil in which the cakes are baked, should be as hot as possible.

BREAD.

Bread made from white flour and yeast is the staff of death. Few people realize that if they wish to use white bread as a food the proper amount of minerals, fats and nitrogen must be added, in order to make it a perfect food. Yeast bread, if eaten with jams and jellies in large quantities between meals, is health destroying and dwarfs the body. It is also unwise to eat white bread in combination with other starches, as rice, potatoes and soft puddings. The average individual who takes plenty of out-door exercise may get along well for years on such mixtures and suffer no inconvenience, but people with poor eliminating organs or chronic ailments, or those who do much indoor work, do well to use yeast bread in moderation, especially if prepared from white flour.

Baked and boiled cereals are more nutritious than bread. In the fermenting process which takes place in rising bread, valuable substances such as lime and salts are lost. It is rendered more acid, and therefore unfit as a food for people with weak stomachs. If yeast bread is combined with foods which render the fluids of the stomach alkaline, it is less harmful.

SOUPS.

Many American housekeepers do not know how to prepare soups and do not like them. The fact that people of many nations in the old world, with smaller incomes than the average American working man, use soups daily, once or twice, and are far superior in physical strength and endurance to the latter, who lives mainly on beefsteak, white bread, potatoes, sugar, tea and coffee, should convince every one that nutritious soups are an important article of diet. Close study and persistent effort will enable every homekeeper with small means to learn how to prepare a soup that is palatable and nutritious. The daily use of white bread and butter is expensive. Besides it produces diseases, imperfect bodies and premature old age.

All who are in the habit of eating more than their systems require and especially those who indulge in large amounts of bread at dinner, would do well to begin their meal with a soup. Legume and cream soups will furnish a satisfactory meal by themselves. For combinations, see “Menus.”

PART TWO

PREPARATION OF FOODS.

TABLE OF MEASURES AND WEIGHTS.

A standard measuring cup contains 8 ounces or ½■ pint.

1 tablespoon = 3 teaspoons 2 tablespoons = 1 ounce 8 tablespoons = 4 ounces or ½■ cup 16 tablespoons = 8 ounces or 1 cup

All ingredients measured by the cup, tablespoon or teaspoon are measured level.

1 pound (English weight) = 425 grams or 16 ounces 1 pound (Metric system) = 500 ” 2 pounds (Metric system) = 1000 ”

CHAPTER I.

GREEN VEGETABLES.

Green vegetables furnish a large amount of easily digested carbohydrates and contain much mineral matter in which meats and cereals are deficient. That they add to the highest purity of our blood has been proven by the fact that many blood and skin diseases have been cured by the application of specific greens alone. However, no matter how valuable an article is, it should be used according to the needs of the individual. As vegetables also contain a large amount of water, it is not wise for one who has to perform active mental or physical labor to indulge in a large amount of cooked, especially underground, vegetables at the noon meal. At this time of the day the system requires the most nutritious foods in the form of proteid elements, no matter whether the meal consists of cooked food, cold or warmed over. Green peas and corn are best eaten at the noon meal, as they are rich in proteid elements. Asparagus, tomatoes, string beans and leaf greens are also suitable at this time of the day, provided some nutritious food of the proteid class is served with them. For further combinations, see “Left Overs” and Menus.

The blanching of vegetables, as advised by some authorities, will always remove valuable constituents of the plant. The blanching and ventilation of vegetables during the process of cooking is advised, in order to make them more wholesome. All artificially prepared foods will lose certain constituents through the process of cooking, and this loss is generally made up by additional flavoring or sauces. Vegetables which are cooked in very little water and kept well covered (not ventilated), will lose less of their natural qualities, and the injurious gases which do not escape by this process can be made harmless through the addition of fats, in the emulsified form, as sauces, the yolk of an egg, lemon or cream.

In the consumption of food, as well as the custom of dress and education, some people have reached that stage of refinement where degeneration begins. We cannot refine natural food without paying the penalty for it, which means the producing of disease and the shortening of life. The excessive use of refined sugar, alcohol and other artificial stimulants, has produced a dislike for fatty foods by many people, so that they refuse to eat sauces, or fat meats in any form, the only fat they use being butter. While the latter is a valuable food, it often cannot be assimilated by the system if spread on white bread, or mixed with cooked vegetables; it generally serves only as a lubricant. If butter is eaten in excess, especially in the summer, it clogs the system. Some people prepare vegetables and soups with melted butter for the sake of convenience. This is a waste, since a tablespoonful of butter or other fat properly emulsified as directed under butter sauces will often give more nutriment than one-quarter of a pound of butter

wasted by soaking into toast or other cooked foods.

The American method of cooking green vegetables in a large amount of water and throwing it away, then seasoning them with butter and spices and serving them with lean meat and white bread, produces a starvation diet. In such a meal, the important mineral matter and the fats in vegetables and whole wheat grains are left out, and are supplemented by an excess of starches and water in the form of bread, beverages and desserts. Additional fats should be added scientifically and combined with foods which are rich in minerals and acids.

All vegetable water, especially that of canned or sterilized fruits and vegetables, is very wholesome and antiseptic. Strained, sterilized tomato, currant, gooseberry and strawberry juices are unsurpassed as a liver medicine in some conditions. These same foods will lose their medicinal value if stewed in an open kettle. They should be prepared in Mason jars or cans. After opening, these fruit juices may be kept in earthenware on ice for twelve hours, and served again. After this they should be reboiled or sterilized, in order to check fermentation. For the sick, the same precaution should be taken with keeping fruit juices as with milk.

When using canned vegetables, never throw away the water, if it is not to be used for dressing. Add it to soups or use it in place of beverages. Pea, bean and asparagus water may be made very palatable if cream is added. See preparation of legume teas under "Fluids."

In preparing vegetables for the sick, the finest of all dressings is the yolk of an egg and lemon juice, with a small amount of butter. The fat in the yolk of the egg being emulsified in a perfectly natural state, it feeds the mucous membrane of the entire alimentary tract and blood vessels. Besides neutralizing the gas producing tendencies of the foods, it aids in the digestive and assimilating processes and feeds the nerve sheaths. In all chronic conditions, which are the result of hardening of the arteries, a large amount of the yolk of eggs, combined with lemon and oil, may be used. There are a few vegetables which do not combine well with the yolk of an egg, such as turnips, carrots, beets and onions. These contain a large amount of sulphur and iron, which is also found in the yolk of the egg. Fat meats are good additions to the last mentioned vegetables, except onions, which are rich in oil themselves. If underground vegetables are served in the form of purees, they should be mashed very fine or rubbed through a colander; the butter which is added should not be allowed to boil. Peas, beans, cauliflower and cabbage are most likely to disagree if served with butter only. Butter sauces, cream sauces, yolks of eggs and lemon are the best additions to make them agreeable.

Some people prefer vegetables cooked in oil. Those whose systems can digest a large amount of fat will find them agreeable.

ARTICHOKES.

Wash them thoroughly and remove the outside leaves. Drop into salted boiling water and cook for 20 or 30 minutes. Add a few drops of vinegar to the water while boiling. Serve warm with a white sauce or let cool and serve with French or mayonnaise dressing.

ASPARAGUS.

Wash and cut them into inch pieces until the hard part of the stem is reached. Boil them for 20 minutes, or until tender. Serve warm with butter, milk, cream, or egg sauce, or cold with French or mayonnaise dressing. The asparagus may be scraped and tied into bundles when boiling.

BEETS.

Remove the green tops and wash them carefully. Do not prick the skin, as the juice will then escape and injure the color as well as the flavor. Young beets will be tender in about one hour, older ones take two to three hours. When done, peel and slice. Serve with a butter or cream sauce, or plain, with butter and chopped parsley. For salad, cut into slices and pour over them boiling vinegar, diluted with one-half water. Add whole spices if desired.

MASHED BEETS.

Prepare like the above. When tender, peel and mash very fine with a potato masher, and add butter and a few drops of lemon juice.

BEET GREENS.

Wash the tops and boil in a very little water until tender. A small piece of salted or smoked lean meat may be boiled with them to give them a better flavor. Chop fine and flavor with butter and lemon juice. A brown butter sauce may be prepared from the water in which the greens have been boiled; when done mix with the finely chopped greens, and let it boil a second, and flavor with lemon.

ROASTED CARROTS.

Wash, scrape, and cut them lengthwise into halfs and quarters, then cut crosswise into inch pieces or smaller. Cover with boiling water and cook for 10 or 15 minutes, with a little salt. Drain off the water (add to soups); brown some fat and flour, add to it soup stock, whey or the water which was drained off, and roast the carrots in it until done. Cover them tightly and add more fluid while roasting, if necessary. Flavor with chopped parsley.

CARROT PUREE. No. 1.

Steam or cook the carrots with salt and as little water as possible. A small piece of lean bacon or cornbeef may be added for flavoring. When done, mash very fine with a potato masher. Flavor with butter and a little pepper and parsley or lemon.

CARROT PUREE. No. 2.

Prepare like the above, and add one potato to three medium-sized carrots. If the potatoes require less time to cook, add them when the carrots are half done. This preparation may be especially recommended for chronic invalids or for those who have a dislike for the sweet flavor of the vegetable.

CREAMED CARROTS. No. 1.

Cook like carrot puree. When tender, make a butter sauce with the water; add parsley and hot cream, if desired.

CREAMED CARROTS. No. 2.

Cook like number one, thicken with flour or corn starch, and add some hot cream and parsley. Serve, like soup or vegetables, for breakfast or supper, with dry whole wheat or black bread. Butter is not required at the meal if cream is used. If the butter and cream are emulsified as in sauces, they are more wholesome.

PEAS.

Wash the peas while in the pods, then shell. Boil the pods in a very little water for 15 minutes, then take out and put the peas to boil in the same water. Add a little salt and sugar when almost done. Prepare further like creamed carrots. Some people prefer them with no dressing except butter. Those who have difficulty in digesting starch and wish to cut out the bread at the meal may use sauces or cream dressings with their vegetables, especially in the winter.

MIXED PEAS AND CARROTS.

Put the peas on to boil, and when half done, add an equal amount of carrots which have been cut into half inch pieces. Prepare with a butter sauce like creamed carrots, and add chopped parsley. This will afford a perfect meal for dinner in spring or summer. A few bread or flour dumplings may be served with it. The latter should be cooked with the peas 10 minutes before serving. Salted or smoked meats give them a good flavor.

PEAS AND CODFISH (Saxon Dish).

Cook the peas with a very little water, and add meat broth while they are boiling. Boil some fresh codfish in a separate saucepan, and when done remove the skin and bones, cut into pieces and mix with the peas. Prepare a butter sauce from the liquid remaining on the peas. Carrots may be added.

PEAS WITH LAMB.

Boil the lamb with sufficient water to cover it. Add salt and onion. When half done, put it to boil with the peas, which should have been boiled with water in another saucepan for 10 minutes. When meat and peas are done, remove the fat, thicken with flour and add the pea water to make a butter sauce. Flavor with parsley. Use the meat broth for soup or add the yolk of an egg or two, and

serve in cups.

MIXED VEGETABLES (Leipsiger Dish).

Use asparagus tops, young French carrots, peas, and cauliflower. Cook each vegetable separately with salt, in as little water as possible. When done, drain the water from each and use for soup. Mix the different vegetables in one dish and pour browned butter over them. Serve with Lobster Curry. A butter sauce may be prepared from the vegetable water in place of brown butter. Bread or flour dumplings may be served with it. Lean meat is also a good combination.

CAULIFLOWER.

Cauliflower should be avoided by those who have delicate stomachs, at the evening meal. It should be perfectly fresh and put into salted water for an hour before cooking, in order to take out any hidden insects. It should be boiled 20 to 30 minutes; if steamed it takes a little longer. Flavor with salt and a little sugar while boiling. Serve with brown or melted butter and lemon, or prepare a butter sauce with soup stock and the yolk of an egg, or with cream. Season with pepper. Serve with chipped beef or grated cheese for breakfast, or with lean meat for dinner. Left over cauliflower may be baked in the oven with cheese or bread crumbs, and served for breakfast. Tomato sauce is also suitable as a dressing. Cold cheese is a better combination with the latter than cream sauce or baked cheese.

STRING BEANS.

They are very purifying and should be eaten often, by people of a bilious tendency. Select young string beans, pull off the string on each side and break in pieces an inch long. Boil in slightly salted water and prepare like green peas. They may be mixed with carrots. Ribs of beef or lamb can be cooked with them as described in recipe for peas. For other combinations, see “Boiled Mixed Dinners.”

SPINACH.

This is also a very valuable vegetable. Besides being rich in iron and phosphates, it is laxative, and excellent as a medicinal food for constipation. Wash it thoroughly. For a delicate stomach use the leaves only. Steep in as little water as possible, chop very fine or rub through a colander; season with pepper, salt, lemon and butter, or prepare with a brown or white butter sauce from soup stock, or spinach water. Gelatine may be used in place of soup stock by dissolving the gelatine in the vegetable water. Smoked or salted lean meat may be cooked with it for flavoring. Serve with eggs or lean meat.

SPINACH (Saxon Dish).

Boil in as little water as possible, and chop fine. Then chop fine some well watered salt herring or other salt fish. Prepare the spinach with a butter sauce made from soup stock, add the fish and serve on toast. Dried bread crumbs or browned flour mixed with butter, without the liquid, may be added to any of the green leaf vegetables.

MUSTARD GREENS.

Dandelions, yellow dock, horse radish tops and lettuce may be prepared in the same manner as spinach.

OKRA.

Wash and remove the stems. Boil in salted water for 40 or 50 minutes. Prepare with a butter or cream sauce.

STEWED CUCUMBERS.

Wash and peel them. Then cut into pieces and cook with as little water as possible, until tender. Serve with fish or lean meat for dinner, or with whole wheat or rye bread for breakfast.

CELERY ROOT.

Wash and boil the roots with the skins. When tender, peel them and cut into slices. Prepare with a butter sauce made with soup stock or serve with French dressing. Flavor with parsley.

BLACK CARROTS.

Wash and scrape. Boil in salt water to which a little vinegar has been added. Prepare with a butter sauce, or mash fine. Serve with tongue, croquettes or boiled beef.

EGG PLANT.

Cut in slices about an inch thick. Make a batter of eggs, salt and flour; dip the slices of egg plant in the batter, and fry in hot fat. Serve with lean meat, for dinner or supper, or serve with green salad for breakfast.

STUFFED GREEN PEPPERS.

Cut off the stem end and remove the seeds. Fill the peppers with a dressing such as is given in recipes for bread dumplings or meat croquettes. Place them in a baking dish with two tablespoonfuls of oil or fat; when brown add a little flour and some soup stock, cover the dish and bake in an oven for about 50 minutes. The inner part of the peppers may be mixed with the filling.

ONIONS.

For stewing use small or medium sized onions. Boil them in salt water, drain off the water and serve with butter and lemon, or prepare a butter or cream sauce. They are best eaten for breakfast or dinner with some salted meat, and wheat or rye bread.

RAW ONIONS.

People who like onions and find they disagree on account of the strong acids, should grate them and mix thoroughly with sauces, or French or mayonnaise dressing.

FRIED ONIONS.

Chop the onions very fine in a wooden bowl. Then heat some butter and oil and fry them until light brown and pour over steak or mix with potatoes.

PARSLEY.

Chop enough to last for several days. Melt some butter and add the parsley, and let boil up once. When cold put on ice. This saves time, though it is best to prepare the parsley fresh for each meal.

MUSHROOMS.

Wash and dry them, then roll in flour and fry in fat until brown. Add some soup stock and steep until done. Cover well. If the stock is too thin, add a little browned flour; season and serve on toast.

RED CABBAGE.

Wash and cut in quarters. Mince very fine and put on to boil in a little water; let it cook for 20 minutes in earthen ware, then add three to five ounces of fat or oil, some vinegar, sugar, salt and caraway seed. Let all cook for several hours. A few apples may be cooked with the cabbage and taken out when done. The latter may be served for breakfast. When the cabbage is done, thicken with browned flour and let cook 10 minutes longer. Onion may be added if desired. A piece of salt pork is also a good addition in place of oil.

WHITE CABBAGE. No. 1.

Prepare the same as red cabbage.

WHITE CABBAGE. No. 2.

Cut in quarters and boil in a little water with a small piece of lean salted smoked meat, or without meat. When tender, drain and serve with butter and the yolk of an egg and lemon, or with an egg sauce or tomato sauce.

SPROUTS.

Remove the outside leaves and put to boil in a little salt water. When tender, drain and season with butter and lemon. The yolk of an egg may be added. A butter or egg sauce is also good.

COOKED CORN.

Remove the leaves and put in cold salt water for 30 minutes. Then boil for 20 minutes. Corn is best when eaten raw. It is very nutritious and will afford a perfect meal during the summer with tomato salad and lettuce.

CANNED CORN.

Thicken the corn with flour and water. Add a small amount of hot cream and season with salt and pepper or a few spoonfuls of tomato juice. If no cream is desired, drain off the liquid and thicken like butter sauce. Canned corn, being a rich and soft food, should not be mixed with many other foods at the same meal. It is more suitable for the morning or noon meal than for supper.

KOHLRABI.

Peel, slice thin, and stew in a very little water. When nearly done, add some hot soup. Prepare with a butter sauce. Chop fine some green leaves of the plant previously boiled and add. Serve with boiled beef.

VEGETABLE OYSTER.

Wash, scrape and boil in salt water until tender--about 40 minutes. Prepare with butter, milk or cream sauce, or mash fine and fry like potato balls. Season with lemon or pepper.

TURNIP PUREE.

Prepare like carrot puree. Cook with as little water as possible.

ROASTED TURNIPS.

Prepare the same as roasted carrots. They combine well with mutton.

FRIED PARSNIPS.

Scrape, wash and cut in slices, lengthwise. Boil in salt water for 5 minutes, then drain and fry in smoking hot fat. They can be turned in batter if desired. They may be fried without cooking, like sweet potatoes.

KALE.

This is a desirable vegetable in cold weather. It is purifying and very valuable during the rainy season, in malarial districts. Remove the leaves from the stems, wash and boil in salt water, using as little water as possible. Chop very fine and prepare like spinach. A little smoked meat may be added.

SQUASH.

If young and tender it does not require peeling. Wash, cut into small pieces and steam. When done, mash fine and season with salt, pepper and cream, or butter, and a few drops of lemon. It may be cut in slices and fried in oil, or dipped in butter and fried like egg plant.

TOMATO PUREE.

Cut some fresh, firm tomatoes into several pieces. Cook in a double boiler with as little water as possible. Rub through a sieve with a spoon or potato masher. From 3 to 6 ounces of thick puree is sufficient at a meal, for the average adult. For medicinal purposes, tomatoes may be eaten in large quantities.

CANNED STEWED TOMATOES. No. 1.

They are more wholesome if not cooked. Place a can of tomatoes in hot water to heat, drain off the liquid, and serve with meat, fish, eggs or cheese. The liquid may be kept for soup.

STEWED TOMATOES. No. 2.

Heat a can of tomatoes, thicken with flour and water, and let boil 10 minutes. Add some butter and flavor with onion, and small amount of sugar if desired.

STEWED TOMATOES. No. 3.

Prepare as number two, thicken with bread or cracker crumbs, instead of flour.

STEWED TOMATOES. No. 4.

Heat a can of tomatoes. Then heat some butter and oil in a flat saucepan, thicken with mixed flour, flavor with onion, add the tomatoes gradually, and let boil a few minutes.

STUFFED TOMATOES.

Wash the tomatoes and cut off the upper part with a sharp knife. Scrape out the pulp and fill the tomatoes with cold chopped meat mixed with onion and mayonnaise dressing. Garnish with lettuce and serve with bread and butter, or as an entree.

SAUERKRAUT.

Wash the sauerkraut in cold water several times. People with sensitive stomachs should boil it for a short time. Then drain off the water and put on to boil again. If no meat is served with it, use a few tablespoons of oil, lard, butter, or goose fat. Add onions and a little sugar or some apples for flavoring. Cook from one to two hours. Then add a little flour dissolved in cold water, or two raw grated potatoes. Remove the apples before serving. The latter may be eaten for breakfast or supper. If the onions disagree, remove them before serving. Good combinations with sauerkraut are: Pea puree, pork, bacon, liver, liver-pudding, white fish, and oysters stewed or fried.

CABBAGE ROLLS.

Wash some large cabbage leaves. Fill them with finely chopped left-over meat, mixed with eggs. (See recipe for croquettes.) Then tie the rolls together with a string. Steam in a shallow dish with as little water as possible. Serve with an egg sauce. Flavor with mace.

POTATOES.

Potatoes consist mainly of starch and water. They are more expensive than wheat, rye, oats, barley and corn. They should not be eaten oftener than once a day, or better three times a week. People who do hard physical or mental work should not eat potatoes at the noon meal. Fat meats, eggs, fish and greens combine well with potatoes; if they are served with lean meat, some fatty substance in the form of butter, cream or gravy should be eaten with them. Fried potatoes are not wholesome. The best way to prepare them is to boil or bake them in the skins, or boil or mash them in cream or buttermilk.

POTATO SALAD.

Boil or steam some potatoes with their jackets on. When done, peel and slice them into a deep bowl while warm; then sprinkle over them a little salt, pepper, and finely chopped or grated onion, and pour over them some boiling hot vinegar diluted with one-half water and mixed with melted butter or oil. Cover with a saucer and shake well; let stand for twenty or thirty minutes. If there is too much liquid, pour off some and mix the remainder with mayonnaise dressing and chopped parsley, if desired.

SWEET POTATOES.

Boil the potatoes in the jackets, let cool, peel, slice, and fry in one-half butter and one-half oil. Serve with cranberry sauce, lettuce, and lean meat.

Sweet potatoes may be peeled and sliced in the raw state, and fried in half oil and half butter. Serve as above. They are very suitable for breakfast.

CREAMED POTATOES.

Select small potatoes and boil in the skins. Add some salt. When done, peel and cut into thin slices. Bring some milk to a boil, and thicken with corn starch dissolved in water, or prepare a butter sauce with butter, flour and milk. Add the potatoes and some finely chopped parsley. Serve with fish or salted preserved meat.

CRUST POTATOES.

Use small, imported German potatoes. Boil with the skins, peel and turn in yolk of eggs and rye nuts; fry in oil and butter. Serve with sprouts, or spinach and meat.

STEAMED POTATOES.

Peel small sized potatoes, wash and put into a steamer or colander. When done pour into a dish, and mix with chopped parsley and fresh butter. Serve with fish.

FRENCH FRIED POTATOES.

Peel and cut into long strips or thin slices. Put into salt water on ice for half an hour. Fry in boiling oil.

MASHED POTATOES.

Peel, wash, and boil or steam the potatoes; when done, mash fine, and add some hot cream or cold buttermilk, and a little salt, also a piece of butter.

MASHED SWEET POTATOES.

Prepare the same as white potatoes.

POTATO BALLS.

Beat 2 eggs with an egg beater, mix with one cup of left-over mashed potatoes, shape into balls and fry in hot fat. Serve with bacon, fish, or sausage, for breakfast.

POTATO PUDDING.

Prepare the same as potato balls. Put the mass into a pudding dish and cover with rye nuts, grated cheese, or a beaten egg mixed with rye nuts, and bake half an hour.

POTATO AND APPLE PUREE.

Prepare as for mashed potatoes. Use apple sauce in place of milk or cream, mix well and add a liberal piece of butter. Serve with sauer roast, veal cutlets or sausage. It is good for breakfast with bacon.

CHAPTER II.

LEGUMES AND MEATS.

BAKED BEANS.

Pick over the beans carefully, wash and soak them in soft water as directed in chapter on legumes. If the beans are to be cooked with fat, scald or parboil the meat first, add it to the beans after they have cooked for about an hour. If the beans require long cooking, take the meat out when it is tender. When the beans are tender, pour them into a bean-pot or round pan, cover the top with part of the fat meat cut into slices, or pour some cooking oil over the beans, and add a few whole onions. Bake for about an hour. Onions and fat meat eaten at the same meal are liable to disagree, therefore serve the onions at another time, or use them only for flavoring purposes.

BAKED LENTILS OR PEAS.

Prepare in the same manner as baked beans. They require less fat for cooking, and are more palatable if served without meat than are beans. Onions are rich in oil, therefore if plenty of onions are used, the meat is not missed so much. In cooking legumes, it is best not to add the salt until they are nearly done, because the salt hardens the water. If legumes are preferred cooked instead of baked, it is better to add a thickening of flour and butter before serving, otherwise they may produce flatulent dyspepsia.

Legumes lose their natural flavor and stimulus in the drying and soaking process, therefore they are not palatable or easy to digest without some form of fat and appetizing raw salad, which supplies the needed stimulant. Many people add sweets to legumes or make them more indigestible by adding ground nuts and other rich foods to them, as in many vegetarian dishes. Such foods are a dangerous burden to a weak stomach and liver. Heavy protein foods require an acid medium for proper digestion and utilization. If legumes are used in the form of soups and purees, nothing should be added but a little flour, dry toast, fats, or raw vegetables. If we wish to be strict vegetarians we must live upon raw foods. If we wish to live on cooked foods, a moderate amount of meat is necessary for most people.

LIMA BEANS. No. 1.

Soak some lima beans in soft water. Cook in a small amount of water with a little salt. When tender, dissolve some cornstarch with cold water and add to the beans; boil for 10 minutes, then add a few tablespoonsful of hot cream and remove from the fire. Flavor with chopped parsley, if desired. Serve with frankfurter or other lean, smoked meats. Mashed or raw carrots are also a good addition.

LIMA BEANS. No. 2.

Prepare like the foregoing. Drain off the water and add a piece of butter, the yolk of an egg, a little lemon juice and parsley, if desired.

LIMA BEANS. No. 3.

Prepare like the foregoing. Drain off the water and prepare a butter-sauce, mix with beans and serve plain, or add the yolk of an egg, a little lemon, and parsley.

PEA PUREE.

Soak ¾ cup of dried green peas in soft water. Boil with I quart of water and 1 onion for about an hour. Bake in a bean-pot for 1½ hours or longer; add more water if necessary. Keep the peas covered. When done run through a colander and add 1 teaspoonful of butter. This makes about ¾ of a cup of puree. One-third of this portion is sufficient for a sick person or a young child. Serve on toast, or with raw carrots, or cold fat meat.

BEAN AND LENTIL PUREE.

Prepare and serve like the foregoing. A small veal or mutton bone may be boiled with it. The puree must not be greasy.

SOUR ROAST.

Let a quart or less of vinegar come to a boil, dilute it with one-half the amount of boiling water, add some bay leaves, cloves, whole pepper, onions, or any other flavoring, and pour over a piece of beef (rump piece) which has been slightly rubbed with salt. Let it stand for several days. Then take it out of the liquid, cover with bacon or suet, and put into hot fat. After it has roasted for a while, stir a large tablespoonful of flour into the fat, add some water, and the spiced herbs. Cover well, and let it roast two or three hours. Add water or buttermilk to the gravy, if desired. Serve with potato dumplings, lettuce and stewed prunes.

VEAL CUTLETS.

Sprinkle some lemon juice over the chops, then beat up several yolks of eggs, turn the chops in them, dip in rye nuts and fry in hot fat for ten minutes. Serve with lettuce and tomatoes, or with boiled potatoes, lettuce, stewed prunes or apple sauce.

CHICKEN IN GELATINE.

Put a small veal bone to boil with the chicken. When tender, take a part of the broth, add some vinegar to it, boil for ten minutes with onions and spiced herbs. Cut the chicken into pieces, place in a deep bowl, and pour the hot broth and vinegar over it. Cool and serve the next day. Use about ½ cup of vinegar to 1 quart of broth.

Another way is to pour pure, hot vinegar over the meat in the bowl, let it stand an hour or longer, then pour off the vinegar, and pour enough broth on the meat to cover it. Meat preserved in this way will keep on ice or in a cool place for a week. The meat and gelatine may be brought to a boil again at the end of the week. This will preserve it for a longer time. Goose may be prepared in the same manner.

LAMB OR PORK IN GELATINE.

The loin is the best part for this purpose. Prepare with veal bone like chicken.

PORK CUTLETS.

Prepare the same as veal cutlets. Fry with plenty of onions.

KIDNEY HASH.

Put the kidney into cold water for an hour, then scald with boiling water and boil in the soup together with a soup bone. When done, mince fine and prepare with a brown flour gravy. Serve on toast.

TRIPE.

Cut into small pieces and boil with a very little water, and a pinch of salt. When done, add some sweet whey or tomato juice. Heat some butter or oil, thicken with flour and add the liquid gradually, as for butter sauce. Season with chopped parsley.

HAMBURG STEAK.

Grind some round steak in a meat grinder. Shape into flat cakes and fry in hot fat with plenty of onions. Turn from side to side while frying.

STEAMED LIVER.

Liver must be fresh in order to be wholesome. During hot weather it may become dangerous as a food after it is one day old. Remove the toxic blood by placing the liver in water or sour milk for one hour. Change the water several times. Then remove the skin and tie some bacon or suet over it. Roll in flour and steam in fat for 20 minutes. Then add sufficient boiling water to half cover the meat. Flavor with bay leaves, salt, pepper and plenty of onions, also add a little vinegar and sugar, and steam for about an hour. Keep the saucepan well covered. Serve with potatoes or with apple and lettuce salad. The gravy can be strained and used the next day for breakfast or supper. See recipe for flavoring of sauces.

HASH.

Chop fine any kind of left-over, cold meat. Mix with one-third portion of grated or mashed potatoes, and add plenty of finely chopped onion and parsley. Brown some flour and butter, add a little soup stock and mix with the meat. Cook and serve on toast or with salad of greens.

FRIED CALVES' LIVER.

Slice the liver and put in cold water or sour milk for at least an hour. Change the water several times, then dry the liver and fry on a hot, oiled skillet, with onions. Serve with a salad of apples and lettuce, with French or mayonnaise dressing.

TONGUE.

Soak the tongue over night in cold water. Boil from three to four hours and serve with dried mushrooms and brown flour gravy.

CROQUETTES.

Chop fine some left-over meat, mix with one-half or one-third dried bread-crumbs, a little salt, pepper and mace. Then add several beaten eggs, mix well, form into balls, roll in egg and cracker-crumbs, and fry in hot fat. Drain on paper or in a wire sieve.

TONGUE IN GELATINE.

Fresh left-over tongue may be kept for a while by preserving it in gelatine with veal bone.

BRAINS.

Brains are very nutritious, but they are not a wholesome food for people with chronic indigestion. They should be served on dry toast and eaten with sour salads of fruits and greens.

SALISBURY STEAK.

Secure some fresh, thick, sliced, round steak. Scrape, or grind in a meat-cutting machine, and mould into flat, round cakes. Have an iron spider very hot and oiled to prevent sticking. Lay the meat cake in, and turn from side to side till cooked sufficiently.

CREAMED CHIPPED BEEF.

Bring to a boil some soup stock from veal or mutton bone, thicken with cornstarch or white flour, boil 10 minutes, and add one-quarter or one-third part of hot cream. Cut or chop the dried beef fine, pour over it some boiling water, let stand a minute, then drain, and mix the beef with the cream gravy. Add a pinch of pepper, if desired. In place of cream, milk and butter may be substituted and prepared like butter sauce.

BREADED GOOSE.

Use goose which has been cooked in sour gelatine. Take the pieces out of the bowl and warm in order to remove the gelatine. Then beat up several yolks of eggs, turn the meat in it, then roll in flour or rye nuts, and fry in hot fat. Serve with apple sauce or tomato puree.

HAM HASH.

Take equal parts of mashed potatoes and finely chopped boiled ham. Mix with several well beaten eggs and fry in the form of a large flat cake. Serve with macaroni.

MEAT CAKE.

Soak some stale bread in cold water. Press out very dry and mix fine. Add some finely chopped onions, parsley, and a little pepper, and mix with one-third or one-half of finely chopped left-over or fresh meat. Mix all well and shape into a loaf. Bake in an oven with moderate heat. Add boiling water and fat. Baste occasionally, and bake one hour. When done, thicken the gravy with a little flour. Serve for dinner with salad of greens.

SMALL MEAT CAKES.

Prepare the same as the foregoing. Shape into small balls and fry in hot fat.

TURKEY.

Wash and clean the turkey, stuff it with tart apples, cut into quarters, to which a half cup of dried currants and half cup of bread-crumbs or rye nuts have been added. Sew it up, flavor and cover with sliced salt-pork or bacon. Fill the pan one-third full of boiling water, add onions, cover and roast from two to three hours. Add more water, if necessary. Serve with cranberry sauce. Use the gravy left in the pan the next day, with steamed potatoes or rice, for breakfast or dinner.

TURKEY STEW.

Cut off the wings, neck, and legs, before roasting the turkey. Put to boil with a small veal bone, add the giblets and stew until tender. Prepare a butter sauce from the broth. Flavor with onion and parsley.

TURKEY IN GELATINE.

Prepare like turkey stew, and finish like chicken in gelatine.

RIBS OF PORK WITH APPLE FILLING.

Prepare the same as turkey, sew the ribs together and roast two to three hours.

STUFFED TURKEY NECK.

Cut off the neck from a large turkey. Stuff it with a bread dressing to which the giblets, fat and liver of the turkey have been added. Roast it in the same pan with the turkey or prepare it for another meal.

LIGHT BREAD DRESSING FOR TURKEY OR CHICKEN.

Remove the crust from a small loaf of graham bread. Crumble up the soft part and mix with chopped parsley, onion, garlic, thyme, marjoram, sage, salt, one well beaten egg and one-half cup of finely chopped fat of the bird, or suet. This is sufficient for an 8-pound turkey. This dressing is especially good for people with delicate stomachs.

BOILED BACON.

Select firm, eastern bacon. Wash thoroughly with cold and warm water. Let it come to a boil, throw away the water and pour on some fresh water. Boil about an hour. Let it cool on a platter and use the next day. Warm, fat meat is not wholesome for a delicate stomach.

FRIED BACON.

Parboil the bacon for one-half hour. Follow directions for boiled bacon. Let it cool and slice for frying. If the bacon is preferred raw, pour some boiling water over sliced bacon, let stand 5 minutes, pour off the water and fry or broil in the oven.

LEAF LARD.

Chop some leaf lard very fine and let it stand in cold water for several hours, or over night. Fry in an iron skillet, with apples and onions, until crisp and brown. Strain the lard into a bowl and serve the residue warm with stale black bread. Spread the lard on black bread.

BACON FAT.

Remove the fat from boiled or fried bacon and spread on stale black bread. Combine with raw apples. This is good for breakfast.

CHAPTER III.

FISH, CHEESE AND EGGS.

Fish should be cleansed as soon as it is caught, or directly after delivery from the market, and preserved with salt until ready for cooking. If the fish is to be fried, the salt should be washed off, the fish thoroughly dried and rolled in egg and rye nuts, or flour. If the fish is to be boiled, the salt should also be washed off, and the water for seasoning be flavored with spiced herbs. If more salt is necessary, add it to the water.

BOILED FISH.

Prepare as directed in the foregoing.

Fish in gelatine can be prepared with veal bone as directed for chicken. For gravies with boiled fish, see chapter on “Sauces.”

SHELL FISH.

Shell fish, as well as all other fish, should be eaten only when in season. People with chronic constipation and torpid liver should avoid shell fish because they are soft, and easily putrefy. Oysters and clams are a very valuable food for the sick, and also for the

pregnant woman. They are rich in lime substances and nourish the glands of the body. They should be served in combination with lemon and greens, or be prepared with milk.

PICKLED HERRING.

Clean and wash the fish. Place in a colander and add salt. Let stand for several hours. Then, wash the fish and dry; roll in flour and fry in hot fat or oil. Serve warm with lemon, or lay in a stone jar. Add a few bay leaves, whole peppers, and raw onions. Bring some vinegar to a boil with an equal amount of water, pour over the fish and add the fat in which the fish have been fried. If they are kept for several weeks, an extra amount of fat should be added for covering, so as to exclude the air.

FISH CAKES.

Any left-over fish may be made into a nutritious dish for the morning, noon, or evening meal.

Take equal quantities of finely chopped fish and grated potato, beat up several eggs with a little salt and pepper, add some thick cream, and flavor with grated onions. Form into balls with a tablespoon and fry in hot fat. Serve with rice, or with a salad of apples, or tomatoes and lettuce.

CODFISH CAKES.

Take one-third of shredded or finely chopped codfish with two-thirds of grated potatoes; prepare as in the foregoing recipe.

COTTAGE CHEESE.

Put some whole, or skim milk, into a pan and set in a cool room, which has plenty of fresh air. Do not cover the pan. If the room is exposed to dust, put a few long sticks over the pan and cover with a cheese-cloth. When the milk begins to get thick, set the pan into a larger pan with warm water, and keep it in a warm place or in the oven until the curd separates; it must not become hard. Then put a cheese-cloth on a colander and pour the milk into it. Let stand for several hours, until the whey is thoroughly drained off. Then chop fine some green peppers or onions, mix with the cheese, add a little salt and pepper, and serve with apple or potato salad or spread on sandwiches. A few teaspoonsful of sugar and caraway seed may be added in place of the onion and pepper.

SOFT BOILED EGGS.

Put the eggs into cold water, place on the stove, and when the water begins to boil, the eggs will be done.

BOILED EGGS. No. 2.

Pour boiling water over them and let stand on a hot stove for 10 minutes.

BOILED EGGS. No. 3.

Pour boiling water over the eggs and let them stand on a hot stove for 15 to 30 minutes.

SCALLOPED EGGS.

Prepare a plain white sauce, mustard or horse-radish sauce. Cut some hard boiled eggs in halves, pour the sauce over them. Serve with potatoes.

OMELET.

Mix a tablespoonful of flour with a half cup of warm milk or water, and a little salt. Beat up two eggs, mix well with flour and water, then pour into a hot pan in which some butter has been melted. Cover and bake on the stove with moderate heat for eight or ten minutes. Turn if desired. Serve with lettuce and fruit sauce.

SCRAMBLED EGGS.

Beat together one-half cup of soup stock, milk or water, and 3 eggs. Add one-half tablespoonful of flour and mix well. A little chopped, cold, salted meat may be added. Pour all into a hot pan with melted butter, and stir until it is stiff.

CHAPTER IV.

SOUPS.

LEGUME SOUPS.

Soups prepared from legumes, fruits or cereals require an addition of fat in the form of butter, oil, the yolk of an egg, cream, or fat meat.

A soup of peas, beans, corn or lentils may be prepared from left-over food or fresh cooked legumes. To one cup of cooked legumes add three to five cups of hot water or weak soup stock, boil or mix well, then strain. Heat one or two tablespoonsful of butter or half butter and half cooking oil, add to this one or two tablespoonsful of mixed flour, let boil, then add the hot broth at short intervals, stirring to prevent lumps. When all the broth is used, let the whole boil a few minutes. Remove from the fire, flavor with lemon juice, pepper, bay leaves, chopped fresh thyme, sage or parsley, and serve.

To these soups an addition of hot cream may be made before serving, if desired. They form a perfect and an economical meal without the addition of meat, eggs, fish or other protein foods. Celery, lettuce, raw apples and crackers with butter are a good addition. They should be well masticated, and the soup eaten with them very slowly.

BEAN SOUP.

Wash 1½ cup of black, white, red or mixed beans and soak in 1 quart of warm soft water over night. The next day add about 5 pints of cold or boiling water to the beans, let come to a boil; add two finely cut onions and a potato, parsley or other flavoring. Then wash ½ pound of bacon several times with hot and cold water and put on to boil in sufficient water to cover it. Let boil 5 or 10 minutes, pour off the water and put the bacon into the bean soup. Let all boil for about an hour; when the meat is tender, take it out and put on a plate to cool. Let the soup simmer slowly for 3 hours or longer; then strain. Let stand a little while, remove the fat and mix it with 2 or 3 tablespoonsful of flour in a clean saucepan over the fire, add the strained bean soup gradually, let all boil a few minutes and serve. If the soup is desired thin, use only a part of the fat and a little flour. A cupful of strained tomato juice and chopped parsley may be added before serving. This should make five soup plates full. Serve with fried bread or bread and butter and raw carrots.

CREAM OF BEAN SOUP.

Prepare like the foregoing. Leave out the meat, butter, flour, and tomatoes; mix with one-fifth part or less of hot cream before serving. Add plenty of chopped parsley.

PEA SOUP AND CREAM OF PEA SOUP.

Prepare like bean soup. Flavor with celery roots or stems.

TOMATO SOUP.

Strain a can of tomatoes and heat. Add an equal amount of boiling water or soup stock. Heat some oil, butter or fat; add flour, boil a few seconds; then add the tomato juice gradually and a little salt. Boil all 3 to 5 minutes, then serve. It must be of the consistency of gravy. Raw cucumbers and celery are a good addition.

CREAM OF TOMATO SOUP.

Prepare like the foregoing. Add ½ part or more of hot cream before serving. If milk is used, it must be more in proportion than cream.

CREAM OF TOMATO SOUP. No. 2.

Mix 1 quart of hot water or veal stock with 1 quart of strained hot tomato juice. Dissolve 2 to 3 tablespoons of cornstarch in cold water and stir into the boiling fruit juice. Boil 10 minutes, and season with salt and a little sugar, if desired. Remove from the fire, add hot cream, mix and serve. Good in the summer.

HUCKLEBERRY SOUP.

Wash one quart of huckleberries and boil with two quarts of water and a piece of cinnamon. When done strain or leave the berries in the soup. Shape some dumplings with a dessert spoon and boil in the fruit soup until they rise to the top. Use recipe for flour dumplings No. 1. Cherry soup from fresh cherries may be prepared with dumplings instead of thickening.

BLACKBERRY SOUP.

Prepare the same as the foregoing or see recipe for blackberry gruel.

CHERRY SOUP.

Remove the stones from one quart of cherries, and bring two quarts of water to a boil with a stick of cinnamon, pour in the cherries and let them simmer for 20 or 30 minutes. Add enough sugar to counteract the tart taste and thicken with a little cornstarch. Cool and serve with zwieback. If used for supper on hot days it should be prepared in the morning, and allowed to cool. Beaten whites of eggs with a little sugar may be placed on top. Serve on soup-plates.

DRIED CHERRY SOUP.

Soak some dried cherries for several hours. Cook with the desired amount of water and a little sugar and cinnamon. Finish as the foregoing. This is excellent for convalescents during the winter.

PLUM SOUP.

Wash one pound of blue plums and boil with three to four pints of water, a stick of cinnamon and sugar until well done. Thicken with cornstarch, or with sago which has been soaked. Cook 15 to 20 minutes or longer. Run through a colander and add a piece of butter. Cool and serve with zwieback and beaten whites of eggs, if desired. Hot cream may be added in place of butter.

BEEF SOUP. No. 1.

Select a rump piece, wash thoroughly, put into boiling water, add some salt, and skim. Chop fine some green onions, celery, asparagus, parsley, carrots, turnips, add to the soup; young peas, bay leaves, whole pepper and chopped bacon may be added. Cover tightly, and boil slowly for two or three hours. Then brown several tablespoonsful of flour in the same amount of butter, add to the soup, and boil ten minutes longer. Strain and serve. A glass of Madeira or white wine may be added.

BEEF SOUP. No. 2.

Prepare like number one. Instead of brown flour, add one-half cup of barley which has been soaked and boiled in a small amount of water for an hour. Then add to the soup, boil all together for an hour or longer, strain and serve. A good addition to boiled beef is a salad of celery root, or apples, or potato dumplings.

CLEAR SOUP, WITH RICE.

Select some fresh chicken, beef, lamb or several kinds of meat. Wash thoroughly, and put into boiling water, add salt and skim. Flavor with potatoes, onions, or any kind of greens which is most desirable. Boil two or three hours and strain. Boil some rice with salt water in a separate saucepan, bake in the oven until well done. Remove from the fire, add a piece of butter, the yolk of an egg and some grated nutmeg. Stir all well, pour into a dish, serve with the soup like mush and milk.

Clear broth beaten up with yolks of several eggs may be served in cups.

VEGETABLE SOUP, WITH MEAT.

Wash a piece of bacon or ham thoroughly, cover with cold water and bring to a boil. Pour the water off and put on again in boiling water. When the meat is half done add some bay leaves, carrots, celery, young peas, asparagus, parsley, cauliflower, and dried prunes or pears and cinnamon. When the vegetables are tender, brown some butter and flour, mix with finely chopped marjoram and thyme; add to the soup, boil a few minutes longer, and serve. This is excellent in the spring-time. For people with digestive troubles, the soup must be strained. A few raw yolks of eggs may be beaten up with the soup before serving, if desired.

SOUP STOCK.

Wash some beef, mutton or veal bone thoroughly. Put to boil in cold water, skim and cook for four hours or longer. When done, strain into several stone jars or bowls. Let cool and set on ice. When preparing soup, cook the desired amount of vegetables in a little salt water; when tender, add the soup stock, bring all to a boil and strain. This stock can also be used for the preparation of vegetables and purees, especially for people who do not eat meat. Add one-half to one whole cup of stock to the vegetable water and prepare with a butter sauce.

KIDNEY SOUP WITH RICE.

Use soup stock or prepare a clear strong meat soup from middle rib or soup bone to which one or two kidneys have been added. For flavoring tie the tops of celery roots and green onions into a bunch and cook in the soup. The celery and onions can be eaten as a vegetable if desired. Serve with plain water rice as directed for clear soup.

PIGEON SOUP.

Take old pigeon for soup. Flavor with asparagus or young peas. Boil some rice in a little water and salt separately; when half done, add it to the (pigeon) soup and cook an hour longer. Raw yolks of eggs may be added to the soup before serving.

POTATO SOUP. No. 1.

Boil potatoes with salt water and an onion; pour off water, mash potatoes fine, and add the potato water. Bring to a boil some fresh cream and milk in a separate saucepan, and add it to the potatoes. Flavor with a little pepper, and chopped parsley.

POTATO SOUP. No. 2.

Boil the potatoes in plenty of water with salt and onions; drain off water, mash potatoes, and return to the potato water. Then melt some butter, thicken with flour, add the hot potato soup to it gradually, and boil all a few minutes. Bring some fresh milk and cream to a boil, add it to the soup, and flavor with chopped parsley and pepper.

CLAM CHOWDER.

Prepare like potato soup number two, and add clams and hot cream.

OATMEAL SOUP, WITH HAM.

Wash one-half a cup of steel cut oats with cold water. Bring to a boil with two or three quarts of water; add salt, celery, parsley, onions, and about six potatoes. Wash a piece of bacon or ham with plenty of fat on it, parboil it in water for ten minutes, then put it into the soup; boil all for about two hours. Mash and strain. Take off the grease, mix with flour, add the strained soup to it gradually, let boil a few minutes. It can be prepared without meat. This is an economical and nutritious dish.

BARLEY SOUP.

Prepare the same as oat meal soup. Fat meat may be used in place of ham.

KNORR'S PEA SOUP.

Knorr's pea soup can be bought in all first class grocery stores. Time for preparation, twenty minutes. It may be improved by adding hot cream or gelatine to it, or by thickening it with butter and flour. Bean, lentil, green corn, tomato, and several other soup extracts of Knorr's can be prepared in the same manner and improved in many ways if desired. They are very nutritious and save time and labor.

BEER SOUP. No. 1.

Wash and chop fine some dried currants and raisins, put them to boil with one pint of white, stale bread, three pints or more of cold water, a piece of cinnamon, a little salt, a few spoonsful of sugar and about a pint bottle of imported root beer. Boil very slowly for one-half hour or longer, run through a colander. Add some hot cream or a piece of butter and two yolks of eggs.

BEER SOUP. No. 2.

Bring to a boil a pint of imported root beer and a pint of water. Flavor with a piece of cinnamon. Mix two or three tablespoonsful of white flour with cold water, and put into the boiling beer, add some sugar and salt. Boil eight to ten minutes. Remove from the fire, add to it a cupful of hot cream while stirring. Serve with zwieback.

BEER SOUP. No. 3.

Prepare like beer soup number one, in place of white bread use stale black bread or one-half of each. This is excellent for constipation.

MILK SOUPS.

Milk soups may be prepared with rice, buckwheat, barley, tapioca, oats, wheat, flour, corn, macaroni or rye. Oats and barley should be soaked. Rich milk with one-half water is preferable to skim milk or poor milk. Bring the desired amount of milk and water to a boil, stir the grains into it, and boil one-half to one hour. Whole vanilla, cinnamon, or lemon rind may be boiled with it. Salt should not be added until done. It may be flavored with grated bitter almond, fine pepper, mace or nutmeg, or extract of vanilla or other flavoring. Concentrated flavorings should not be added until it is removed from the fire. Yolks of eggs may be added before serving. (Oats, barley and buckwheat do not mix well with eggs.) Sugar is not necessary for milk soups, but if it is desired, it should be added while boiling.

BUTTERMILK SOUP.

Mix some white flour with cold buttermilk, stir over the fire until it boils, add sugar and boil ten minutes. Add hot cream or yolks of eggs or flavoring before serving, as desired.

MILK SOUP WITH MACARONI.

Break some macaroni into boiling salted water, boil fast for 45 minutes. When done, add an equal part of buttermilk or sweet milk. Thicken with a little rice flour.

MILK SOUP WITH FLOUR DUMPLINGS.

Prepare some flour dumplings with or without eggs. Drop into boiling salted water when done, add some hot milk or buttermilk. Thicken with a little flour, add salt and serve. Sweet dried fruits can be added.

BUTTERMILK SOUP WITH RICE.

Cook some rice with water as directed for "Water Rice"; when done add one quart of buttermilk to one quart of cooked rice, mix well and stir over the fire until it boils. Add one-third cup of sugar and simmer with a piece of cinnamon or vanilla for half an hour longer. Add more salt if necessary. Some dried soaked cold prunes, currants or raisins may be mixed with the soup before serving. This forms a perfect meal for dinner on hot summer days or for supper in winter or summer.

ASPARAGUS SOUP. No. 1.

Cut off one-third of the upper end of the asparagus, then wash, cut in pieces and put to boil in water, add some salt; when tender thicken with mixed flour, let boil 10 minutes. Add one-third rich hot milk, flavor with pepper. Serve.

ASPARAGUS SOUP. No. 2.

Prepare as No. 1; when tender, heat some butter, thicken with mixed flour, add the asparagus water gradually and boil a few minutes. Then remove from the fire, stir several yolks of eggs with a little cold water on a soup plate, add the asparagus soup gradually. Flavor with lemon and serve.

BARLEY SOUP. No. 1.

Soak a cup of pearl barley. Boil with two quarts of water, some celery, onions, and finely cut carrots; cook for two hours or longer. Mash all through a colander, add more boiling water if necessary. It must be thick like gravy. Add a piece of butter or a little cream, and serve.

BARLEY SOUP. No. 2.

Prepare like the foregoing, add more hot water when straining. Melt some butter or fat, add one or two tablespoonsful of mixed flour, and part of the barley soup, and cook. When done, mix with the balance of the barley soup. Let all boil up for a few minutes and serve. Add plenty of chopped parsley.

BARLEY SOUP. No. 3.

Prepare like number one or two, boil without vegetables. Leave the barley in it or strain. Mix with cold stewed prunes before serving. Add cream, if desired.

CARROT SOUP.

Scrape and wash some young carrots. Cut into small pieces and stew in water with a little salt. When done, mash up fine and run through a colander. Prepare with butter, flour and soup stock. Add plenty of chopped parsley, also raw pea juice, if desired.

SPINACH SOUP.

Prepare from spinach water, with butter and flour. When done, add a few tablespoonsful of finely chopped spinach. Flavor with grated onion and lemon.

MIXED VEGETABLE SOUP.

Chop up some celery, onion, potatoes, and parsley stems. Simmer in water slowly for 30 minutes. Strain, and prepare with butter and flour. Add plenty of chopped parsley. Finely cut cauliflower, string beans, and peas can be prepared in the same manner. For people with delicate stomachs the pulp of the vegetables should never be pressed through.

BREAD SOUP. No. 1.

Soak some stale white and black bread in boiling water for half an hour. Put on to boil with more water. Cut up a few apples with the skin and add a stick of cinnamon, a little sugar, salt, and some lemon rind. Simmer for 30 minutes or longer. Press through a colander and add some cold soaked raisins or currants and a piece of butter, also the yolk of an egg, if desired.

BREAD SOUP. No. 2.

Prepare like the foregoing. Leave out the apples. Add hot cream or milk in place of butter and egg. Use dried soaked currants or prunes, if desired.

BREAD SOUP. No. 3.

Prepare as the foregoing. Add imported root beer, omit the apples, and use more sugar. Strain and add hot cream or the yolk of an egg and butter. Good for constipation.

BRAN SOUP. No. 1.

Use equal parts of stale bread and bran. Prepare like the foregoing. Leave out the egg.

BRAN SOUP. No. 2.

Prepare like the foregoing. Use more water, and strain. Melt some butter, thicken with mixed flour, add the hot broth gradually. When done, remove from the fire and mix with soaked cold raisins and a few drops of lemon.

BRAN SOUP. No. 3.

Use one cup of bran, four cups of water, four tablespoons of milk sugar. Strain and thicken with butter and flour as directed for Bran Soup No. 2. Omit the fruit. A little lemon may be used if desired. Good for invalids.

CHAPTER V.

CEREALS, NOODLES AND DUMPLINGS.

BUCKWHEAT GROATS.

Wash one cup of buckwheat groats several times with cold water, add about six cups of boiling water and two teaspoonsful of salt. Boil rapidly for 20 minutes or until it thickens, then allow it to cook 50 or 60 minutes longer on the stove or in the oven. Serve with hot cream. Cooked or stewed dried prunes may be eaten with it, or added to the mush just before serving. Buckwheat is a winter food. People who suffer from eruptions on the skin after eating buckwheat should let it alone.

STEEL CUT OATS.

Prepare the same as buckwheat groats. Rolled oats may be used instead.

ROLLED OATS WITH CRANBERRY SAUCE.

Boil two cups of rolled oats with a quart of water and a teaspoon of salt for 20 minutes. Cover and set in the oven, or cook on the stove for about 40 minutes. Remove from the fire, add a piece of butter and a few drops of lemon juice. Serve on soup plates, pour over it cranberry sauce, prune or apricot jam. Eat cold boiled bacon with it, or raw celery or nuts at the end of the meal. It is good for dinner or breakfast.

RYLAX WITH PRUNE JAM.

Prepare like the foregoing. Omit the lemon. Serve with prune jam and fat meat, or with celery or nuts, or with hot cream.

ROLLED WHEAT.

Prepare and serve like rolled oats. Cranberries, prunes, apricots, or apple sauce, are all good additions. The yolk of an egg may be added to the wheat when mixing it with butter.

BRAN MUSH.

Bring one and one-half to two cups of water to a boil, add one-half teaspoon salt. Drop in one shredded wheat biscuit and one-half cup of bran. Mix all well and boil one minute. Serve with hot cream.

BRAN AND RYE MUSH.

Put one-half cup of rylax into boiling, salt water, and cook 20 minutes. When done, moisten one-half cup of bran with a little hot water, and mix with the rye mush. Serve with hot cream.

RAW WHOLE WHEAT.

Soak one-half cup of whole wheat in three-quarters or one cup of warm water over night. Keep the water warm, if possible. A small amount of salt may be added. Serve with cream and dates, or with bananas, carrots, or nuts.

BOILED WHOLE WHEAT.

Soak some whole wheat over night. Boil for several hours with sufficient water and salt. Serve like the foregoing.

POLENTA (ITALIAN DISH).

Stir some yellow corn meal into boiling, salted water in an iron pot. Boil for about 40 minutes and stir well to prevent burning. Eat with a fork, and serve with cheese for breakfast or dinner.

RICE FLOUR. No. 1.

Mix a cup of rice flour with cold water, then add three or four cups of boiling water while stirring. Boil 15 to 20 minutes. Before removing from the fire, add some dried currants, which have been soaked for a while. Put on a soup plate, and pour over it some hot cream.

RICE FLOUR. No. 2.

Use pure rice flour, or one-half cornstarch and one-half rice flour. Prepare as number one. Before serving, mix with a piece of butter and the yolk of one or several eggs, and flavor with vanilla, lemon or bitter almonds. Put on a soup plate, and pour over it hot cream.

CORN MEAL MUSH.

Stir one and one-half cups of corn meal into four cups of boiling salted water; cook 30 minutes; finish like foregoing. Use lemon for flavoring.

BARLEY.

Soak a cup of pearl barley over night in soft water, and the next day boil it in five or six cups of water for two hours or longer. Flavor with onion, if desired, and if it does not become thick enough, dissolve a little rice flour with cold water, and add it to the barley ten minutes before removing from the fire. Serve with cream or with fresh beef, or salted meat and lettuce for breakfast or dinner.

BREAD AND MILK.

Bring some fresh, whole or skimmed milk to a boil, pour on dried black bread or crusts, and add a little salt. Let it stand for 10 minutes and serve on soup plates.

CRACKER AND MILK.

Prepare like the foregoing, or pour one cupful of boiling salted water over one large unleavened cracker, let stand 5 minutes. Then add one cupful of hot milk and serve.

DIRECTIONS FOR BOILING RICE.

Wash one cup of rice, and pour into seven or eight cups of boiling, salted water. Boil rapidly until the grains burst; then cover and put into a hot oven or on a platter, and cook for 20 or 30 minutes. Remove from the fire and add a piece of butter and the yolk of an egg, or serve the rice with hot cream. Dried currants, raisins, apricots or prunes may be mixed with the rice. If eaten in place of mush, pour the rice on soup plates, and add hot cream.

MILK RICE.

Allow a pint of water and a pint of fresh milk to come to a boil with vanilla or cinnamon, and put into it three or four tablespoonsful of Japan or Carolina rice, which has been soaked for several hours. Boil rapidly until the starch granules burst, then boil slowly for forty minutes longer. If it is not thick enough, mix a little cornstarch in cold water, and add to the rice when nearly done. The yolk of one or more eggs may be added before serving, if desired. It may be eaten plain in the form of a thick gruel or with a fruit sauce. It will serve as a whole meal for children, morning, noon, or evening. A few nuts, or some celery, may be eaten at the end of the meal.

RICE CREAM.

Cook one cup of rice like plain, water rice with a stick of cinnamon or vanilla. When done, add the yolks of several eggs and a piece of butter, or some hot cream and two tablespoonsful of sugar, or one-half cup of soaked currants or raisins. Stir over the fire until it boils again. Serve hot or cold with fruit sauce.

ALMOND RICE.

Cook rice with water as directed for boiling rice. When done, remove from the fire, and mix with it some almond butter stirred smooth with a little water. Some dried currants or apricots previously soaked may be mixed with the rice. In combination with a dish of lettuce it will serve as a whole meal. A few whole almonds may be eaten at the end of this meal.

APPLE RICE.

Boil rapidly for 30 minutes one-half cupful of rice with three cupsful of water and a little salt. Peel three medium sized apples, cut them into small pieces after removing the cores, and add to the rice with one tablespoonful of sugar. Cook on the stove or in the

oven until the apples are tender. Remove from the fire, add a piece of butter, and serve with preserved or fresh meat, eggs, fish or cheese. A stick of cinnamon may be boiled with the rice for flavoring.

APRICOT RICE.

Prepare as apple rice, and let the rice boil until tender. Then drain a few preserved or canned apricots and add them to the rice, also a piece of butter or one-half cup of hot cream. Mix well. Serve with lean meat, eggs, or cheese.

CHERRY RICE.

Prepare like apple rice, and use ripe black cherries, or canned cherries. Omit the juice. A tablespoonful of sugar may be added to the fruit while boiling. It is necessary to have the rice boiled in sufficient water, and long enough to allow each grain to burst before the fruit is added, or the acid of the fruit will prevent the rice from softening. Butter alone, or butter and the yolk of an egg, should be added when acid or sub-acid fruits are mixed with cereals. Serve with sterilized cream or with eggs, or eat nuts at the end of the meal.

CURRANT RICE.

Prepare like cherry rice. Add fresh ripe or dried currants in place of cherries. Serve with sterilized cream or with fried or boiled eggs, or with bacon.

RHUBARB RICE.

Prepare like the foregoing. Use sterilized rhubarb which has been cooled. Serve with sterilized cream.

TOMATO RICE.

Prepare like apple rice. Use one-half to one cupful of strained, canned tomato juice. Omit sugar. An onion may be boiled with the rice, if desired. Serve with fried eggs or fish, and greens.

BROWN RICE.

Brown the rice in butter to a light yellow color. Add sufficient boiling water and salt, and boil one-half hour or longer. Dried mushrooms may be added, if desired. Serve with meat, fish, or eggs.

CARROT RICE.

Put some rice to boil in water with salt. Cut young French carrots into small pieces and add; both will be done about the same time. Add finely chopped parsley and a piece of butter. Serve with peas puree and fat meat, or with fish.

MACARONI WITH CREAM.

Break up some macaroni and put in a saucepan, adding boiling water and a little salt. Boil for 30 minutes, and add more water if necessary. Dissolve some rice flour in a little cold water and thicken the macaroni, then cover and bake in an oven for 30 minutes or longer. Heat some rich cream in another saucepan and mix with the macaroni, and serve. Flavor with a little pepper, or finely chopped, salted, lean meat or parsley.

MACARONI WITH STOCK.

Prepare as the foregoing, boil 30 minutes, then add some stock and a little strained tomato juice. Cover and put in the oven again for 30 minutes. Serve with grated cold cheese.

NOODLES.

Beat two eggs with two large tablespoonsful of water and a little salt. Mix with sufficient white flour to make a stiff paste. Put some flour on a wooden board, knead the dough and add more flour until hard and dry; then roll out as thin as possible, dry in the sun or on a table, and cut into fine strips. Boil in salted water for half an hour. Serve with boiled beef or preserved salt meat, or with grated Swiss cheese and lettuce.

DUMPLINGS.

LIGHT FLOUR DUMPLINGS.

Cream a tablespoonful of butter, and add to it a whole egg and the yolk of one egg, some salt, nutmeg, chopped parsley, and two tablespoonsful of flour. Stir well for several minutes. Form small dumplings with a spoon, put into hot soup and boil eight minutes.

POTATO DUMPLINGS. No. 1.

Cream a tablespoonful of butter, add to it three yolks of eggs, a cup of cold grated potato, and one cup of dry bread crumbs. Flavor with lemon, rind, salt and nutmeg, and mix the beaten whites of two eggs with it. Roll out into small dumplings, and boil eight minutes in soup or water.

POTATO DUMPLINGS. No. 2.

Mix two cups of cold grated potato with two-thirds of a cup of flour and one-half cup of creamed butter, adding the yolks of four eggs, the whites of two eggs, and salt and flavoring. Mix well and form dumplings. Boil in hot water for about 15 minutes. Serve with roasts.

BREAD DUMPLINGS. No. 1.

Put some stale white bread or rolls to soak in cold water and press out as dry as possible. Add a tablespoonful of creamed butter, the yolks of two or three eggs, salt and nutmeg. Add the beaten whites of two eggs. Form dumplings with a spoon and boil in water, soup or fruit juice until they swim on top. Serve with stewed prunes or apricots.

BREAD DUMPLINGS. No. 2.

Remove the crust from one-third of a loaf of milk bread and soak the soft part in cold water for 5 minutes. Put it into a clean cloth and force out the water. Cream three tablespoonsful of butter, or melt some soup fat, mix with the bread and stir it very smooth. Let it cool, and add the yolks of four eggs, salt, a little mace, some finely chopped parsley, and onion, if desired. Then beat the whites of two eggs, mix with the mass and form dumplings with a dessert spoon. Put them into the boiling soup and cook for about 5 minutes or until they swim on top.

BAKED CORN MEAL DUMPLINGS.

Boil in two cups of milk or water two cups of white corn meal with a tablespoonful of butter, stirring all the time, until the mass is very thick. Let cool. Flavor with lemon rind and nutmeg, and mix with three or four well beaten eggs. Shape into dumplings with a spoon, turn in rye nuts or bread crumbs, and bake in butter. Serve with sugar and cinnamon, or with apricot, apple or wine sauce.

MIXED DUMPLINGS.

Mix over the fire one and one-half cupsful of flour with two cupsful of milk and a large tablespoonful of butter, until it does not stick to the saucepan. Let it cool, add the yolks of four eggs, salt, cinnamon, a tablespoonful of sugar, one-half cupful of finely cut fried bread crust and bacon, then the beaten whites of eggs. Form medium sized dumplings with a tablespoon, and boil in salted water for 5 or 6 minutes. Serve with stewed pears, cranberries or prunes. They are also good with sauerkraut.

FLOUR DUMPLINGS. No. 1.

Mix one cupful of flour with one-half cupful of melted butter, one cupful of hot water, and some salt. Stir well on a hot stove until no more lumps appear. Cool a little, then mix with several yolks of eggs, and flavor with mace, chopped parsley or other spices. Dip a spoon in hot water and form dumplings of the desired size. Put into boiling salt water or on top of stewed fruit, and boil 6 or 10 minutes, or until they rise. The spoon must be dipped into hot water each time before forming a dumpling. Serve with peas or stewed fruit.

FLOUR DUMPLINGS. No. 2.

Mix one cup of white corn meal and one cup of flour with a little cold water, and stir it into boiling milk. Let it soak for 5 minutes or until it is thick. Then add a piece of butter, salt, and flavoring; let cool, mix with several yolks of eggs, and shape dumplings with a spoon, and put into boiling soup or blackberry juice. Boil about 10 minutes, or until they swim on top.

FLOUR DUMPLINGS. No. 3.

Mix some white flour, or three-fourths white and one-fourth rice flour, with baking powder and salt. Shorten with butter and fat like dough for pie. Roll out, enclose some apples and bake in the oven for 20 minutes or longer.

FLOUR DUMPLINGS. No. 4.

Mix some flour with baking powder and salt. Stir to a light paste with cold water, adding several eggs or yolks of eggs. Boil with meat stew or in water.

CHAPTER VI.

BREADS, CAKES AND PUDDINGS.

POMPERNICKLE OR BLACK BREAD.

Prepare a sponge with a pint of white flour, three-fourths of a yeast cake, a little salt and sugar, and a pint of warm water. When light, add two quarts of rye meal, a tablespoonful of salt and about one quart of water. Mix well, and let rise over night. The next morning add about one quart of warm rye meal, and one of white flour; knead the dough for at least one-half hour. Let rise again, knead a little more, and shape into loaves. When light, bake in a hot oven, for about an hour. Pure rye meal may be used in place of one-fourth white flour.

WHOLE WHEAT BREAD.

Prepare the same as black bread. Use whole wheat flour in place of rye meal.

LIGHT WHOLE WHEAT BREAD.

Make a sponge from one cupful of luke warm water and one cake of yeast, with enough white flour to make the thickness of sponge cake. Cover and set in a warm place, about 90 degrees F. When foamy, add about three pints of luke warm water, or milk which has been scalded and cooled to luke warm, about two teaspoonsful of salt, a little sugar and a piece of butter or fat. Stir into it with a spoon sufficient white flour to make it of the same consistency as the first sponge. Beat it from 10 to 15 minutes, dust the top with flour, and put it into a warm place to rise. When light, add enough whole wheat flour to make a stiff dough. Put it on bread-board with flour to prevent sticking, knead for half an hour or longer, and let it rise again. When light, shape in loaves without kneading, put into pans and prick top with a fork several times. When sufficiently raised, bake in hot oven for about an hour. Cover top with pieces of oiled paper, the first 20 or 30 minutes. When done, put the bread on a sieve or in towels to cool.

LIGHT GRAHAM BREAD.

Prepare in the same manner as light whole wheat bread.

WHITE BREAD.

Prepare the same as whole wheat bread, using pure, rich milk, cream and water, or sweet whey. Add a large piece of butter or cocoanut. Use white flour instead of whole wheat, mix it with one-fourth white corn meal, or rice flour.

COFFEE CAKE.

Prepare the same as white bread, using less flour, and add a few well beaten eggs, the grated rind of several lemons and oranges, or flavor with nutmeg, dried fruit, vanilla, mace or bitter almonds. Serve with fresh, sweet milk, or with scalded milk, as a whole meal for supper.

All breads and cakes made with yeast are more nutritious and wholesome when stale, on account of the evaporation of water and the changes which take place in the bread. They should be kept in tins with holes on all sides, to allow a perfect circulation of air.

The tins should be placed in the sunlight, or on a high, dry place near a stove. In many foreign countries pompernickle is kept for many months during the winter by placing it on top of high stone ovens near the ceiling. It finally assumes a sweet taste similar to that of nuts.

Bread and cake may be kept sweet and free from mildew for a long time in the following way: Cut it with a sharp knife, when about four days old, into slices about one inch thick, then place it on a large, wire screen in the hot sunshine, cover with a cheese cloth, and let it lie for several hours, turning each slice until thoroughly dry. Then place the slices in an upright position in a square box made of wire screening, and keep in a dry or sunny place, covered with a light cloth. The box may be placed in the sunshine several times a week.

ROMAN MEAL BREAD.

Prepare the same as whole wheat bread, and use Roman meal instead of whole wheat flour.

BISCUITS.

Mix one quart of white flour with one-fourth of entire wheat flour, corn meal, or rice flour. Mix it thoroughly with two level teaspoonsful of salt, and four of baking powder. Rub into it two tablespoonsful of vegetable fat or butter. Mix with rich milk and prepare as usual. Serve with salted, preserved meat and eggs, or with rich cheese and olives and salad of greens.

POP-OVERS.

Grease the iron gem pans, and place on the stove or in the oven, to have them very hot. Then beat two eggs very light, mix a cup of rich milk with a cup of flour, and a half teaspoonful of salt; add the eggs and beat with an egg beater until all is very light. Pour the mixture into the pans, filling two-thirds full, and bake in a quick oven. This will make about eight pop-overs.

BRAN MUFFINS.

Mix one cupful of white flour with one-half cup of graham flour and one and one-half cups of finely sifted bran. Rub into it three tablespoonsful of butter; then add one and one-half cups of sour milk, a teaspoonful of soda, a little salt and three tablespoonsful of molasses. Put into hot muffin tins, and bake in a hot oven.

BRAN BREAD.

Beat the whites of three eggs to a stiff snow, add a little salt, and mix with two tablespoonsful of fine, sifted bran, and two of fine rye nuts. Put the mixture on a pie tin and bake in a very moderate oven. Leave the door open. Serve with apple salad and lettuce.

BOSTON BROWN BREAD.

Mix together one cup of coarse corn meal, one of rye flour, one of graham flour, and a teaspoonful of salt. Dissolve two teaspoonsful of soda in two cupsful of sour milk and mix with the flour, adding three-fourths cup of molasses. Pour into narrow, oiled tins, and steam for four hours. Serve with lettuce, celery and apple, or tomato salad, and nut butter.

WHITE MUFFINS.

Use mixed flour, or rice and wheat as suggested for white bread. Mix with baking powder and salt. Use two eggs and about one and one-half cups of rich milk to about three cups of flour. Serve with tomato or peas puree and lettuce for breakfast or supper.

PASTRY FOR TARTS OR PIES.

Mix one and a half cups of white flour with one-half cup of rice flour. Add one-half teaspoonful of salt, shorten the flour with three tablespoonsful of butter and three of oil. Then add to it the yolks of two eggs beaten with sufficient ice cold water and a little rum to make a paste which is not very stiff. Roll it several times, then cover and put it in the ice box for an hour.

SAND TART.

Mix one-half pound of white flour and one-half pound of rice powder, or wheat starch. Keep in a warm place. Melt one pound of butter, cool and cream with one pound of sugar, adding ten yolks of eggs, alternating with the flour. Stir the mass for one-half hour,

add the rind of two lemons, the juice of one-half lemon, and two tablespoonsful of rum. Beat the whites of ten eggs, mix lightly with the dough, and add a teaspoonful of baking powder. Bake in a moderate oven for one and one-half to two hours. During the first half hour have more heat at the bottom than at the top. During the last half hour have little or no heat at the bottom. The cake tin should not be moved.

The tart may be baked in layers or on round tins and be mixed with different colors, if desired.

PLAIN CAKE.

Cream one-half cup of butter with one-half cup of sugar, add two eggs, two cups of flour, two teaspoonsful of baking powder, a little salt, one cup of water, one-half cup of raisins or currants, and any kind of flavoring. Bake in cake tins. Cake prepared with water is more wholesome than with milk.

FROSTING.

Cream equal quantities of butter and chocolate. Spread on the layers when cold. Frosting prepared from pure sugar is unwholesome.

STRAWBERRY SHORT CAKE.

Prepare a light biscuit dough, bake in tins and cover with strawberries and whipped cream. Use no more sugar than is necessary.

FRUIT CAKE.

Chop up one cup of currants, citron, and raisins, and mix with one cup of flour. Sift one cup of flour with a teaspoonful of soda, one of cinnamon, and a little salt. Cream one-half cup of butter with one cup of brown sugar, one-half cup of molasses and two well beaten eggs; add the flour, fruit and one-half to three-fourths cup of strong black coffee. Stir well and bake in a moderate oven for one hour.

MIXED FLOUR.

Mix two cups of white flour with one cup of rice flour and one of cornstarch. Sift and keep in a tin box for sauces and soups.

RYE NUTS. No. 1.

Remove the outer crust from a loaf of stale pompernickel and grate the soft part on a grater. Pour the crumbs on a large piece of paper, and dry in the sun or in an oven. Keep in a dry place, in a tin with good ventilation.

RYE NUTS. No. 2.

Cut a loaf of stale pompernickel into thin slices and remove the crusts. Cut the inside into small strips, lengthwise and crosswise. Allow it to dry thoroughly in a moderate oven or in the sun, and while still warm, grind it through a coarse meat grinder. Place it again in an oven or in the sun to dry, or brown slightly. If desired as fine as grape nuts, grind it again or sift it, and keep in a dry place. It may be mixed with one-half grape nuts. Use as directed in menus and recipes. The outside crusts may be dried in the oven or sun, and kept in tins. The crusts are an excellent addition to milk soups or other soft foods.

SUN DRIED BREAD.

Cut stale pompernickel, whole wheat or white bread into slices, then cut in strips crosswise and lengthwise to the size of lump sugar. Allow it to dry in a moderate oven or in the sun. Keep in a dry place in sacks or tins. Use with milk as directed in recipes. It may be dried in slices and eaten in place of fresh bread.

FRIED BREAD.

Cut into strips as directed in the foregoing recipe. Fry in hot oil, or butter and oil. Serve with legume or fruit soups.

CRUSTS.

Cut some stale whole wheat or black bread into slices. Remove the outer crusts with a sharp knife and dry them in an oven. Keep in a tin box in a dry place.

IMPERIAL STICKS.

Cut stale buttered bread into long narrow sticks, and brown in the oven.

CORN BREAD. No. 1.

Three-fourths of a cup of white or yellow corn meal, one and one-fourth cups of white flour, one teaspoonful of salt, two tablespoonsful of butter or one-half oil and one-half butter, two teaspoonsful of baking powder, two well beaten eggs, one and one-half cups of rich milk, and sugar, if desired. Bake in a quick oven for 30 minutes.

CORN BREAD. No. 2.

Bring one quart of water to a boil, and add a teaspoonful of salt. Stir about one cup of coarse yellow corn meal into it and let boil 30 or 40 minutes. Then take it off the fire, beat thoroughly with a spoon, and cool until lukewarm. Add a large tablespoonful of oil or butter, a little lemon juice and four yolks of eggs. Stir well, and add the beaten whites of the eggs. Put the mixture into a flat, oiled pan and bake or heat on a griddle. Small cakes may be formed from the batter and baked in an oven or fried until browned nicely. The whites of eggs may be left out, if desired. Serve with salads of lettuce, watercress, tomatoes or apples, or with fruit sauces. Acid and super-acid fruits combine best with this bread.

CORN BREAD. No. 3.

Prepare the same as number two, using white corn meal. Flavor with cinnamon, vanilla or bitter almond, and mix with dried, soaked fruits as currants, finely cut apricots, or prunes, or serve with a fruit sauce prepared from blackberries, huckleberries or the above mentioned fruits.

DOUGHNUTS.

Use four eggs, a small cup of sugar, two cups of rich fresh milk, a teaspoonful of salt, and about one quart of flour finely sifted with two teaspoonsful of baking powder. Add grated lemon rind or cinnamon, for flavoring. Beat the dough until very light. Drop by the tablespoonful into hot fat. Stewed cold prunes or apricots may be placed in the middle of each doughnut. They may be served with fruit soups, fruit sauces, or green salads for dinner in the summer, or for supper in the winter.

CEREAL OMELET.

To two cupsful of left-over boiled wheat add two well beaten eggs, half a teaspoonful of salt, finely chopped parsley and onion. Heat butter and oil in a frying pan, and pour into the mixture. Cook by moderate heat until firm. Serve with crisp bacon, if desired.

HOMINY CAKES.

Prepare the same as Cereal Omelet or mix with eggs only, and serve with fruit sauce.

BREAD OMELET.

Remove the crust of one-half loaf of stale milk bread. Soak the bread in cold milk or water for 5 minutes. Lay it in a cloth and press out as dry as possible. Cream one-half cup of butter with one-half cup of sugar; add one-half cup of dried currants, one-half cup of almond meal, the rind of one or two lemons or oranges, four yolks of eggs, some cinnamon or mace and a little salt. Mix well, and add the beaten whites of four eggs. Heat a large flat pan, oil it well, sprinkle with rye nuts and pour in the batter. Bake on a medium hot stove, turning the omelet, or bake in the oven. Serve with fruit sauce and green salad.

SNOW BALLS.

Place four eggs in warm water. Mix two cups of flour with a cup of warm water, salt, and one-half cup of melted butter. Stir it over the fire until the flour does not stick to the saucepan. Let cool and mix with the eggs. Beat the dough for about ten minutes. Shape balls with two tablespoons, and bake in the oven or fry in hot, deep fat. Sprinkle with sugar and serve for afternoon tea or for

supper.

EGG TOAST.

Soak slices of stale bread in milk, and beat up some eggs with a little salt and cinnamon. Turn the soaked bread into the egg, and fry in hot butter. The milk and eggs may be beaten up together and the bread soaked in it before frying. Serve with apple, cranberry or apricot sauce, or with syrup and lettuce. This is suitable morning, noon or night.

RICE FRITTERS.

Mix some left-over rice with several well beaten eggs, and the grated rind of a lemon. Bake on a hot griddle. Serve with fruit sauce and lettuce, morning, noon or night.

UNLEAVENED GERMAN PANCAKES. No. 1.

Use six eggs, six tablespoonsful of flour, one and one-half cup of warm milk, one-half cup of cream, and a little salt. Mix well the yolks, salt, cream, milk and flour, then add the whites of the eggs beaten stiff. The dough must be of the consistency of thick cream. Bake in thin layers in half butter and half oil, in a small pan. Serve with lettuce and fruit sauce or with French dressing at the noon meal.

GERMAN POTATO PANCAKES. No. 2.

Grate five large raw potatoes and one onion. Mix two tablespoonsful of white flour with a little warm water and a cup of rich cream, add salt and mix with the potatoes. Then add three whole eggs beaten well, and fry in hot fat like griddle cakes, until brown. Serve with apple sauce, or lettuce and French dressing.

GERMAN PANCAKES. No. 3.

Mix one pint of white flour and one-fifth pint of rice flour with one pint of rich warm milk, or with one-half milk and one-half warm water, and a teaspoonful of salt. Beat four whole eggs, add to the mixture and beat with an egg beater for a few minutes, until perfectly smooth. Bake on a small, shallow, iron, griddle, using about four tablespoonsful of the mixture for each cake. The fat used for frying must be boiling hot. Pile on a plate standing over hot steam until all are done. Cut in sections and sprinkle with sugar, if desired. Serve with green salads or apples, or with apple, apricot or cranberry sauce.

PLUM PANCAKES.

Prepare the batter a little thicker than the foregoing. Peel and slice some blue plums very thin, mix with the batter and bake as above.

GERMAN PANCAKES WITH BACON.

Cut some bacon into narrow short strips. Fry until crisp, place in a bowl and mix with a piece of butter or with oil. Keep it in a warm place while baking the pancakes. Pour some fat and six pieces of bacon into the pan for each cake, and bake the same as German pancakes. Do not allow a metallic spoon to remain in hot fat.

APPLE PANCAKES.

Peel some apples and cut in thin slices. Mix with the dough as directed for German pancakes and fry on both sides. If fewer eggs are used, take a little more flour.

CHERRY PANCAKES.

Remove the stones from ripe black cherries. Prepare the dough as directed for German pancakes, mix the cherries with it and fry in hot fat.

BUCKWHEAT CAKES.

Mix prepared or unleavened buckwheat flour with sweet cream or one-half cream and one-half water, and bake on a hot griddle. Serve with fruit sauce or French dressing at the morning or noon meal.

ROMAN MEAL CAKES.

Soak two tablespoonsful of dried currants in a little hot or cold water. Mix one-half cup of flour with one teaspoonful of baking powder, a little salt, and one cup of Roman meal. Beat two eggs very light, with about one-half cup of water, mix with the flour and currants and bake in hot fat. Serve fruit sauce with them.

MATZOON PUDDING.

Soak matzoon in cold water or milk for several minutes. Then press out dry, stir until fine and mix with several well beaten eggs, cream, or butter, and raisins, chopped apples, currants, lemon rind or any other flavoring. Heat a cupful of oil or suet in a high iron pot, put the pudding mixture into it and bake in a moderately hot oven for about one hour. Serve warm with fruit sauce or wine sauce.

MATZOON CAKES.

Prepare the same as the foregoing. Shape into small balls with two tablespoons and fry in hot fat.

FISH PUDDING.

Cream three-fourths of a cup of butter, add to it four eggs, nutmeg, salt, parsley, two cups of bread crumbs, four cups of finely chopped left-over codfish or salmon, and some lemon juice. Mix well and steam one and one-quarter or one and one-half hours. Serve with a butter sauce prepared with soup stock.

MEAT PUDDING.

Prepare like fish pudding. Use four cups of finely ground meat in place of fish.

LIVER PUDDING.

Prepare like fish pudding. Use three and one-half cups of grated or ground left-over liver and one-half cup of finely chopped cold, fat meat or suet. Serve with caper or tomato sauce.

POTATO PUDDING.

Cream one-half cup of butter with one-half cup of sugar, add the yolks of six eggs, two cups of grated potatoes, salt, cinnamon and the rind of one lemon; then add one cup of black or white bread crumbs and the beaten whites of six eggs. A half cup of almond meal mixed with a few bitter almonds may be added to the mixture, if desired. Bake this pudding for about sixty or seventy minutes, or boil two hours. Serve with stewed prunes or apple sauce.

PLAIN BREAD PUDDING.

Soak some stale bread in cold water, press it out thoroughly and stir smooth over the fire, with some butter or fat. When cool, add salt and several well beaten eggs or some flour, syrup and chopped suet, mix well and add any desired flavoring or sugar. Tie in a cloth and boil for two hours in salt water, or with white beans. Serve with stewed fruit.

RICE PUDDING.

Cook some rice as directed for water or milk rice. When cool, cream some butter with an equal amount of sugar, and add several well beaten eggs, lemon rind, cinnamon, a little bread crumbs, some raisins or currants and some sweet or sour cream, or melted butter. Bake for about an hour.

SAGO PUDDING.

Soak the sago and cook with one-half water and one-half milk. Finish like rice pudding.

FLOUR BREAD PUDDING.

Mix over the fire two cups of flour with two cups of milk or water, and three-fourths of a cup of melted butter, until the batter loosens from the bottom of the saucepan. Let it cool a little and add the yolks of four eggs, two tablespoonsful of sugar, two cups of bread crumbs, salt and mace. Then beat the whites of four eggs, mix and add one-half glass of cognac. Pour the mixture into an oiled pudding pan and steam two and one-half hours. Serve with stewed plums, pears, or cherries.

CORN MEAL PUDDING.

Bring two cups of milk to a boil, and mix four cups of yellow or white corn meal with a pint of cold water. Stir into the boiling milk and add two tablespoonsful of butter. When it is thick, remove from the fire and cool. Cream half a cup of butter with three-fourths cup of sugar, add the yolks of four or five eggs, salt, lemon rind, several grated bitter almonds, and the beaten whites of the eggs. Put into a pudding pan and steam from two to two and one-half hours. In place of bitter almonds use lemon juice, if desired. Serve with white or red wine sauce, or with stewed apricots or cranberries.

RICE FLOUR PUDDING.

Prepare the same as corn meal pudding.

APPLE-BREAD PUDDING.

Grease a pudding dish and fill with alternate layers of mixed bread crumbs and apple sauce. Begin with bread crumbs, using whole wheat or rye nuts. Mix the apple sauce with a large piece of butter, while still warm. When the dish is filled, beat up two eggs with a tablespoonful of sugar, one-half cup of cream, a little salt and some cinnamon; pour it over the top and bake in moderate hot oven for forty or fifty minutes. It affords a perfect meal for the evening. If served at noon, eat some nuts at the end of the meal.

BAKED BREAD PUDDING.

Pour two pints of hot milk over two cups of bread crumbs, cool a little, then cream one-half cup of butter with one-half cup of sugar, mix with the bread crumbs, adding three well beaten eggs, a teaspoonful of salt, a little nutmeg or cinnamon, the juice of one-half a lemon and the rind of two lemons. Mix well together, and bake in a buttered dish for fifty or sixty minutes. Serve with wine sauce, lemon, cherry or any kind of fruit sauce. Dried fruits may be mixed with the batter. Serve for supper, using broth, meat soup, or cream soup at the beginning of the meal. Celery is an excellent addition to almost any food at the evening meal.

VEGETABLE PUDDING. No. 1.

Prepare as baked bread pudding. Use legume soup in place of milk, leaving out the sugar. Use butter or cream and mix with two tablespoonsful of peanut butter or other nut butter or walnut meats. The eggs can be omitted. Flavor with finely chopped onions, celery and parsley. Pour on oiled pie tins and bake thirty to forty minutes. Serve with tomato sauce or string beans for dinner.

VEGETABLE PUDDING. No. 2.

Boil some rice with salt and water. Add a cupful of thick legume puree and finish like the foregoing.

STEAMED BREAD PUDDING.

Soak some stale bread in cold water, press out dry, and stir smooth. Melt one-third of a cup of fat and one-half of a cup of butter, and mix the bread with it on a hot stove, stirring until it loosens from the saucepan. Cool a little, and flavor with mace, nutmeg, lemon rind or cinnamon and salt. Add several well beaten eggs and some finely cut dried fruit. Mix well and steam from one to one and one-half hours. Serve with lettuce and fruit sauce. In place of fruit and the above flavoring, chopped parsley, onions and pepper, bacon, anchovy, capers or codfish may be used. Serve with tomato or apple sauce.

SUET PUDDING.

Mix four and one-half cups of flour with three cups of milk, one-half pound of finely chopped suet, four well beaten eggs, four tablespoonsful of sugar, a teaspoonful of salt and the rinds of two lemons. Grease a pudding pan, sprinkle some black or white bread crumbs into it, pour in the batter and steam for two hours. Serve with stewed fruit, cherries, pears, or plums, or with wine

sauce, for dinner.

UNCLE TOM'S PUDDING.

Mix one-half a pound of flour with one-half a pound of syrup. Then chop fine one-fourth of a pound of suet, and mix with a little flour. Beat one-half a pint of milk with two eggs, and add a half cup of sugar, salt, mace, cinnamon, cloves and one tablespoonful of soda. Mix well and pour into a pudding dish, and steam for two hours. Serve with wine sauce No. 1 or with fruit sauce.

BLACK BREAD PUDDING.

Cream one cup of butter with three-fourths of a cup of sugar, and add the yolks of five eggs, three-fourths of a cup of dried currants or raisins, the rind of a lemon, a little cinnamon and cloves, salt, three cups of grated black bread and one-half a glass of wine or brandy. Mix well and add the beaten whites of the five eggs. Oil a pudding pan and pour the mixture into it. Steam two and one-half hours, and serve with vanilla, or white wine sauce. A cupful of rich cream, diluted almond butter or one-half cup of almond meal may be mixed with the batter, if desired.

PLUM PUDDING. No. 1.

Moisten two cups of bread crumbs with a little cream, and add two cups of finely chopped suet, two of currants, two of raisins, one of sugar, one-half cup of almond meal, one-half cup of finely chopped orange and lemon rind, a little nutmeg, salt, one-half glass of brandy and two or three well beaten eggs. Mix all well and steam in a cloth or pudding pan for five hours.

PLUM PUDDING. No. 2.

Use two cups of flour, one-half cup of bread crumbs, one cup of rich milk, and a little fruit. Mix and boil like No. 1. The almond meal may be left out.

CHAPTER VII.

SAUCES AND SALAD DRESSINGS.

SAUCES.

Sauces are a necessary addition to cooked foods, especially in cold weather. The proper utensils used for sauce making are wooden spoons and flat, round bottomed saucepans.

Good fresh butter, oil and dry flour are necessary to make nutritious sauces. Flour for thickening should boil at least ten minutes. If the flour is to be cooked with fat before the liquid is added, only a few minutes of boiling is necessary, for the reason that fat, when boiled, reaches a higher temperature than water or milk. Mixed flour is preferable to pure wheat flour. Sauces prepared from soup stock, vegetables or fruits and gelatines are a better addition to meats than brown gravies, which are prepared from the small amount of juice which is extracted from the meat by roasting. Sauces prepared in the latter way are too rich as a food if eaten in combination with meat; they are a perfect meal by themselves if eaten in combination with whole wheat bread and greens.

BUTTER SAUCE. No. 1.

Melt three tablespoonsful of butter, or half butter and half oil, mix with two tablespoonsful of flour over the fire, and boil for a few seconds. Then add gradually a pint of boiling water or soup stock or hot whey, while stirring it. Boil a few minutes. Flavor with salt, onion, chopped parsley, celery, nutmeg, bay leaves, anchovy-paste, lemon, chopped salted meat or whatever flavor is desired. Serve with meat or fish.

BUTTER SAUCE. No. 2.

Prepare like the foregoing. Use milk in place of water, or soup stock.

TOMATO SAUCE.

Prepare as number one, using strained tomato juice instead of water. Serve with meat, fish, or grains.

CAPER SAUCE.

Prepare as number one, add capers and lemon before serving.

HORSE RADISH SAUCE.

Prepare as number one, adding dried currants and grated horse radish at the last minute. This is excellent with boiled beef or fish.

MUSTARD SAUCE.

Prepare as number one, adding two to four teaspoonsful of prepared mustard a minute before serving. Serve with hot or cold boiled beef, or with hard boiled eggs.

MUSHROOM SAUCE.

Prepare as number one, add the desired amount of dried mushrooms, which have been soaked in water for several hours, and boil for ten minutes. Serve with poultry, game or rice.

CREAM SAUCE. No. 1.

Prepare as number one; remove from the fire, add a few tablespoonsful of hot cream, or the yolk of one or several eggs, which have been diluted and stirred with a little cold water. Flavor with mace, pepper, nutmeg, parsley, lemon, or vanilla. Serve with macaroni, boiled fish, plum pudding, French toast, chipped beef, salted meat or boiled onions.

CREAM SAUCE. No. 2.

Thicken some water or soup stock with flour. Cook ten minutes, and add hot cream and flavoring.

ALMOND SAUCE.

Prepare with hot water as directed for butter sauce. Stir smooth a tablespoonful of almond butter or paste with two tablespoonsful of cold water, remove the sauce from the fire, add the almond butter and stir thoroughly. Serve with baked apples, rice, or bread.

OLIVE SAUCE.

Prepare as butter sauce. Soak some olives in warm water, remove the stones and add to the sauce, boiling all a few minutes. Serve with duck, game, fish or meat.

DRIED CURRANT SAUCE.

Soak the currants in boiling water, and let stand thirty minutes. Prepare a plain butter sauce from butter, flour, and hot water, and when done mix the currants with it. It can be prepared with soup stock or fish-water, and served with boiled white fish or boiled beef.

BACON SAUCE.

Cut some bacon into pieces about the size of lump sugar. Fry until brown. Pour the fat into a stone jar and put the bacon on a plate. Mix a tablespoonful of the bacon fat and one of butter with a tablespoonful of flour, and add hot water, whey, or soup stock. Flavor with chopped parsley or strained tomato juice and add the bacon.

FLAVORING OF MEATLESS SOUPS AND SAUCES.

Soups and sauces prepared with flour and water may be improved by an addition of left-over meat gravies or with crisp bacon and flavored with finely cut onions.

MINT SAUCE.

Wash half a handful of young fresh mint, pick the leaves from the stalks, and chop them very fine. Make a plain butter sauce with soup stock, and add vinegar and sugar to suit the taste. Then remove from the fire, mix with the chopped mint, and serve with lamb

or mutton.

LEMON SAUCE.

Wash a lemon, remove the peel and steep in three cups of water for fifteen minutes. Add the juice of one or two lemons and the necessary amount of sugar. Dissolve three teaspoonsful of cornstarch with a little cold water and stir into the lemon juice. Boil ten minutes. Remove from the fire and mix with a tablespoonful of butter while warm. The lemon rind can be grated and added to the sauce instead of boiling the rind. This is good for steamed puddings. The yolk of an egg may be added.

CHERRY SAUCE.

Remove the stones and steep the cherries in water with a stick of cinnamon. Add a little sugar and thicken with cornstarch or arrowroot. Strain or leave the cherries in it.

DRIED CHERRY SAUCE.

Soak the cherries and prepare as the foregoing. Strain, if desired.

WHITE WINE SAUCE.

Mix a teaspoonful of flour with two tablespoonsful of sugar, a little cinnamon, and ten ounces of wine. Then beat up four eggs, mix with the wine and beat over a hot fire with an egg beater until it foams. (It must not boil.) Then pour into a large dish and beat until nearly cold. Serve with steamed puddings.

RED WINE SAUCE.

Prepare like white wine sauce. Add a little more sugar, and a teaspoonful of brandy, if desired.

SALAD DRESSINGS FOR MEATS, CEREALS, FISH, VEGETABLES AND FRUITS.

They can be prepared from oil, butter, eggs, cream or nut butter. Dressings prepared from nut butter are especially good during the summer months. They can be prepared by making a plain butter sauce with flour and water, and adding nut butter before serving, or by diluting nut butter with water to the desired consistency. They may be flavored with orange or lemon juice. If a sweet flavor is desired, boil a little water with sugar, then add the juice of lemon or oranges and mix with nut butter. Serve hot or cold.

FRENCH DRESSING.

Mix three tablespoonsful of olive oil with one of vinegar, or with the juice of one lemon and one grated onion. To this may be added sugar, pepper, salt, parsley or mustard, if desired. The proportion of oil and vinegar may be changed according to the taste. For fruit salads, lemon should always be used instead of vinegar. For raw vegetables, the dressing should not be poured over the salad until ready to serve.

MAYONNAISE DRESSING. No. 1.

Put into a high narrow bowl the yolk of an egg and one whole egg, a tablespoonful of flour, one of olive oil, one of vinegar, and a little mustard; beat with an egg-beater about five minutes, or until it becomes thick, adding slowly one cup of cottonseed or olive oil while beating it. Flavor with lemon juice, onion and salt, to suit the taste. Keep on ice.

MAYONNAISE DRESSING. No. 2.

Stir one or several yolks of eggs and mustard with a fork on a soup plate for several minutes. Slowly add some olive oil, and if it becomes too thick, add lemon juice, then salt, sugar and onion, if desired. Keep on ice.

MAYONNAISE DRESSING. No. 3.

Make dressing number two. Add salt and sugar to suit the taste, and one cup of thick cream. Keep on ice.

MAYONNAISE DRESSING. No. 4.

Take the yolks of three hard boiled eggs and one raw yolk. Stir as smooth as butter, with one teaspoonful of mustard, one of sugar, one of grated onion, a little salt and pepper, the juice of a lemon or some good vinegar, then add slowly one-half or one cupful of olive oil. If the dressing is too thick add some cold veal jelly until it has the right consistency. Keep on ice.

MAYONNAISE DRESSING. No. 5.

Grate one medium sized cold boiled potato, stir one or two hard boiled eggs through a strainer and mix with the potato. Add the yolk of one or more eggs, stir well, then slowly add some olive oil, mix with lemon juice or vinegar, and flavor.

MAYONNAISE DRESSING. No. 6.

Cream one-fourth of a pound of butter, add the yolk of one raw egg, and the finely grated yolks of two hard boiled eggs. Mix well, and add finely chopped parsley, onion, a little mace and some lemon juice. Serve with cold meat or fish, or spread on bread.

MAYONNAISE DRESSING. No. 7.

Prepare butter and eggs as directed in number six, adding finely chopped boiled ham, sardellen, anchovies or well soaked salt herring. Eat with cold meat, or spread on bread.

MAYONNAISE DRESSING. No. 8. (BOILED.)

Mix two tablespoonsful of flour with five yolks of eggs, then add a half cup of butter or a cup of cream, a little salt and pepper, (sugar if desired), three to four tablespoonsful of vinegar and one to two cups of soup stock. Pour into a double boiler and stir over a hot fire until thick, then remove and stir until cool. Finely chopped parsley, capers, pickles, or olives may be added. If lemon is desired, use half the amount of vinegar while boiling, and add the lemon juice after it has been removed from the fire.

MAYONNAISE DRESSING. No. 9. (BOILED.)

Boil a small veal bone in three or four pints of water, adding salt, several onions, whole pepper and some spiced herbs. When, nearly done, add three to six tablespoonsful of good vinegar, strain and add the yolks of several eggs. Stir until cool, and place on ice. Serve with cold fish or meat. If the sweet-sour taste is liked, a little sugar may be added to the broth while boiling. Ripe olives are also a good addition.

SYRUP DRESSING. No. 1.

Add the juice of one lemon, orange, or grapefruit, to one-half cup of maple or table syrup. Mix well and serve with pancakes. This is more nourishing and wholesome than pure sweets. Do not prepare more than enough for one meal at a time.

SYRUP DRESSING. No. 2.

Let a half cup of syrup and a small tablespoonful of vinegar come to a boil. Add one finely chopped onion. Remove from the fire and cool, adding the desired amount of oil, and mixing well. This is good for lettuce and watercress. Serve with pancakes, meats, fish, or baked rolled oats, or with rye or wheat. If lemons or oranges are used in place of vinegar, do not allow the latter to boil. Prepare fresh for each meal. Do not use vinegar or onions with fancy fruits.

CHAPTER VIII.

SALADS.

Salads consisting of =mixed= nuts or =mixed= boiled vegetables are not wholesome for delicate people.

LETTUCE SALAD.

Lettuce should be kept in a cool, dry place and not left in water longer than 15 minutes. It may be served alone as a salad mixed with French dressing or served in combination with fruits, starchy foods or other vegetables, and eaten in addition to meats and fish or cheese. Watercress salad can be prepared and served in the same way as lettuce salad.

MEAT SALAD.

Use any kind of cold left-over meat, cut into small pieces or chopped fine, mixed with dressing and garnished with green leaves.

FISH SALAD.

Cut some left-over fish in small pieces, mix with dressing and garnish with leaves.

CUCUMBER SALAD.

Peel and slice the cucumbers thin and pour French or mayonnaise dressing over them. They may be combined with lettuce, tomatoes, chopped parsley or onions.

TOMATO SALAD.

Prepare and mix like cucumber salad. Serve with French or mayonnaise dressing.

BOILED VEGETABLE SALAD.

Use left-over asparagus, string beans, cow beans, lima beans, green peas or cauliflower. Pour over them French dressing half an hour before serving, adding lettuce and mayonnaise dressing when ready to serve.

SPINACH SALAD.

Take some fresh leaves of raw spinach or use cold boiled spinach, and mix with French dressing.

CHEESE SALAD.

Chop up some tart apples, arrange lettuce in a salad bowl, pour in the apples, and sprinkle over it grated Swiss cheese.

NUT SALAD.

Chop or grind in a nut grinder some almonds or walnuts. Arrange lettuce and chopped apples in a salad bowl, sprinkle the nuts over it, and serve with celery and raisins. The French dressing may be omitted.

EGG SALAD.

Arrange lettuce in a salad bowl. Cut up hard boiled eggs, pour over them French or mayonnaise dressing. Caper or olives may be added.

ANCHOVY BUTTER.

Soak the fish for 20 minutes or longer, wash, clean, and chop fine. Add several finely chopped yolks of hard boiled eggs, and parsley, if desired. Cream some sweet butter and mix with the chopped fish and eggs. Spread on stale slices of bread. Serve with lettuce or celery, and hard boiled eggs. Apples and tomatoes combine well with all kinds of fish.

The anchovy butter may be mixed with mayonnaise dressing and served in egg shells cut in halves.

EMPIRE SALAD.

Ingredients: One large well soaked salt herring, two raw apples, two cold boiled potatoes, one cup of cold boiled chopped veal or beef, six hard boiled eggs, three boiled beets, three stalks of celery or one boiled celery root, onions, parsley, and two tablespoonsful of mustard. Chop fine each of the ingredients separately. Set apart three tablespoonsful of chopped whites of eggs, yolks of eggs, beets and parsley. Mix all the other ingredients well and add about one cup of mayonnaise dressing. Put the salad on a platter or into a large glass dish; garnish with lettuce and olives and make designs of green, red, white, and yellow with left-over ingredients. Let the salad stand in a cold place for several hours before serving. If it stands too long, the taste of the herring becomes too strong.

DRIED FISH SALAD.

Soak in warm water for 15 minutes some dried smoked herring or salmon. Cut in small pieces, mix with mayonnaise or French dressing, and garnish with lettuce. The fish may be left whole and served with apple salad.

CABBAGE SALAD.

Use the innermost part of a head of cabbage. Cut and chop very fine, add lemon and olive oil, and mix with mayonnaise dressing. A cold grated potato may be added for those who have difficulty in digesting cabbage.

TOMATO AND WATERCRESS SALAD.

Carefully wash some watercress, dry, and mix with equal parts of sliced tomatoes. Use French or mayonnaise dressing.

DANDELION SALAD.

Carefully wash and mix with finely cut green onions and French dressing.

YELLOW DOCK SALAD OR SOUR GRASS.

Wash and serve plain or mix with lemon and olive oil.

HERRING SALAD. No. 1.

Remove the skin and bones from a smoked herring. Cut the fish into small pieces, and mix with thinly sliced apples or tomatoes, and salad dressing. Garnish with lettuce. Serve with soda crackers or with wheat or rye bread.

CELERY SALAD.

Cut the tender white stalks into small pieces. Add chopped apples and nuts or salad dressing.

ANCHOVY SALAD.

Soak the fish for half an hour, remove the bones, fins, and head. Chop up green onions and parsley. Cut tomatoes or apples into small pieces and mix with equal parts of fish, add the onions and mix with French or mayonnaise dressing. Lettuce and hard boiled eggs cut in halves may be mixed or served with it.

HERRING SALAD. No. 2.

Prepare the same as anchovy salad. Use pickled herring.

RADISH SALAD. No. 1.

Wash and slice some radishes, mix with chopped onions, finely cut chipped beef or any left-over meat or ham. Garnish with lettuce, and serve with French or mayonnaise dressing.

OLIVE SALAD.

Stone and slice some ripe olives. Mix with equal parts of thinly sliced tomatoes and French or mayonnaise dressing. Serve on lettuce.

RHUBARB SALAD.

Wash the rhubarb, cut the red part of it into one inch pieces and mix with mayonnaise dressing.

APPLE SALAD.

Arrange some lettuce in a salad bowl, add chopped or sliced apples, onions and parsley, and mix with French or mayonnaise dressing. Grapenuts or ryenuts may be sprinkled over it. Serve with fish, meat or cheese.

ASPARAGUS SALAD.

Cut off the tips of raw asparagus, arrange some lettuce or watercress in a salad bowl, and mix with French or mayonnaise dressing. Sliced tomatoes may be added. Boiled asparagus may be prepared in the same way.

MUSHROOM SALAD.

Arrange some lettuce or watercress in a dish, select fresh mushrooms, wash and mix with French dressing, and pour over the green leaves.

BANANA SALAD.

Arrange lettuce and sliced bananas in a salad bowl, adding a French dressing of lemon and olive oil. Ryenuts or grapenuts may be sprinkled over it. Scrape off the inside of the skin of the bananas, and mix with it.

ORANGE SALAD.

Peel some oranges, slice them crossways, remove the seeds, put into a bowl and grate some of the orange rind over them. Serve plain or with lettuce, and pour a French dressing of lemon and olive oil over it.

PINEAPPLE SALAD.

Peel and slice crossways, serve with lettuce and lemon or with sweet cream.

PINEAPPLE AND APPLE SALAD.

Mix equal parts of sliced apples and pineapples. Serve like the foregoing or with nuts.

PINEAPPLE AND ORANGE SALAD.

Mix equal parts of sliced oranges and pineapples. Serve like the foregoing.

APPLE AND BANANA SALAD.

Prepare and serve like the foregoing, with cream or nuts.

ORANGE AND BANANA SALAD.

Scrape off the bitter pulp of the inside of the skin of the banana, mix with sliced oranges and bananas, and serve like the foregoing.

FRUIT SALAD IN GELATINE.

Prepare some lemon or orange gelatine. Let cool and pour over the sliced fruit. Set on ice and serve plain or with cream.

CRANBERRY AND CELERY SALAD.

Wash and cut some celery the size of cranberries. Mix with an equal amount of cranberries, and serve plain or with lemon and olive oil.

PEACH SALAD.

Wash and slice some peaches. Serve with cream or lettuce, lemon, and olive oil. Fried beachnut bacon and shredded, puffed or raw rolled wheat are a good addition, if lemon and oil is used.

APRICOT SALAD.

Prepare and serve in the same manner as peach salad.

CRANBERRY AND BANANA SALAD.

Cook some cranberries, strain, and thicken with a little cornstarch. Cool and pour over sliced bananas. Serve with raw celery.

CRANBERRY AND PEAR SALAD.

Combine like the foregoing or use baked pears. Raw cranberries with raw pears and celery is also good.

BANANA AND GRAPE SALAD.

Slice some bananas and mix with an equal quantity of green grapes. Garnish with lettuce, and add lemon and olive oil, if desired.

RADISH SALAD. No. 2.

Mix some chopped or sliced radishes with French or mayonnaise dressing, and add lettuce or celery. Serve for breakfast with whole wheat bread and butter, or with raw wheat flakes.

BEET SALAD.

Mix some left-over sliced beets with French dressing. Serve with cold fat pork or bacon for breakfast or dinner. Celery and whole wheat or black toast with butter make a good combination in place of the meat.

MIXED SPINACH SALAD.

Wash some fresh tender spinach leaves. Cut fine and mix with French dressing, mint and onions. Tomatoes may be added. Serve with hard boiled eggs.

CARROT SALAD.

Grind, chop or slice the carrots and mix with French dressing. Add chopped parsley, lettuce or celery. Serve with rye or wheat flakes or with bacon.

RAW CORN.

Remove the husks from fresh raw corn and place it in cold salted water for 15 minutes. Cut from the cob with a sharp knife, and serve plain or with tomatoes, lettuce and French dressing. This affords a perfect meal for dinner during the summer.

CELERY ROOT SALAD.

Scrub the roots with a brush and boil in the skins until tender. Peel, cut into slices, heap in a high bowl, and pour a little diluted vinegar or lemon juice over them. Let stand for 15 minutes, pour off the acid and mix with French or mayonnaise dressing. This is good for diabetic patients.

CEREAL SALAD. No. 1.

Mix a cupful of raw rolled wheat, oats or rye with a cup of finely grated or chopped carrots. Add a few drops of lemon or orange juice, and a little olive oil. Lettuce, celery or parsley may be mixed or eaten with it.

CEREAL SALAD. No. 2.

Wash and chop lettuce or celery, and apples. Mix with French or mayonnaise dressing. Then add an equal amount of rolled raw cereals and serve. Parsley or watercress may be added. A syrup dressing or onions combine well with it. Peaches and apricots may be used in place of apples and carrots. Onions should not be used with peaches or apricots.

CHAPTER IX.

GELATINES AND TOASTS.

GELATINE PREPARATIONS.

Gelatine is a valuable food for the sick. The nutritive value of gelatine is under-estimated. While it alone cannot sustain life, it is superior to beef tea, and if eaten with other articles which supply the elements which it lacks, it can partially take the place of meat and other nitrogenous foods for sick people and for people of sedentary habits. For people who do hard labor gelatine is of little

value.

FRUIT GELATINE.

To prepare fruit gelatine the acid and super-acid fruits are best, and =no more sugar= should be used than is necessary. Gelatine preparations must be kept on ice, or in a very cold place, and not be prepared in large quantities, as they easily putrefy. For the sick and for children, it should not stand longer than twenty-four hours, and it should not be kept in metallic dishes. The best time to serve gelatine is for the evening meal. It may be served with sterilized cream, and zwieback or wafers.

Prepare some gelatine according to directions on package. Add to it juice from preserved apples, cherries, raspberries, strawberries or currants.

GELATINE PUDDING MADE WITH SOUR MILK.

Prepare some white gelatine with two cups of water. Take twice the amount of gelatine directed and add one-half cup of sugar. Remove from the fire, cool slightly, then add two cups of sour milk which has been beaten, and mix all well. Flavor and set in a cool place. Serve with sweet cream and zwieback.

WHIPPED SOUR MILK.

Beat one quart of thick, sour milk with an egg beater for 10 minutes. Serve with zwieback in soup plates. Three-fifths tablespoonful of powdered sugar and a little cinnamon may be added, if it is agreeable.

Whipped sour cream may be prepared the same as sour milk.

WHIPPED SWEET CREAM.

Whip one quart of sweet, thick cream with two-fifths of a tablespoonful of powdered sugar, add a little vanilla, if desired. Serve with fruit gelatines or ground white figs, stewed prunes, baked apples or raw fruits, such as peaches, strawberries, raspberries or bananas.

BANANA GELATINE.

Prepare some gelatine with orange, cranberry or lemon juice. When nearly cold, cut up some bananas and mix with the gelatine. Flavor and set on ice, serve with whipped or sterilized cream.

PINEAPPLE GELATINE.

Prepare some gelatine with lemon or orange juice. When nearly cold, add some fresh or canned pineapple. Serve with whipped or sterilized cream, and zwieback.

BEER GELATINE.

Prepare with rye beer in the same way as the fruit juice. Take one pint of beer to one pint of water. Use the imported root beer.

BLANC MANGE

Prepare some gelatine with milk, sugar and a little salt. Remove from the fire, set on ice, and mix with boiled custard when cool. Flavor with vanilla or bitter almond.

CALVES' FOOT JELLY.

Wash a calf's foot several times in hot and cold water. Bring to a boil and pour off the first water. Bring to a boil again, add some salt, and cook from two to three hours. Strain through a cheese-cloth. The next day remove the fat, bring to a boil again, add one to two cups of wine, the juice and rind of several lemons or oranges, and sufficient sugar to counteract the sour taste. Pour into a dish which has been oiled, and set on ice. It may be served with whipped cream or the beaten whites of eggs, and shredded wheat or zwieback.

SNOW PUDDING.

Soak some gelatine according to directions. Add a pint of boiling water, some tart fruit juice and the necessary amount of sugar. Let it come to a boil, stir and strain, and let stand in a cold place for several hours. When it begins to set, beat up the whites of two eggs with a little salt or lemon juice, and sugar, and mix with the gelatine. Pour into molds and set on ice. Serve with whipped cream or custard sauce.

RICE GELATINE.

Boil one cup of rice in about three pints of water with a little salt, for 40 minutes. Soak gelatine, half the amount directed on the package, and when soft, add the strained rice water to it, bring to a boil, sweeten to taste, and put into molds or cups. Serve with whipped or sterilized cream and zwieback. Merk's sugar of milk should be used if prepared for the sick.

TOMATO GELATINE.

Strain a can of tomatoes, mix with soaked gelatine and bring to the boiling point, adding lemon or salt, if desired. Put into molds and set in a cool place. Serve with cold meat or fish, olives and greens.

BARLEY GELATINE.

Prepare like rice gelatine. Half rice and half barley may be used. Dried raisins or currants may be added, if desired.

WHEAT GELATINE.

Cook three tablespoonsful of Cream of Wheat with two or three pints of water and some salt. Boil 20 to 30 minutes. Strain and prepare like rice gelatine. Flavor according to desire. If the rind of a lemon is used, boil with the gelatine. This gives it an excellent flavor.

BUCKWHEAT GELATINE.

Wash the buckwheat groats several times with cold water, then soak or put into boiling water at once. Boil from 30 to 40 minutes. Flavor to taste. Finish like the foregoing. It is very good during the winter.

OAT GELATINE.

Wash and soak one cupful of steel cut oats in two quarts of water. Add some bran, if desired. Boil 30 to 40 minutes with a little salt, and drain and strain. Do not press the starch through. Prepare like rice gelatine.

BRAN GELATINE.

Soak one cupful of bran in three pints of soft water for several hours, or over night; one-half cupful of rylax or black crusts may be added. Bring to a boil slowly and let simmer for 15 or 20 minutes. Soak some gelatine, a little less than the directions call for. Add the strained bran juice and a few dried currants which have been soaked in boiling water. If sugar is desired, add a small tablespoonful. Let it come almost to the boiling point, add salt, and put into molds. Serve plain or with sterilized cold cream.

RYE GELATINE.

Prepare like bran gelatine, using less bran. Toast thoroughly brown three or four slices of stale pompernickel and soak with the bran. If boiling water is used for soaking, less time will be required for it. A stick of cinnamon gives the rye a good flavor. Rylax may be used in place of pompernickel.

PEA GELATINE.

Wash and soak over night one cupful of whole dried green peas in three pints of soft water. The next day let them slowly come to a boil and add cut-up onions, carrots, celery or parsley, and salt if desired. Simmer slowly in earthen ware for one hour at least. Strain and prepare with gelatine as directed in the foregoing. Do not press the peas hard through a strainer; allow only a little pulp in the broth. Serve with zwieback spread with almond butter or with a little finely ground walnut meat.

COFFEE GELATINE.

Pour two pints of boiling water on four or five tablespoonsful of coarsely ground coffee. Steep (not boil) for five minutes, then strain. Soak some gelatine according to directions on package. When soft, mix with the hot coffee, add sugar to suit the taste, and let it come almost to the boiling point. Mix well and pour into molds or cups, which have been rinsed in cold water. Serve with whipped or sterilized cream, and zwieback or Nabisco.

CEREAL COFFEE GELATINE.

Prepare some strong cereal coffee according to directions on package. Prepare like the above. A small amount of coffee may be mixed with the cereal coffee, just before removing from the fire.

CHOCOLATE GELATINE.

Grate eight tablespoonsful of chocolate, put into a pint of cold sweet milk, bring to a boil, and add a few tablespoonsful of sugar. Soak some gelatine, and when soft, add one pint of hot milk and heat to the boiling point. Then mix with the hot milk containing the chocolate, pour into molds or cups, and set in a cool place. Serve with cream, zwieback or Nabisco.

For invalids, it is better to prepare the gelatine and chocolate in water instead of milk, and serve with whipped or sterilized cream.

WINE GELATINE.

Use part wine, sherry or claret. Prepare like fruit gelatine. Serve with cream or custard sauce, and wafers.

BREAD GELATINE.

Toast two slices of white and two slices of black bread. Pour three pints of boiling water on them. Simmer for half an hour. Soak some gelatine, and when dissolved, strain the bread-water and add to the gelatine. Bring to a boil, add sugar, and flavor with a little wine or lemon juice. Pour it into molds and cool.

BEAN GELATINE.

Prepare like pea gelatine with or without flavoring. Lima beans or horse beans are best in summer; small white beans in the fall; red, brown, or black beans are best in cold weather, as they are richer in iron and minerals. They can all be served plain with toast or zwieback and butter, cream or nut preparations. Black toast or crusts combine better with lima and white beans than white toast or bread.

LENTIL GELATINE.

Prepare like the foregoing. Flavor richly with onions. Serve with white toast.

TOASTS.

WATER TOAST.

Use zwieback, or toast some stale white bread over the open fire. Lay on a plate and pour over it quickly boiling water, slightly salted, and drain off at once. Serve plain, or spread with sweet butter, or the yolk of an egg.

TOMATO TOAST.

Prepare like the foregoing, spreading with tomato puree in place of butter. Drink with it rich fresh milk. This is excellent for people who have difficulty in digesting milk. Strained hot tomato juice may be used in place of water.

BARLEY TOAST.

Prepare like tomato toast. Use thick, barley jelly prepared from pearl barley, or soften the toast with barley water.

RICE TOAST.

Use thick rice jelly prepared from Carolina rice. Flavor with cinnamon, if desired.

RYE OR BRAN TOAST.

Make a strong tea from toasted black bread and bran, and prepare like the foregoing.

PRUNE TOAST.

Soften some black or white toast with boiling water, and add a little salt. Spread with thick prune juice. Sterilized cream may be added.

APRICOT TOAST.

Prepare the same as prune toast. Add cream or a piece of butter and the yolk of an egg.

APPLE TOAST.

Use thick apple sauce. Prepare the same as apricot toast. The four last recipes are excellent for constipation.

MILK TOAST.

Scald some fresh milk. Add a stick of cinnamon, if desired. Pour over white or black toast.

CREAM TOAST. No. 1.

Prepare like water toast. Bring some fresh cream to a boil with a stick of cinnamon. Add when the toast is soft. Use black or white toast.

CREAM TOAST. No. 2.

Prepare a white sauce from butter, salt, flour and hot water, as directed in "Sauces." Add one-fourth of a cup of hot cream and pour over black toast, which has been softened with one-half cup of hot water.

CREAM TOAST. No. 3.

Use sweet whey in place of hot water, and prepare as No. 2. The cream may be omitted.

CELERY TOAST.

Cut some celery and cook until tender. Soften the toast with the celery water. Prepare a plain butter sauce and add cream, if desired. Mix with the celery and pour over the toast.

CLAM TOAST. No. 1.

Soften the toast with hot clam broth and strain, if desired. Mix the remainder with hot cream and pour over the toast.

CLAM TOAST. No. 2.

Soften the toast with clam broth. Prepare a white sauce from the remainder, add hot cream and pour over the toast.

OYSTER TOAST.

Prepare like the clam toast, with or without cream.

SPINACH TOAST.

Cut off the stems and select only fresh tender leaves. Cook and chop as fine as possible, flavoring with butter and lemon juice. Soften some black or white toast with broth or spinach water, and add the spinach. Serve with hard boiled eggs for dinner. If it is desired for supper, and if the patient's stomach is delicate, use only the hard yolks. Fried beachnut bacon may be added. If the flavor of onion is desired, remove the onion before serving. This is good for constipation.

EGG TOAST. No. 1.

Beat one egg with three tablespoonsful of water or soup stock, and a little salt. Let the toast soften in it and fry to a golden brown in one-half butter and half vegetable fat or oil.

EGG TOAST. No. 2.

Use cream or unsweetened condensed milk. Beat up with eggs, salt and cinnamon, and prepare like the foregoing. This is good for diabetic patients.

CHAPTER X.

FRUITS, PUDDINGS AND GRUELS.

STERILIZED DRIED FRUITS.

Place some dried cherries, apricots, currants or prunes in a Mason jar. Fill to the top, cover with water, and let stand over night. The next day set the jar into a water bath, heat to the boiling point, then cool. Enough can be prepared to last for several days. The juice may be used again for soaking, or it can be used for fruit gruels.

SOAKED FRUIT. No. 1.

Wash some dried fruit, put into a bowl, pour over some hot or cold water, place over it a little saucer with a weight upon it; in this way it requires less water; let stand over night. It is ready for use the next morning, and may be mixed with boiled cereals in place of sugar.

SOAKED FRUIT. No. 2.

Place some dried fruit in a bowl, pour over it some hot cereal coffee. Use in the same way as number one. This is excellent for people suffering with fermentation of the stomach. The cereal coffee acts as a preservative.

FIG BUTTER. No. 1.

Wash some dried figs, dry them; then cut into small pieces, and grind on a nut grinder. Mix with one-fourth (in quantity) of ryenuts. Serve with whipped or sterilized cream.

FIG BUTTER. No. 2.

Prepare as the foregoing. Mix with about one-third or one-fourth of ground nuts, also with ryenuts, if desired. Serve with lettuce.

RAISIN OR CURRANT BUTTER.

Prepare like figs. Mix with ground nuts. Serve with lettuce or with chopped apples.

GROUND DATES.

Remove the stones and prepare as above. Mix with ryenuts or orange juice. Serve with lettuce and sliced bananas or nuts.

GROUND DRIED PRUNES.

Prepare like figs. Mix with ryenuts. Serve with cream or with nuts and lettuce.

BAKED APPLES.

Wash and remove the core; then place in a baking tin, stem end down; pour over some water and a little sugar, if desired, bake in a moderate oven until tender. Let cool and serve plain with butter and bread or with whipped or sterilized cream.

BAKED PEACHES.

Prepare the same as baked apples, and serve with cream.

AMBROSIA.

Mash baked apples very fine and rub through a colander. Mix with soaked or stewed raisins, if desired. Serve in place of apple sauce with beaten whites of egg or whipped cream and zwieback.

BAKED APPLES IN GELATINE.

Prepare in the usual way, pour some fruit or rye gelatine over them.

APPLE SAUCE. No. 1.

Wash some tart apples, cut into four pieces and remove the seeds; steep with a little water and sugar until tender. Then mash fine with a potato masher and run through a colander. Add a piece of butter while warm. Apple sauce prepared in this way is more wholesome than prepared from apples that have been peeled.

APPLE SAUCE. No. 2.

Soak some dried apples over night, steep for 30 or 40 minutes with a piece of cinnamon and a little sugar, and mash fine with a potato masher. Add a piece of butter. Let cool and serve with fish, eggs, boiled beef or cheese.

APPLE SNOW.

Prepare some apple sauce from dried or fresh apples, run through a colander; when cool, mix with the snow of whites of eggs. Serve with zwieback.

APRICOT SNOW.

Prepare same as apple snow.

APRICOT SAUCE.

Wash some dried apricots thoroughly, cut into small pieces, soak over night, then simmer slowly until soft. Run through a colander and add a piece of fresh butter while warm. Serve with French toast, corn bread, corn cakes, steamed puddings or omelet; also good with fish and meats, especially fat meats.

GOOSEBERRY COMPOTE.

Remove the stems, wash the berries and pour some boiling water on them. Let stand 5 minutes; then pour off the water and add fresh boiling water, a stick of cinnamon and the necessary amount of sugar. Thicken with cornstarch. Serve with unleavened pancakes.

GOOSEBERRY PUDDING.

Prepare the gooseberries in the same manner as for compot, but use more water. When done, strain and thicken with cornstarch. Let boil 10 to 15 minutes. Serve hot or cold with cream.

STEWED BLACKBERRIES.

Wash a pint of blackberries, put on to cook with about two pints of boiling water and a stick of cinnamon. Let simmer slowly and add a few tablespoons of sugar. When nearly done thicken with a little cornstarch. Cool and serve with milk rice, custard or pancakes.

STEWED HUCKLEBERRIES.

Prepare the same as stewed blackberries. Strain, if desired.

BAKED APPLES IN OIL.

Wash some tart apples, wipe and core them. Have some vegetable oil, goose grease or lard boiling hot, drop in the apples and cook until tender. Let cool and reheat when needed.

BEER GRUEL.

Soak a half cup of instantaneous tapioca with a half cup of water for 10 minutes. Bring a cup of water and a cup of beer with a stick of cinnamon to a boil, stir in the tapioca, let boil to minutes, add sugar and salt. Then remove from the fire, add three to five tablespoonsful of fresh hot cream and serve. A piece of butter and the yolk of an egg can serve as substitute for the cream. Serve with zwieback.

APPLE TAPIOCA.

Prepare as the foregoing, from apple cider or unfermented apple juice. Serve with cream or with butter and the yolk of an egg. Hot or cold. Serve with zwieback or wafers.

TOMATO TAPIOCA.

Use one cup of strained tomato juice to one of water. Prepare as the above. Serve with cream and zwieback.

BERRY TAPIOCA.

Cook one quart of raspberries or blackberries with two quarts of water, a piece of cinnamon, add three-fourths to one cup of sugar, let boil slowly, then, strain and cool. Reheat and prepare with instantaneous tapioca. Pour on a soup plate, pour sterilized cream over it. In cold weather, the cream as well as the tapioca should be served warm.

RHUBARB PUDDING.

Wash the stalks and cut off the green end. Cut the remainder in small pieces and steep in earthenware with a stick of cinnamon. When, tender, strain and add the necessary amount of sugar. Dissolve some cornstarch, arrowroot or agar-agar with cold water and stir into the fruit juice. Let boil 10 minutes and serve warm on soup-plates with sterilized cream or put into molds and cool. If it is eaten warm, it is preferable to let the fruit juice cool first, then reheat and add the thickening.

APPLE PUDDING.

Save all the peeling from several days; add a few whole apples. Cook with water, strain and prepare like rhubarb pudding.

CURRANT, RASPBERRY OR PEACH PUDDING.

Prepare the same as the foregoing. If peaches or peach skins are used, do not press much of the pulp through. It is better to use more peeling than whole fruits. In serving peach or apple salad, the peelings can be saved from a day or two and preserved by stewing them in a little water until ready for use.

LEMON FILLING FOR PIE.

Stir the yolks of three eggs with one-half cup of sugar, add the grated rind and juice of two lemons or one lemon and one orange, then add two tablespoons of cornstarch, one of butter and one and one-half cup of hot water. Stir in a double boiler over the fire until it is thick. Then pour it into the baked crust. Beat the whites with a tablespoon of sugar and a little lemon juice. Put over the top and brown in the oven.

STRAWBERRIES WITH WHIPPED CREAM.

Select fresh ripe berries and wash. Put the desired amount on flat medium-sized plates. Beat up some cream with the whites of several eggs and a little powdered sugar. Cover the berries with the cream and serve with wafers or triscuit.

PEACHES AND PEARS WITH WHIPPED CREAM.

Peel and slice them. Prepare and serve the same as the foregoing. These dishes are not good for delicate stomachs.

PLAIN JUNKET.

Warm one pint of milk to blood heat, flavor as desired; stir in one junket tablet which has been dissolved in a little water and pour into a dish; set on ice. Serve with cranberry or prune sauce and wafers.

WINE GRUEL.

Bring equal parts of white or red wine and water to a boil, flavor with lemon rind or cinnamon, add sugar, thicken with instantaneous tapioca or with potato flour. Serve plain or add a piece of butter and the yolk of an egg.

WINE GRUEL OF PORT OR SHERRY.

Soak some plain sago or tapioca for about three hours, then pour into boiling water, add sugar, lemon rind, and a pinch of salt. When almost done, add port or sherry (one to three ounces to one person). Serve plain, or with butter and the yolk of an egg.

WINE GRUEL OF RED CLARET.

Bring equal parts of wine and water to a boil, thicken with potato flour or instantaneous tapioca, add sugar and a little salt, add a small amount of preserved raspberries or strawberries, jam or jellies, or sliced pineapple. The whites of several eggs beaten to a snow with a little salt may be mixed with it before serving. Zwieback or wafers is a good addition.

RICE GRUEL. No. 1.

Mix two to three tablespoonsful of rice flour with a little cold water, add to it a pint of boiling water, two level tablespoonsful of sugar of milk, salt to taste, boil fifteen to twenty minutes. Put on a soup plate, pour hot or cold sterilized cream over it.

RICE GRUEL. No. 2.

Prepare as number one. After removing from the fire, add a piece of butter, and the yolk of an egg, mix thoroughly, then put on a soup plate. Serve with or without cream.

CHOCOLATE CORNSTARCH.

Bring a pint of water to a boil, mix with two tablespoonsful of chocolate, let boil two minutes, then thicken with two tablespoons of cornstarch. Flavor with salt and vanilla. Pour on a soup plate. Serve with sterilized cream, hot or cold.

BOILED CUSTARD.

Bring one pint of sweet cream or rich milk and one pint of water to a boil with a piece of vanilla. Then mix one tablespoonful of cornstarch with a little cold water and three yolks of eggs, two tablespoonsful of sugar, and a little salt. Add all to the boiling milk, stir over the fire or in a double boiler until it thickens. Remove and beat until nearly cold. Put on ice. It may be served with zwieback and fruit juice or with fresh berries. For dyspeptics, it is better if prepared with water and butter instead of milk and served with sterilized cream.

BLACKBERRY SAGO.

Boil one quart of blackberries with about two quarts of water and some sugar very slowly, then strain and cool, bring to a boil again, prepare with instantaneous tapioca or plain sago. The latter must be well soaked. Serve warm with zwieback or wafers and sweet butter.

APPLE SAGO.

Boil tart apples with the skin in plenty of water; when tender strain and cool. Reheat, flavor with cinnamon and sugar. Prepare with instantaneous tapioca or plain sago. After removing from the fire add orange juice, lemon, butter and the yolk of an egg or serve with sterilized cream.

ONION GRUEL. No. 1.

Cut fine three or four onions, stew them in a quart of water very slowly and keep them well covered. When tender strain; heat butter or olive oil and thicken with mixed flour; add the onion broth slowly, let boil a few minutes. Flavor with salt and lemon. One-half soup stock and one-half onion broth may be used. Cream can be added if desired.

ONION GRUEL. No. 2.

Put one-half of a cup of barley to soak, boil with four dried or green onions. Add salt, and strain.

BREAD GRUEL. No. 1. (WITH BARLEY.)

Soak and boil one-half cup of barley with salt in three pints of water, very tender, until there remains about a cup of liquid. Strain this. Then, take some French bread or soda crackers, pour sufficient boiling water and a tablespoonful of milk sugar or cane sugar on it, let stand until it is perfectly soft, or until the water is all soaked into the bread. Then add the cup of barley water, let all boil for a few minutes or until bread and barley are well united. It may be strained, if desired.

BREAD GRUEL. No. 2. (WITH BRAN.)

Take a cup of select bran, simmer slowly with two pints of water and a little salt, while boiling, add three tablespoonsful of milk sugar or a teaspoonful of can sugar. Strain, finish like bread gruel number one. Add dried soaked sweet fruit, if desired.

BREAD GRUEL. No. 3. (WITH OATS AND BRAN.)

Take one-third of steel cut oats and two-thirds of bran. Prepare like bread gruel number one. Add sweet fruits, if desired.

OATMEAL GRUEL. (WITH BRAN.)

Soak a half cup of steel cut oats or rolled oats and a cup of bran. Put on to boil with three pints of cold or boiling water and salt. Let boil slowly for three-fourths of an hour. Strain, add butter and serve. This is excellent for nursing mothers. Use more water if it is desired thin.

CORNMEAL GRUEL.

Put one-half to three-fourths of a cup of corn meal to boil with three pints of boiling water and some salt. Let boil fast during the first ten minutes, then set aside and boil slowly for twenty or thirty minutes. Remove from the fire, add a small tablespoonful of butter, the yolk of an egg and a few drops of lemon; the rind of the lemon may be grated over it. Mix all well, pour on a soup plate, eat plain or with hot sterilized cream. The butter, egg and lemon, may be left out, and cream added only.

CODFISH GRUEL.

Soak two tablespoonsful of shredded codfish for twenty minutes, change the water several times. Add boiling water and flavor with onion. Heat butter or olive oil, thicken with mixed flour, add the onion water slowly, at last the soaked codfish. Let all boil a few minutes. Chopped parsley and hot cream may be added, if desired. Serve with toast.

BARLEY GRUEL.

Soak a half cup of pearl barley, put on to boil with three pints of water, add salt and three tablespoonsful of milk sugar. Let boil slowly for one hour, then strain. Heat a tablespoonful of butter, thicken with mixed flour, add the barley gruel gradually, let all boil a few minutes, then serve.

WHEAT GRUEL.

Put two to three tablespoons of cream of wheat or farina into a saucepan. Add a pint of boiling water, a pinch of salt, and a tablespoon of milk sugar. Let boil half an hour. Remove from the fire and mix with a teaspoon of butter or two to three ounces of hot cream. Dried soaked raisins or currants may be added.

GLUTEN GRUEL.

Prepare as directed on package. Add cream or butter and the yolk of an egg.

RAW CEREAL GRUEL.

Soak one-half to one-third cup of flaked raw cereal with a cup or more of warm salted water. Let stand for several hours or over night in a warm place. Serve plain or with sweet dried fruits and fresh cream.

MIXED FLOUR GRUEL. No. 1.

Mix two tablespoonsful of mixed flour with a little cold water, add two to three cups of boiling water, salt and a tablespoonful of milk sugar. Let boil ten to fifteen minutes, remove from the fire. Add two to four ounces of hot cream. Flavor with vanilla, cinnamon, grated lemon rind or bitter almond.

MIXED FLOUR GRUEL. No. 2.

Put to boil the same amount of flour as in number one. Use a cup of rich milk and one and one-half of water instead of water alone. Flavor and serve.

ARROWROOT GRUEL.

Prepare the same as mixed flour gruel. Add hot cream.

NUT GRUEL. No. 1.

Mix two tablespoonsful of mixed flour with a little cold water, add two to three cups of boiling water, salt, and a teaspoonful of sugar, if desired. Boil 10 to 15 minutes. Stir a tablespoonful of almond-butter or combination nut-butter with one or two tablespoonsful of water to a smooth paste, add the gruel gradually, mix all well and serve.

NUT GRUEL. No. 2.

Heat a tablespoonful of butter in a flat saucepan, thicken with mixed flour, add two cups of boiling water, and salt, let boil a few minutes. Stir smooth a teaspoonful of almond-butter with cold water, add the gruel, mix well, flavor with lemon, if desired.

SAGO GRUEL.

Wash and soak a half cup of sago for several hours in a cup or more of cold water. Put into three cups of boiling water, add salt, a tablespoonful of milk sugar, or a teaspoonful of cane sugar, a stick of cinnamon, vanilla or lemon rind. Boil the sago 20 to 30 minutes. Remove from the fire, add three to six ounces of hot cream. Less sago may be used and a tablespoonful of rice flour dissolved with cold water added to it while boiling.

CORNSTARCH GRUEL.

Mix two tablespoonsful of cornstarch with a little cold water, add three cups of boiling water, salt, a tablespoonful of milk sugar or a teaspoonful of cane sugar, boil 10 to 15 minutes. Add two to three ounces of hot cream. One-half of rice flour and one-half of cornstarch may be used in place of pure cornstarch. Flavor as desired.

MILK GRUEL. No. 1.

Mix a tablespoonful of rice flour and one of cornstarch with a little cold water. Add one quart of boiling milk. Boil 10 to 20 minutes. Add salt and flavor, as desired.

MILK GRUEL. No. 2.

Bring one pint of milk and one pint of water to a boil. Dissolve two or three tablespoons of white flour with a little cold water and stir into the hot milk. Let boil 10 to 15 minutes. A stick of cinnamon, vanilla or lemon rind can be boiled with the milk. If the flavor of almonds is desired, grate one bitter-almond on it after it is removed from the fire. The yolk of an egg may be added, if desired.

PEPTONIZED GRUEL.

Prepare a gruel from any farinaceous article. Pour into a bowl and allow it to stand until lukewarm. Add peptonized powder according to direction.

CHAPTER XI.

FLUIDS.

STERILIZED MILK.

Put the desired amount of milk into clean sterilized bottles, put in cotton stopper, set on a grate and heat in a water bath to 170° F. or 212° F. Keep the milk at this temperature for 40 minutes or longer, then remove from the fire; when the water has cooled take out the bottles and place them on ice.

Recipes for the preparation of different forms of peptonized milk can be found in the directions given with digestive ferments, when bought at the drug store.

KUMYSS.

Dissolve one-fourth of a cake of compressed yeast in a little warm water. Take a quart of fresh blood-warm milk, add to it a tablespoonful of sugar and the yeast. Put the mixture into beer bottles with patent stoppers, filling them to the neck. Place them for about twelve hours in a room suitable for raising bread, at a temperature of about 70°, then put the bottles on ice, up side down, until wanted.

RICE WATER.

Wash one-half a cup of Carolina rice several times with water, then soak or put on to boil at once with three pints of water. Boil slowly for about an hour, strain, and sweeten, or flavor as desired. Serve plain or with one-fifth part of sterilized cream.

BARLEY WATER.

Prepare in the same manner as rice water.

EAGLE BRAND CONDENSED MILK.

It can be prepared in many different ways, and mixed with barley-water, and cream, or used for sweetening in the preparation of gruels.

TOAST WATER.

Toast a slice of stale wheat or black bread until thoroughly brown. Break into small pieces and pour on it two or three cups of boiling water. Cover tightly, and set aside for twenty minutes or longer. Strain, and flavor to suit the taste. Serve hot or cold.

TOAST AND APPLE WATER.

Prepare like toast water, and add the peelings of one or two apples before pouring on the boiling water.

LEMONADE.

Boil a quart of water for several minutes with three to five tablespoonsful of sugar, and the rind of one lemon. Remove from the fire, add the juice of two or three lemons or oranges, strain and cool. Fresh clean cold water may be added to suit the taste. This is excellent in fevers, where much fluid food is required. It may be served hot or cold.

BRAN TEA.

Soak over night a cupful of Ralston's select bran in one quart of soft warm or cold water. The next day strain it and serve raw, or put it on to boil, simmer for one-half hour, then strain. Serve hot or cold. The bran may be mixed with oats or ryenuts when put to soak, and may be used raw or boiled. Hot bran tea with cream is excellent as a substitute for tea. It can be prepared without soaking.

BEEF JUICE. No. 1.

Broil one pound of thick round steak, cut into small pieces and press the juice out with a lemon squeezer or meat press. It may be served with or without lemon juice and be diluted with warm water, if desired. When heating, do not coagulate the albumen by boiling, but place the cup or bottle containing the juice in a kettle of warm water.

BEEF JUICE. No. 2.

Grind or chop some round steak, put into a quart jar and fill with warm water. Place the jar in warm water and let stand three or four hours. The temperature must not rise above 155° F. Strain through a cheese-cloth, and flavor with a little lemon or salt.

BEEF BROTH.

Wash a beef bone thoroughly with hot and cold water. Put on to boil and cook very slowly for three or four hours. It may be flavored with onion, potato or soup greens. Strain through a fine strainer or cheese-cloth. Serve hot or cold. If a few teaspoonsful of hot sterilized cream or the yolk of an egg is added before serving it will improve the taste and make it more nutritious.

JULIENNE BROTH.

Soak the desired amount of dried vegetable. Prepare as directed on package. Add some soup stock or beef extract before serving.

VEAL BROTH OR JELLY.

Take a bone of veal without meat, wash it thoroughly first with cold and then with warm water. Bring to a boil with cold water and pour off the first water. Bring to a boil again with hot or cold water, skim carefully, add salt, and let it simmer gently for several hours. Strain through a fine sieve or cheese-cloth. When cool set on ice. If thickening is desired, cook one-half a cup of Cook's flaked rice in an equal amount of water, and add a little salt. Mix with one-half a cup of veal jelly, and serve. A few tablespoons of cream may be added to it, or the broth may be served clear with zwieback.

BROTH WITH EGG.

Stir the yolk of an egg with two tablespoonsful of cold water until well mixed. Then gradually add eight to fifteen ounces of broth. Stir constantly to prevent the egg from curdling. If the whole egg is desired, beat it with an egg-beater and prepare in same way. Less than eight ounces of broth to one egg will make it too rich. A few drops of lemon may be added.

TOMATO AND VEAL JELLY.

Mix an equal amount of strained veal broth and strained tomato juice. Let cool and serve. If freshly strained canned tomatoes are used, do not cook the tomatoes. If it stands longer than twelve hours, bring to the boiling point in order to prevent fermentation.

VEAL JELLY.

Veal jelly may be flavored in many different ways. It is better to cook the stock with salt only. In this way the flavor can be changed each time by adding vegetable broth obtained by boiling vegetables in a small amount of water and straining. Onions are a very good flavoring. A great variety of vegetables should not be used at one time.

MALTED MILK. No. 1.

Put two teaspoonsful of malted milk into a cup, pour on some boiling water and add a pinch of salt and one-fourth of a cup of cream.

MALTED MILK. No. 2.

Prepare as the foregoing, omitting the cream. Serve plain, or add a few drops of lemon juice.

UNFERMENTED BEER.

Soak a cup of bran and a slice of thoroughly toasted black bread for several hours in a quart of water. Add a stick of cinnamon, bring to a boil and let simmer slowly for 20 minutes or longer. Strain and serve hot or cold.

CAMOMILE TEA.

Put a tablespoonful of tea into a teapot and pour on it one-half a pint of boiling water. Allow it to stand on a hot platter or over steam for 5 minutes. Then strain and serve.

FENNEL TEA.

Prepare the same as camomile tea.

BUCKTHORN TEA.

Put two tablespoonsful of buckthorn bark into a teapot, pour on it a cup of boiling water, and allow to steep from 10 to 15 minutes. Strain and serve warm (not hot).

WHEY. No. 1.

Soak one of Hansen's rennet tablets in a little cold water. Heat one quart of skim milk or fresh milk until it is lukewarm. Crush the tablet and mix with the milk, and stand on a warm place for 5 minutes or until it is thick. Then heat over the fire until the whey separates. Strain and throw away the curd.

WHEY. No. 2.

Heat some fresh milk until it is blood-warm. Add Fairchild's essence of pepsin, according to directions.

IRISH MOSS.

Wash and let it soak for several hours, or over night. Boil for 10 minutes, strain through cheese-cloth, and add one-half or two-thirds of a cup of hot milk. Flavor as desired.

RAW GREEN PEA JUICE.

Wash some fresh green peas in the pods and grind through a meat grinder, allowing the liquid to drain into a bowl.

LEMON WHEY.

Heat a pint of fresh milk to about 200° F., remove from the fire and squeeze into it the juice of one-half a lemon. Let stand for a few minutes, beat with a fork, and strain through a cheese-cloth. Serve hot or cold.

ALBUMEN WATER.

Add to the white of one fresh egg eight ounces of water and a little lemon juice or brandy, and shake thoroughly. Keep on ice.

FLAXSEED TEA.

Add a quart of water to two tablespoonsful of whole flax seed. Boil one or two hours with one or two tablespoonsful of sugar. Strain and add lemon juice or cream, to suit the taste.

APPLE BARLEY WATER.

Soak a cup of barley over night. Put to boil with two quarts of water, add a little salt and the skins of two or three apples, and a little sugar. Boil slowly for an hour or until it becomes red in color. Strain, and add lemon juice, if desired. Serve hot or cold.

WATER EGGNOG. No. 1.

Beat the whole of an egg with one-half a cup or less of water. Flavor with lemon juice.

WATER EGGNOG. No. 2.

Beat the yolk of an egg with one-half or a whole cup of water. Flavor with lemon juice.

LEMONADE WITH EGG.

Take some lemonade prepared from oranges and lemons and add to it the yolk or the whole of an egg. The acid taste must dominate the sweet taste.

MILK EGGNOG.

Beat up the whole or the yolk of an egg with a little water and some brandy, sherry, cognac or whiskey, and one or two teaspoonsful of sugar. To this add eight to ten ounces of rich raw or sterilized milk, or one-half cream and one-half water. Flavor with nutmeg or bitter almond.

FRUIT LEMONADE.

Boil some water with a little sugar and the rind of a lemon, orange or apple. Add to it some preserved strawberry, cherry, pineapple, currant or raspberry juice, and seltzer water, or add a mixture of several different fruit juices. This is excellent for fever patients, but not for people suffering with lung or heart diseases.

ALMOND MILK.

Blanch one cup of almond meats, chop or grind them coarsely, and pour over them a quart of hot water. Let stand several hours or over night, press through a cheese-cloth, and keep on ice. A few bitter almonds may be added.

BEER LEMONADE.

Wash a half cup of dried currants or raisins, put on to boil with a pint of water, a tablespoonful of rye nuts or black toast, a piece of cinnamon, some lemon rind and one or two tablespoonsful of sugar. Simmer slowly for fifteen minutes, add a pint of Munchener's Spatenbraü, let it boil for one minute, and strain. Keep in a cool place. Serve hot or cold.

STRAWBERRY MILK.

Wash two cups of fresh strawberries. Put into a milk-pitcher and add two quarts of fresh raw or cold boiled milk, a little vanilla and a small piece of ice. Strain, serve with zwieback or shredded wheat. Sugar may be added, if desired. This is more wholesome than ice cream.

EGG WINE.

Mix thoroughly the yolk of three eggs with three teaspoonsful of sugar. Add a pint of white or red wine or one-half of wine and one-half of water. Serve with zwieback or wafers.

TEA.

Rinse the teapot with boiling water. Take a teaspoonful of black Japan tea, add a pint of boiling water, and let stand over steam for one or two minutes. Strain, and serve hot or cold with lemon juice or cream.

COFFEE.

Grind very coarsely two tablespoonsful of fresh coffee beans. Pour two cups of boiling water on them, let stand 5 minutes (do not boil), then strain. Serve black or with cream. Tea and coffee should be used for medicinal purposes only.

MALT OR CEREAL COFFEE.

Take one-half cup of instantaneous Postum or Kneipp's malt coffee, pour three or four cups of boiling water on it. Let stand from 5 to 15 minutes, then strain. Serve hot or cold, with or without cream. People who wish to leave off coffee may add a teaspoonful of coffee beans to the cereal coffee a few minutes before straining. In this way they will gradually lose the desire for coffee. Bran tea or legume tea may be substituted for black tea or coffee.

COCOA. No. 1.

Dissolve one teaspoonful of cocoa and one of sugar in a little boiling water or milk and add a cup of rich milk. Let all boil a few minutes. Hot or whipped cream may be added before serving.

COCOA. No. 2.

Dissolve one-half a teaspoonful of cocoa and one teaspoonful of milk sugar in a little boiling water, add one cup of hot rich milk or one-half cup of cream and water, and boil a few minutes. Add more cream, if desired.

COCOA SHELLS.

Boil cocoa shells for twenty minutes, then strain. Use as a substitute for tea or coffee.

BEAN TEA.

Use white, brown or black beans; soak one-half cup of beans in warm soft water over night. The next day put on to boil in a quart of water, cook slowly for one hour or longer, and keep covered well. Then strain and serve plain, or add some hot cream to it. Small white and lima beans are excellent in the summer.

PEA AND LENTIL TEA.

Prepare the same as bean tea. Dry green peas are richer in minerals than yellow peas. Yellow peas contain more starch.

PART THREE

CHAPTER I.

FOOD REQUIREMENTS.

It is important that the diet should contain the proper amount of protein, starches and fats, suitable to the individual needs. Age, weight, size, occupation, season and climate must all be considered. The majority of civilized men and women consume from two to three times the amount of food necessary. Numerous and careful researches regarding food requirements have been made during the last fifty years.

The composition of American food materials and the dietary standards of Professors Voit and Atwater can be found on the last pages of this book.

The recent experiments of Professor Chittenden, of Yale University, have demonstrated that 60 grams of protein, with the necessary amount of fats and carbohydrates to yield from 1500 to 2500 calories per day, is sufficient. These requirements are regarded as presenting the minimum of what is necessary for the maintenance of health, strength and activity. To take more food than the body requires means not only waste of food, but an unnecessary strain upon the body, by this excess, which must be gotten rid of at the expense of energy, that could be more profitably expended for other purposes.

The sample menus given on following pages are taken from the results of my own experimental work with different people, under different conditions, and of weights varying from 130 to 160 pounds. They were people in poor health, suffering from lack of nutrition brought about by unsuitable food, such as too much protein or starchy foods; insufficient fats and minerals in the food; excess of cooked foods; improper combinations and wrong time for eating. Some improved in health and strength immediately after the change of diet, and were able to do from eight to twelve hours of active work, while others found it necessary to take a rest and develop their stomachs gradually by a change to raw foods.

I am convinced that the amount of protein presented in the sample bills of fare is sufficient for the average individual, provided the food is properly masticated, digested and assimilated, and not forced down by artificial stimulants and poisonous beverages. The amount of carbohydrates and fat required differs greatly with different temperaments and individual peculiarities, and must be determined by the individual himself. Those who can use a considerable amount of cereals and fruits require less fat, while others who are not so well able to digest large amounts of starchy foods and fruits require more fats.

Cooked foods are more easily digested than raw foods, but the nutritive value is very definitely influenced by the process of cooking; therefore it is important to consume as much food as possible in the raw state.

Sample of Daily Food Requirements (roughly described):

TABLE 1.

Grams _contain_ Protein Fats and Carbohydrates Milk 50 2 4 Rice, barley, noodles or corn 100 12 40 Lean meat 250 54 32 Greens 125 3 6 Bread 200 14 56 Butter 50 -- 34 Oil, ½■ cup (or fat meat) 150 -- 102 Fruit 300 -- 18 Eggs 100 12 16 -- ---- 97 308

TABLE 2.

Milk 50 2 4 Rice or any other cereal 100 12 40 Greens 125 3 6 Potatoes or carrots 100 2 11 Cheese (or nuts or legumes) 100 25 36 Oil, ½■ cup (or fat meat) 150 -- 102 Fruit 300 -- 18 Bread 300 21 84 Butter 50 -- 34 -- ---- 65 335

SAMPLE MENUS

I. BREAKFAST.

(Winter.)

Pearl barley with hot cream and French prunes. Two soda crackers.

Portion of food containing calories Pearl barley (measured raw) ½■ cup 450 Cream ½■ cup 230 French prunes 5½■ 100 Soda crackers 4 100 ---- 880

DINNER.

Tomato and lettuce salad with mayonnaise dressing. Baked beans with lemon and fat meat. Carrots.

Tomatoes 2 raw 100 Lettuce ½■ head 10 Oil 4 tablesps. 400 Egg 1 whole 60 Beans ½■ cup (raw) 300 Fat meat ½■ lb. 650 Carrots 1 large 50 Lemon Juice of ½■ 8 ---- 1578

SUPPER.

Tomato cream soup with toast and raw celery.

Butter 1 tablesp. 105 Strained tomato juice 1 cup 100 Cream ½■ cup 230 Toast 2 small slices 75 Celery 3 stalks (raw) 25 ---- 535

II. BREAKFAST.

(Summer.)

Strawberries, two boiled eggs with shredded wheat or toast, or raw wheat flakes.

Strawberries 1 cup 60 Eggs 2 120 Shredded wheat 2 200 Butter 1 tablesp. 105 ---- 485

DINNER.

Apple and celery salad with French or mayonnaise dressing. Boiled codfish with white sauce. Bread and butter. Black unsweetened coffee.

Apple 1 large 100 Celery 2 stalks 16 Oil 4 tablesps. 400 Egg 1 60 Lemon ½■ 8 Fish ½■ lb. 130 Butter 2 tablesps. 200 Flour 1 tablesp. 30 Black Bread 2 large slices 200 ---- 1144

SUPPER.

Muskmelon with lemon. Creamed chipped beef on toast.

Melon ½■ 60 Lemon Juice of ½■ 4 Chipped beef 3 slices 50 Cream ½■ cup 230 Toast 1 large 100 ---- 444

III. BREAKFAST.

(Summer.)

Banana, apple and lettuce salad with French or mayonnaise dressing. Stale black bread.

Apple 1 large 100 Lettuce ½■ head 10 Banana 1 100 Oil 2 tablesps. 200 Lemon Juice of ½■ 4 Black Bread 1 slice 100 ---- 514

DINNER.

Cream of wheat porridge with hot cream. Almonds and raisins.

Cream of wheat (raw) ½■ cup 250 Cream 3 ounces 273 Almonds 12 large 120 Raisins 12 large 100 ---- 743

SUPPER.

Strawberries with a large glass of raw mixed milk and cream and zwieback.

Strawberries 2 cups 120 Zwieback 2 100 Cream 4 ounces 230 Milk 8 ounces 165 ---- 615

IV. BREAKFAST.

(Summer or Winter.)

Steel cut oats or wheat with butter or hot cream. Two large carrots or cucumbers.

Oats (measured raw) ½■ cup 100 Butter 1 tablesp. 105 Carrots 2 large 100 ---- 305

LUNCH OR DINNER.

Sandwiches with butter and sliced American cheese or one-half blood or liver sausage and two apples.

Black or whole wheat bread 2 large slices 200 Butter 3 tablesps. 315 Cheese ½■ lb. 450 Apples 2 large 100 ---- 1065

SUPPER.

Green pea soup with fried bread and stewed prunes.

Peas (measured before soaking) ½■ cup 80 Onion 1 6 Bread 2 small slices 75 Fat for cooking and frying 4 tablesps. 400 Flour for cooking and frying 2 tablesps. 60 Prunes 6 120 ---- 741

V. BREAKFAST.

(Summer or Winter.)

Banana salad with lettuce and French dressing, grapenuts or ryenuts.

Banana 2 medium 200 Lettuce ½■ head 10 Olive Oil 2 tablesps. 200 Lemon Juice of ½■ 8 Grapenuts 1 tablesp. 30 ---- 448

DINNER.

Strained barley soup with prunes, beefsteak, sprouts and butter sauce, toast and black coffee.

Barley (before soaking) ½■ cup 450 Prunes 5 100 Butter 1 teasp. 105 Beefsteak ½■ lb. 160 Sprouts ⅜■ cup 30 Butter Sauce ½■ cup 135 Toast 1 large slice 100 Butter 1 teasp. 35 ---- 1115

SUPPER.

Baked apple with cream, puffed wheat or corn flakes mixed with pieces of butter, two soft boiled eggs, one-half cup of black coffee.

Apple 1 large 100 Cream ½■ cup 115 Puffed wheat ⅜■ cup 75 Butter 1 tablesp. 105 Eggs 2 120 ---- 515

FOOD FOR THE AGED

Many people at the ages of sixty and seventy still lead an active life, while others retire from activity at forty-five or fifty. Therefore, the food must conform to the person's mental and physical requirements. If the teeth are poor and the digestive powers are weak, the food should be light, consisting mainly of well cooked cereals, baked potatoes, rice, cooked greens, a small amount of meat, raw fruits and raw greens in combination with fatty foods, as salads, milk and buttermilk, toasted breads and soups. The total fuel requirement depends upon whether the individual leads a quiet or active existence. For a person who lives mainly indoors, and makes little use of the muscles of the arms, shoulders and trunk, 1000 to 1200 calories is sufficient for twenty-four hours. If more food is eaten than the body requires, the excess will manifest itself by the development of chronic ailments and obesity, or feeble-mindedness.

The morning and evening meals should consist of fluid and semi-fluid foods, or of toasted breads and salads. Meats, eggs (except the yolks), cheese, beans, peas and nuts should be eaten only during the middle of the day in small quantities. One can cut down his amount of food greatly by thoroughly chewing each morsel. The demand for protein at this period is small, while the amount of fat should be increased. A few sample bills of fare may be of assistance to those who wish to make a study of food requirements for themselves or for others.

MENUS FOR THE AGED

I. BREAKFAST.

Apple salad with lettuce finely chopped, onion and mayonnaise dressing, bacon and crusts.

Portion of food containing calories Apple 1 medium 72 Lettuce ½■ head 5 Onion ½■ piece Oil 4 tablesps. 100 Lemon or vinegar About 2 teasps. 4 Yolk of egg 1 48 Bacon 2 ounces 325 Crusts 2 50 ---- 604

DINNER.

Clear soup with rice and egg. One lamb chop with sprouts, and one triscuit with butter.

Soup 1 cup 100 Rice (measured before soaking) 2 tablesps. 100 Yolk of Egg 1 48 Lamb chop 1 small 100 Sprouts ½■ cup 20 Butter sauce ½■ cup 135 Triscuit 1 35 Butter 1 teasp. 35 ---- 573

SUPPER.

One large glass of buttermilk, kumyss, peptonized hot milk or Dr. Metchinikoff's sour milk, with one slice of graham toast.

Milk 12 ounces 247 Graham toast 1 large slice 100 ---- 347

II. BREAKFAST.

Raw cranberries and celery with olive oil, one slice of graham or whole wheat toast with butter and unsweetened black malt coffee.

Cranberries ½■ cup 10 Olive oil 2 tablesps. 100 Toast 1 large slice 100 Butter 1 tablesp. 105 Raw Celery 2 stalks 16 ---- 331

DINNER.

Rice with cream or tomato sauce, eight almonds or one large zwieback with one level tablespoonful of almond butter and raisins.

Rice 3 tablesps. 150 Hot cream 2 ounces 115 Almonds 8 80 Raisins (large) 8 80 ---- 425

SUPPER.

Calves'-foot and tomato jelly with graham toast or puffed wheat and milk or black malt coffee.

Jelly ½■ cup 50 Puffed Wheat 1 cup 100 Milk 8 ounces 165 ---- 315

III. BREAKFAST.

Raspberries or strawberries, plain shredded wheat with cream.

Raspberries ½■ cup 30 Shredded wheat 1 100 Cream 2 ounces 115 ---- 245

DINNER.

Potato or apple salad, and lettuce with mayonnaise dressing, fish, black crusts and black coffee.

Potatoes 2 medium 150 Oil 4 tablesps. 400 Yolk of egg 1 48 Lemon or vinegar About 1 tablesp. 5 Raw onion (finely chopped) ½■ piece 3 Crusts 3 75 ---- 681

SUPPER.

Cook's flaked rice gruel with hot cream, cream toast or vegetable cream soup.

Flaked rice 1 cup 100 Hot cream 2 ounces 115 Hot water 1 cup ---- 215

IV. BREAKFAST.

Cooked string beans with butter sauce and parsley, fried bacon and triscuit with butter.

String beans (cut up) ½■ cup 20 Butter sauce ½■ cup 135 Fried bacon 2 ounces 200 Triscuit 1 35 Butter 1 teasp. 35 ---- 425

DINNER.

Barley soup with crackers, pea puree on toast, stewed prunes with cream.

Barley 3 tablesps. 270 Butter 1 teasp. 35 Cracker 1 25 Pea puree 2 tablesps. 100 Toast 1 large 100 Prunes 5 100 Cream 2 ounces 115 ---- 745

SUPPER.

Bran tea with cream. A piece of cake or a slice of light egg toast.

Bran ½■ cup 110 Cream 1 ounce 58 Egg 1 60 Soupstock ½■ cup 25 Butter for frying 1 tablesp. 105 ---- 358

CHAPTER II.

DIET DURING PREGNANCY.

A healthy woman will be guided by intuition as to the selection of food suited to her condition. Unfortunately, only a few women are properly matured in these days of forced education and unnatural occupations for young girls during the age of puberty.

The craving of pregnant women for pickles, spices and certain fruits out of season indicates an anemic condition. The individual longs for an article, of which her mind is most conscious, to bring about satisfaction.

Pregnant women require a larger amount of phosphates, lime and other minerals in their food, especially during the first four months. The amount of food taken should be rather less in quantity; and the starches and sweets should be cut down as much as possible, unless the mother has to perform a large amount of physical work.

Vomiting during the early months of pregnancy is generally due to excess of starches and indigestible foodstuffs. The eliminating organs not being able to throw off the excess of waste, the system rids itself of it through the effort of the liver, before the waste enters the blood stream.

A suitable diet depends much upon the constitution of the mother. In severe cases of vomiting or headache, a diet should be prescribed by a physician.

DIET FOR THE MOTHER AFTER LABOR.

This is another important period for the welfare of the mother as well as of the infant. Improper feeding during the first month after the child is born is responsible for many nervous breakdowns of the mother, at the time when she should be in the best of health and ready to take charge of her infant. A healthy new born infant can stand an enormous amount of abuse in the matter of feeding before it is sent to an early grave, or before the foundation is laid for a life of long suffering.

The mother's milk during the first month of the infant's life is richer in cream and sugar than in the later months. Therefore, such foods should be given as yield these elements to the milk. The mother herself, having expended a large amount of energy, demands a food rich in lime, fats, sugar and organic salts. The physiological enlargement of the abdominal organs must be treated with great care.

As a rule, no food is required during the first few hours except water. In exceptional cases where the mother is greatly exhausted, a glass of fresh milk or some warm stimulating food may be served.

The food during the first four days should consist largely of strained water gruels, prepared from steel cut oats and bran, or from rolled wheat or cream of wheat. Stewed prunes, toast, soft boiled eggs or other egg foods should be served once per day at the noon meal. Fresh milk is best given during the afternoon or evening or at 10 a. m. A slice of toast may be served with it. If the milk of the mother is scanty, serve water gruels several times per day. If the mother has too much milk, fluid foods should be restricted and a dry diet adopted. After the fourth day add rice, baked potatoes, fish and a small amount of meat to the diet. Avoid drinking milk or other liquid food, except a little water with the dinner. If milk or broth is desired, take it at the beginning of the meal. Avoid artificially prepared desserts at the end of the meal. Use oranges or grapes as desserts, or a little black coffee and toast.

Suggestive Menus for Breakfast during the First Week.

1. Three-fourths of a pint of barley gruel with or without cream, 2 crusts.

2. Eight ounces of cornmeal mush with egg and dried fruit. 4 ounces of hot cream. 2 crusts.

3. Stewed or soaked French prunes with whole wheat bread and butter. 10 ounces of bran tea or Kneipp's malt coffee with cream and milk-sugar.

4. One pint of bran and oatmeal gruel with butter, soaked French prunes, 2 black crusts.

5. Eight ounces of fresh raw or boiled milk with 3 ounces of barley water and a slice of toast.

6. Rice flour with egg and currants and hot cream and 2 crusts.

7. Rylax with hot cream, soaked prunes or raisins.

8. Bread soup with hot cream, soaked prunes or raisins.

9. Rice with hot cream and soaked prunes or raisins.

10. Malt coffee with toast and butter. Soft boiled eggs.

Menus for Dinner during the First Week.

1. Cream toast, light rice, or cornmeal with egg.

2. Soup of asparagus or green peas with toast.

3. Soft boiled eggs with toast, baked apple.

4. Cream of bean or lentil soup, bread and butter.

5. Broth with egg. Fish with baked potatoes, apple sauce with toast and butter.

6. Spinach with boiled eggs and bacon. Bread and butter.

7. Barley soup with crackers. Lamb chop with sprouts and yolk of one egg.

8. Chicken soup with rice. Chicken with string beans, stewed prunes.

Menus for Supper during the First Week.

1. Strained barley or oatmeal gruel with cream.

2. Cream of wheat or farina with cream.

3. Sago or tapioca with cream and zwieback.

4. Malt coffee or bran tea with cream and zwieback.

5. Boiled custard with fruit sauce and zwieback.

6. Cream of pea or lentil soup with celery.

7. Cream toast or shredded wheat with cream.

8. Cream of tomato soup with zwieback and celery.

If food is required between meals, give plain milk, bran tea, or malt coffee with cream and zwieback.

CHAPTER III.

CARE AND FEEDING OF CHILDREN.

THE NURSERY.

The nursery should be well lighted and ventilated, and if possible be located on the southeast side of the house. The windows should be broad and not too low. The wall-paper should be a cheerful green or blue with designs of lighter shades, and the rug of brown or tan color. Avoid all bric-a-brac, useless curtains, and other hangings which tend to darken the room, gather dust and absorb odors. The furniture should be adapted to the size and needs of the child. During the first four years the meals are best served in the nursery, or at a time when the parents are not at the table. It avoids much unnecessary excitement and temptation, and if the child is under the constant care of the mother it will give her relief during these hours. All children between the ages of four and ten should have their evening meals served alone, or else be so well trained as not to expect to eat the same food as the adults.

PREPARATION OF FOOD FOR INFANTS.

MILK.

In preparing modified milk or other fluid foods for infants, where top milk is used, it is very important that the milk contain the same amount of cream for each feeding, or else digestive disturbance and irregularity of bowel movements will occur.

If milk, fresh from the cow and run through the cooler, is put into bottles or jars and kept at the same temperature, the same percentage of top-milk will be obtained daily. Five hours is generally sufficient to obtain the desired quality. The best means of removing it is by a spoon or siphon.

If raw milk is used without being sterilized, the desired amount for each meal should be put into sterile bottles directly after delivery and lightly covered by cheese-cloth or cotton and kept on ice or other cold place. In this way each bottle will contain the same amount of cream.

PREPARATION OF MODIFIED MILK (RAW).

Put the desired amount of top-milk into as many bottles as are required for feeding during twelve hours. Prepare a solution of water and milk-sugar by dissolving the sugar with the desired amount of boiling water. Let cool and keep on ice for twenty-four hours. At each feeding, add the prescribed amount of water to the milk, shake and heat in a water bath. Add a tablespoonful of lime water or barley water. If the milk cannot be obtained fresh twice per day, it is safer to scald the milk which is used during the night.

All milk, even if handled carefully, contains a large number of germs. When one is not certain that the cows from which the milk is obtained are healthy, the milk should be sterilized. During the summer it is safer to scald or sterilize all milk for infants.

SCALDED MILK (MODIFIED).

Dissolve the desired amount of milk sugar in boiling water in a clean saucepan, add the milk, stir over a quick fire until it foams, which means that the milk is heated to about 200° F. The most harmful germs are generally destroyed by this process. Pour the milk into a clean pitcher and set the latter in a pan of cold water. Stir the milk until cold and change the water several times. The stirring makes the milk homogeneous and easier to digest. If any scum has formed on top, through careless preparation, the milk should be strained through a cheese-cloth before putting it into bottles. Put a cotton stopper in the bottles and set on ice. Milk prepared in this manner is generally suitable for the average healthy infant.

STERILIZED MILK (MODIFIED).

Dissolve the milk sugar as directed for scalding milk. Add the desired amount of milk, top-milk or cream, and prepare as directed in the chapter under "Sterilized Milk."

PASTEURIZED MILK.

Put the desired amount of milk or milk and cream mixture into sterile bottles, put on a stopper and set in a water bath; heat the water to 155° or 170° F., and keep it at that temperature for 30 minutes. Then remove the bottles at once, cool them in a pan of cold water and set on ice.

BOILED MILK.

Put the desired amount of milk, or modified milk, into a clean saucepan, stir over a hot fire and boil from 2 to 5 minutes. Then cool by setting the pitcher into a pan of cold water; stir until cold and set on ice. This is excellent for infants as well as for the sick who suffer with diarrhœa. The milk may be modified with arrow-root, barley water or rice flour gruel, which has been boiled with salt and water and a stick of cinnamon. Milk-sugar should be boiled with the gruels, two level tablespoonsful to a pint of boiling water.

ESKAY'S FOOD.

Prepare as directed on label or use like the foregoing in place of arrow-root.

DR. BIEDERT'S MILK AND CREAM MIXTURES.

1st month--4 ounces of cream, no milk, 12 ounces of water, 3 tablespoonsful of milk-sugar.

2nd month--4 ounces of cream, 2 ounces of milk, 12 ounces of water, 3 tablespoonsful of milk-sugar.

3rd month--4 ounces of cream, 4 ounces of milk, 12 ounces of water, 3 tablespoonsful of milk-sugar.

4th month--4 ounces of cream, 8 ounces of milk, 12 ounces of water, 3 tablespoonsful of milk-sugar.

5th month--4 ounces of cream, 12 ounces of milk, 12 ounces of water, 3 tablespoonsful of milk-sugar.

6th month--no cream, 16 ounces of milk, 8 ounces of water, 2 tablespoonsful of milk-sugar.

DIRECTION FOR PREPARATION.

Put the desired amount into a saucepan and scald, as directed under "Scalding Milk," or put into bottles and pasteurize or sterilize.

If the bowels of an infant are too loose, lessen the amount of cream, and add more milk in place of it. If the child is constipated, add more cream and use less milk. If it disagrees, add oatmeal, rice, rye, barley or legume water. For preparation, see "Teas," in Chapter on Fluids. Use one-half the amount of water, as directed above, add the other half in the form of tea. Prepare the tea separately, and add the desired amount to each bottle when heating. Camomile tea is often beneficial for a few days. It can be added in the same manner as other teas, or given without sugar or cream, when colic appears. The latter way is preferable to too much hot water, when the infant is suffering with colic.

ORIGINAL RECIPE FOR DELICATE INFANTS.

=Mixture of Cream, Milk, Water, Milk-Sugar, Rice Flour and Pearl Barley--(Condensed Milk, if Required).=

Dissolve two tablespoonsful of rice flour in a little cold water, stir into twelve ounces of boiling water, add one-fourth of a teaspoonful of salt, and boil for 20 minutes. Pour into a pitcher and keep on ice for 24 hours. Use.

Soak one-fourth of a cup of pearl barley for several hours, or over night. Boil with a quart of water and a little salt for one and one-half hours. This will make about ten ounces of barley water when strained. Keep the barley water and rice flour gruel in separate pitchers. If an additional amount of condensed milk is found more agreeable, add one tablespoonful of Eagle Brand Condensed Milk to the barley water in place of milk-sugar, before straining it.

Prepare the milk as follows: Dissolve two tablespoonsful of milk-sugar in ten ounces of boiling water, add four ounces of cream and four of milk, stir the milk and water in a saucepan over a quick fire until it foams, and pour into eight clean warm bottles which have been set in a kettle of hot water. Put cotton stoppers in the bottles, and pour enough water into the kettle so that it is even with the

milk in the bottles. Let it stand on a hot stove and keep the water at the temperature of 170° to 200° F. for half an hour. Then set the kettle on the floor and when the water is cold, remove the bottles and put them on ice. At each feeding, add one ounce of the prepared barley water, and a tablespoonful of rice flour gruel to the bottle; shake well, and heat by setting the bottle in warm water. This will make about 28 ounces of food for 24 hours, or 3½■ ounces per bottle for eight feedings during 24 hours. This quantity is required for the average child during the second month. Ten feedings are generally required during the first month.

During the first week of the infant's life use 5 ounces of cream, 5 ounces of water, 8 ounces of rice and barley water, and no milk. This makes 18 ounces of food for 24 hours, or about 2½■ ounces per bottle for ten feedings during 24 hours. If a larger quantity is desired during the first month, add 2½■ ounces of water and 2 ounces of milk to the cream mixture, then gradually change to the proportion given in above formulas. As the child grows older, increase the amount of milk to 12 or 15 ounces until the age of ten months. After that age 42 ounces of food is required during 24 hours, and the child is generally able to begin with semi-liquid or solid food. The rice flour alone, or any other cereal gruel or water may be used in place of barley and rice, but the latter is found especially beneficial for delicate infants with whom plain modified milk disagrees.

It is often desirable to change the cereal occasionally. Use oats, rye and barley during the winter and the lighter cereals during the summer. Other suitable foods for the infant are bran or rye tea with or without milk or cream, and broths from veal or mutton with the yolk of an egg (10 ounces of broth to one yolk). Strained steel cut oats and bran are excellent for a while where milk or cream are found to disagree.

During the period from the tenth to the fifteenth month the healthy infant requires an addition of solid food. The appearance of the teeth indicate when it should begin. The change must be made gradually from liquid to semi-liquid and finally to solid food. The middle of the day is the best time to begin with the change of food. Lean meat is not a necessary food for children, therefore it is mentioned only occasionally for those who think their children must have it. On, the other hand, legumes are a very important food for young children, and their use should begin during the second year. They are easily digested if prepared in the form of soups and purees, and combined as directed in the different menus. They should not be given at night.

SECOND PERIOD: FROM THE TENTH TO THE FIFTEENTH MONTH.

During this period the infant should sleep three times during the day: From 8 to 10 a. m., from 1 to 3 p. m., and from 6 to 8 p. m. If the child should not awaken for the last feeding and sleep until 4 or 5 a. m., give the feeding at 4 a. m. instead of between 8 and 10 p. m. If it should be in the habit of awakening during the middle of the night, change the habit by awakening it at 10 p. m. Reduce the quantity of milk given at this time gradually to 3 or 4 ounces, and finally replace it by water.

If the child should sleep from 6 p. m. to 6 a. m. without awakening, it does not require the extra feeding; four meals are sufficient.

Some children require five meals until they are two years old. With intelligent study and simple regularity the mother can make her work very easy. She can transform delicate children into strong, vigorous ones, avoid disease and many unnecessary doctor bills.

Do not begin the habit of stuffing the child with bread and crackers every time it cries. If it desires something to bite upon give it a teething-ring. Give the child as many meals as it requires, but avoid feeding between meals. Give it cold or slightly warmed water between meals. Do not force the child to drink water. If fed correctly it will call for the necessary amount of water. If a child is too heavy in weight for its age, reduce the amount of milk. Give it strained oatmeal, bran and barley gruels, with butter or cream. Some children require three pints of milk during 24 hours, between the tenth and fifteenth months, while others are satisfied with one and one-half pints of milk and four to six ounces of cream. If broths or other nutritious liquids are substituted for milk, the amount of milk required for the day would be less than that mentioned above. Never force the child to eat food; when it awakens in the morning it generally requires food immediately. When it awakens for its dinner, let it play for a while until it calls for food. If it refuses food, leave out a meal once in a while, or reduce the number of meals to suit the appetite.

MENUS FOR THE SECOND PERIOD: FROM THE TENTH TO THE FIFTEENTH MONTH.

I.

Between 6 and 8 a. m.--Plain or diluted milk.

Between 10 and 12 a. m.--Flaked rice gruel with sterilized cream.

Between 2 and 3 p. m.--Ten to twelve ounces of plain or diluted milk.

Between 5 and 6 p. m.--One cup of broth with egg, one-half slice of toast with butter.

Between 8 and 10 p. m.--Ten to twelve ounces of plain or diluted milk.

II.

Between 6 and 8 a. m.--Gruel of steel cut oats with one-half part of sterilized cream.

Between 10 and 12 a. m.--Bread gruel with butter or cream.

Between 2 and 3 p. m.--Ten to twelve ounces of plain or diluted milk.

Between 5 and 6 p. m.--Sago gruel with zwieback and butter (prepared with unfermented beer).

Between 8 and 10 p. m.--Ten to twelve ounces of plain or diluted milk.

III.

Between 6 and 8 a. m.--Strained barley gruel with sterilized milk.

Between 10 and 12 a. m.--Prune toast with beachnut bacon. Between 2 and 3 p. m.--Plain or diluted milk.

Between 5 and 6 p. m.--Sago gruel with cream and crackers or zwieback.

Between 8 and 10 p. m.--Plain or diluted milk.

ADDITIONAL MENUS SUITABLE BETWEEN 10 AND 12 A. M.

1. Cream toast. 2. Barley and bread gruel. 3. Bran and oatmeal gruel. 4. Cream of tomato soup with crackers. 5. Toast with creamed chipped beef. 6. Baked oats with prune jam and beachnut bacon. 7. Baked cornmeal with egg and cranberry sauce. 8. Light egg toast. 9. Soft boiled egg and toast.

MENUS FOR THE THIRD PERIOD: FROM THE FIFTEENTH TO THE TWENTY-FOURTH MONTH.

I.

Between 7 and 8 a. m.--Strained steel cut oats with sterilized cream.

Between 11 and 12 a. m.--Ten to twelve ounces of plain or diluted milk.

Between 1:30 and 2:3O p. m.--Light rice with sterilized cream and crackers.

Between 5 and 6 p. m.--A cup of unfermented beer and toast with butter.

Between 8 and 9 p. m.--Ten to twelve ounces of plain or sterilized milk.

II.

Between 7 and 8 a. m.--Cream of wheat with sterilized cream.

Between 11 and 12 a. m.--Broth with egg, and toast with butter.

Between 1:30 and 2:30 p. m.--Juice of one-half an orange, black bread pudding, celery.

Between 5 and 6 p. m.--A cup of plain milk and two graham crackers.

Between 8 and 9 p. m.--Ten to twelve ounces of milk, plain or diluted, with rice or barley water.

III.

Between 7 and 8 a. m.--Cornmeal mush with cream.

Between 11 and 12 a. m.--A cup of unfermented beer with zwieback and butter.

Between 1:30 and 2:30 p. m.--Three to five strawberries, one to one and one-half egg with toast and cereal.

Between 5 and 6 p. m.--A cup of plain milk with zwieback and calves' foot jelly.

Between 8 and 9 p. m.--Ten to twelve ounces of milk.

IV.

Between 7 and 8 a. m.--Bread soup with cream or butter.

Between 11 and 12 a. m.--Plain milk with unsweetened graham crackers.

Between 1:30 and 2:30 p. m.--Strained bean soup with buttered toast.

Between 5 and 6 p. m.--A cup of milk with crackers, or cream of tomato soup.

Between 8 and 9 p. m.--Plain or diluted milk per bottle.

V.

Between 7 and 8 a. m.--Rylax with sterilized cream.

Between 10 and 12 a. m.--Plain milk and crackers.

Between 1:30 and 2:30 p. m.--One-third to one-half cup of raspberries, eggs with toast and butter.

Between 5 and 6 p. m.--Plain milk and crackers.

Between 8 and 9 p. m.--Plain or diluted milk.

VI.

Between 7 and 8 a. m.--Turoena with cream and black crusts.

Between 10 and 12 a. m.--Plain milk and crackers.

Between 1:30 and 2:30 p. m.--Pea puree on toast, celery.

Between 5 and 6 p. m.--Plain milk and crackers, or tomato soup with cream.

Between 8 and 9 p. m.--Plain or diluted milk.

VII.

Between 7 and 8 a. m.--Black cream toast or shredded wheat with cream. Between 10 and 12 a. m.--Plain milk or broth and crackers.

Bet'n 1:30 and 2:30 p. m.--Light rice pudding, three ounces of strained tomato juice.

Between 5 and 6 p. m.--Unfermented beer, stale bread and butter.

Between 8 and 9 p. m.--Plain or diluted milk.

VIII.

Between 7 and 8 a. m.--Rice with sterilized cream or butter and egg.

Between 10 and 12 a. m.--Plain milk with crackers.

Bet'n 1:30 and 2:30 p. m.--Two leaves of lettuce, one carrot, one tablespoon of bean puree on toast.

Between 5 and 6 p. m.--Cream of tomato soup with zwieback.

Between 8 and 9 p. m.--Plain or diluted milk.

ADDITIONAL MENUS FOR DINNER DURING OR AFTER THE THIRD PERIOD:

1. One-half orange, one or two ounces of boiled fish, one-half of an apple, one to two tablespoons of raw rylax.
2. One-half of an apple, one or two eggs, one to two tablespoons of raw rylax.
3. Cereal salad with carrots and fish.
4. Legume soup, butter and bread, raw carrots.
5. Well boiled macaroni, one to two tablespoons of cold grated cheese.
6. Light rice with cold grated Swiss cheese.
7. Cereal salad with apple and eggs.
8. Lettuce, baked potatoes, beachnut bacon and one egg.
9. Mashed carrots, two tablespoons of young green peas, bacon, toast with butter.
10. String beans with stale bread and butter, bacon and egg.
11. Finely chopped spinach, bacon, egg, stale bread, butter.
12. Three to five cherries, light omelet.
13. Cereal salad with chopped apples, two to three tablespoons of cottage cheese.
14. Baked oats with prunes or cranberry sauce and bacon.
15. Whole wheat with sterilized cream and celery.
16. Peach and cereal salad, beachnut bacon and one egg.

ADDITIONAL MENUS FOR SUPPER DURING OR AFTER THE THIRD PERIOD.

1. Rice with egg and clear soup.
2. Gruels prepared with milk, cream, bran, bread, egg or soup stock.
3. Plain milk with stale bread or zwieback.
4. Huckleberry or cherry soup with whites of egg, and zwieback with butter.
5. Cream of tomato or thin pea soup with celery or zwieback.
6. Vegetable soups of asparagus or of strained canned corn.
7. Rice flour with egg, currants and cream.
8. Chocolate cornstarch with cream and black crusts.
9. Apple-sago or cornstarch with egg and cream, and zwieback.
10. Calves' foot jelly with tomato, zwieback with milk.
11. Cook's flaked rice gruel with cream and cracker.
12. Boiled custard with fruit sauce and black crusts.
13. Potato soup with cream and black crusts.
14. Clam broth with cream and zwieback, or with Grant's crackers.
15. Melon with lemon, finely chopped chipped beef on toast.

16. Poached eggs on toast.

17. Fruit or vegetable soups with cream or egg.

18. Milk soups or milk gruels with black crusts.

19. Beer soups with egg or cream and zwieback.

20. Fruit toast with rich milk.

21. Broth with egg triscuit or zwieback with butter.

22. Red fruit pudding with cream and zwieback.

23. Baked apples in gelatine with cream and zwieback, or with Grant's crackers.

24. Thin legume soups with cream or butter.

Some children are able to digest all the above mentioned foods before they are three years old; others are not. Certain foods are agreeable to certain temperaments and disagreeable to others. No exact rules can be laid down. Reason and judgment must guide the mother in the selection of foods as well as in other details.

GENERAL SUGGESTIONS.

Unleavened crackers, raw cereal flakes and stale sundried pompernickle or whole wheat bread are the best dry cereal foods for children. If cooked cereals are served, crackers and wheat bread are not necessary at the same meal. A few black crusts or raw vegetables combine better with cooked cereals.

Soda crackers or thoroughly toasted unsweetened zwieback may be given occasionally for the evening meal in combination with sago, fruit gruels or jellies.

Do not feed a child fresh breads and cakes which contain soda, yeast or baking powder.

A child over three years of age may eat occasionally unleavened fruit cake, pancakes and fruit tarts which are prepared with eggs.

Never allow a child to eat ice-cream at the end of a heavy meal. Serve it at the beginning of the meal or during the afternoon.

Four meals per day is generally the best plan for a child, as long as it sleeps during the day-time. If it is fed on plain, non-stimulating food it generally takes a nap up to the age of 4 or 5 years, and sometimes later, while a child that is fed upon meats, beef juices, meat soups and excess of starch and sweets often refuses to sleep during the day-time at the age of two.

Meats and sweets or excess of any kind of food irritate the sensitive nerves and produce restlessness and sleeplessness in the child, and much unnecessary work and sleepless nights of the mother. Any normal healthy child can be trained in the matter of eating, sleeping, evacuation of the bowels and in other details like clock-work, if the proper conditions are furnished.

At the end of the third year the child may begin to eat well baked beans, peas or lentils several times per week during the winter. They should be given at the noon meal, in combination with raw or finely mashed carrots, or with a tomato salad and raw greens. No more than two tablespoonsful should be given at one meal. Systematic training in chewing is absolutely necessary for a good digestion. If legume foods should cause gas on the stomach, they must be strained and given in the form of soups or purees. Walnuts may also be used. Give two or three at the end of the meal. For combination, see "Menus for Adults." The amount of food should be increased gradually. At the age of 12 or 14, a child may eat nearly as much as an adult.

Moving picture shows, car and automobile rides require more nervous energy than strolling in the woods. Instead of supplying the system with plain nutritious foods, such as milk, nut preparations or wholesome sandwiches on such occasions, the excitable nerves are generally more stimulated by artificial foods: candies, cookies, sweet graham crackers, gums or by exhilarating (pure fruit?) lemonade or germ laden ice-cream.

Artificial lights and amusements of this kind, associated with nerve starvation, cause much eye trouble in children. Think of the amount of nervous and muscular energy expended during those hours in comparison with walks or other kind of natural amusements!

If the chewing of gum, candies and other fancies is permissible in cars and theatres, why not wholesome foods? A small satchel will hold an aluminum can with milk, a few napkins and other wholesome food products. If confectionery and ice-cream parlors and cheap restaurants were supplanted by hygienic food laboratories and pure water stands, saloons would soon be on the decrease.

WRONG MANAGEMENT.

The dyspeptic business men and women who have no time or power to digest a meal during the middle of the day are generally the victims of early habits acquired when at school.

We cannot try to change the fixed and immovable laws of nature without paying the penalty. Nature will keep us in order and control our machine, if we fulfill her laws. The sun is in sympathy with our digestive forces; therefore we should rest from labor during the middle of the day, so that the muscles of the stomach may be able to give all the circular movements, and others that are necessary, to thoroughly mix the food with the stomach juices for rapid digestion. Solid foods of the protein class, can only undergo perfect digestion if eaten in the middle of the day. They require many hours to digest, and in this way they are ready for oxidation and assimilation at night, when the air is cool. The body can rest, and the lungs and heart can work better when the stomach is emptied. While on the other hand, if the heaviest meal is taken at night, it is either too rapidly digested by physical force, or it is left half digested in the stomach over night. It congests the liver and kidneys, produces fermentation, robs lungs, heart and skin of their nerve force, and creates an abnormal appetite the next morning for an excess of energy-giving food, or it produces a languid feeling and loss of appetite. Such a system of living is responsible for the large number of acute and chronic diseases and consumption, while those who seemingly keep in good health under such conditions do surely shorten their life.

Perfect health and comfort are worth more than earthly possessions, and those who strive earnestly to possess and retain health will find a way to change their system of living. There is strength in union, and if a sufficient number of sensible people demanded different hours for school-children and for people who work indoors, it would be possible to obtain them.

During hot summer days or in the tropics the noon hour is not always the best for the heaviest meal of the day, but neither should it be spent for work. Two meals per day is the best plan on hot days. An individual who is always keyed up to the highest point during the middle of the day, and expends the best of his energy for work, cannot expect anything else but bankruptcy.

For people who desire two meals per day, the best time for breakfast is between nine and ten in the morning, and for dinner between three and four in the afternoon.

If three meals are taken, hard muscular workers, or those who are employed out of doors, do well to substitute for their dinner a substantial cold or warm lunch. If through lack of time and convenience a child cannot have its dinner before 4 p. m., it is better off without it. Remember that a cooked dinner consisting of meat, potatoes and vegetables is not at all necessary for the child's welfare and development, and cooked vegetables should never be forced upon it if it prefers to eat them raw. Healthy children have keen instinct, and unless their appetite has become perverted by sweets and other artificial, unnatural foods, they are more likely to select the right kind of food than the average adult.

This book gives a large number of menus, consisting of raw foods, which can be quickly prepared when the child comes home from school. Nuts, fruits and raw vegetables form an ideal diet for the summer. Baked beans, peas and lentils warmed over, or jellied fish, egg foods, cheese or steamed puddings in combination with a warm soup or raw apples form a perfect meal during cold, winter days. If the dinner is eaten between the hours of 3:30 p. m. and 4:00 p. m., no more food is necessary. If it is served at noon, give milk or soup between 5 and 6 p. m. Children should take at least one-half an hour's rest before eating, when coming home from school. The better way would be to allow children two hours for their noon meal or curtail the hours of school work from 9 a. m. to 1 or 2 p. m. Such is the custom in many European countries, and there is no reason why it could not be practiced here.

Children between the ages of eight and fourteen should retire between 7 and 8 p. m. If they get sufficient sleep and are properly fed, children's diseases need not be feared.

CHAPTER IV.

LIGHT LUNCHES AND SANDWICHES.

LIGHT LUNCHES.

Menus for children, students at college and men and women who have to toil indoors. They can be had in almost any good cafeteria, or be prepared quickly on a gas or alcohol stove:

1. Corn and tomato soup with black crusts.

2. Cream of tomato soup with zwieback.

3. Green pea soup with zwieback and celery.

4. Broth with egg. Sandwiches with bologna or cold meat.

5. Buttermilk with graham toast.

6. Fresh milk with tomato toast.

7. Fruit gruel with white of eggs, and bread or toast with butter.

8. Strained canned tomato juice with whole wheat toast and butter.

9. Orange juice, green leaf vegetable with fried bacon and soft boiled eggs.

10. Pineapple salad with whipped cream and toast.

11. Apple or banana salad with lettuce and French or mayonnaise dressing, orange juice.

12. Potato salad with lettuce and soft boiled eggs.

13. Strawberries, raspberries or blackberries with rich fresh milk and zwieback or toast, butter and eggs.

14. Cherries and egg food.

15. Cream cheese with apples and sandwiches.

16. Fig or date butter with ryenuts and rich fresh milk or sandwiches.

17. Raw huckleberries (one-half to one cupful) with butter and stale bread.

18. Lettuce with two or three bananas and one-half to one glass of strained cranberry juice.

19. Apple salad with lettuce and almond cream or whole almonds.

20. Apples, raisins and six to twelve nuts.

21. Gelatine of fruit, or bread and bran with cream and toast.

22. Clam broth or cream soup with toast and raw celery.

23. Musk melon with lemon and berries.

24. Baked apples in gelatine with fish salad.

25. Ambrosia or apple sauce with whites of eggs and toast.

LUNCHES FOR THEATRES.

Cocoanut wafers, macaroons prepared with almond paste, Hershy's chocolate, white figs and rye nuts, sandwiches with fruit butter or ground dried fruits and nuts.

AFTERNOON DRINKS AND DAINTIES.

Postum, weak tea, bran tea with cream, unfermented apple juice, fresh apple cider.

FOODS--Fruit cakes, tarts, cream puffs, cream rolls, zwieback, Huntly and Palmer biscuits, nabiscos, sandtarts, ice-creams, fruit gelatines.

SANDWICHES.

The sandwich is an important part of the bill of fare. It is not necessary to eat a cooked dinner in order to have a square meal, but for those who work indoors and are unable to take walking exercises before or after their noon meal, it is important to take some warm fluid or semi-fluid food in the form of broth, milk or soup as an entree or with their meal. With the convenience of modern inventions of gas, alcohol and electric stoves, or patented bottles which keep food warm for hours, this is easily obtained.

An endless variety of nutritious lunches can be prepared from left-over or fresh vegetables, meats, fish, eggs and cheese, or from raw cereals, nuts, fruits and greens. The bread used for sandwiches should always be stale or sun dried and be kept in a dry place in a tin box with good ventilation.

MENUS FOR LUNCH OR SUBSTITUTES FOR DINNER.

Grated Cheese with Apples and Buttered Bread.

1. Grate two to four ounces of Swiss or American cheese and carry in a glass jar or paper bag. At lunch-time peel one or two apples, cut them up in small pieces and mix with grated cheese. Eat with buttered bread.

Meat Sandwiches with Olives and Mayonnaise Dressing.

2. Prepare a salad from left-over meat, mixing with olives and dressing, or slice the meat and put between layers of bread, and mix the olives with mayonnaise dressing.

Scrambled Eggs on Sandwiches, and Cherries.

3. Eat the cherries at the beginning or at the end of the meal; lettuce is a good addition.

Ground Nuts with Apples and Raisins.

4. Grind six to twelve nuts in the morning and keep in a jar or paper bag. At lunch-time cut one apple into small pieces, add twelve raisins and the ground nuts. Eat with or without bread and butter. It is best to use only one kind of nuts at a time. Celery is also a good addition.

Nut and Date Sandwiches.

5. Remove the stones from one-half dozen or more dates, cut the dates into small pieces and mix with one-third or one-half the amount of chopped or ground walnuts. Spread on buttered bread or eat the bread with it. Apples combine well with it, either as a substitute for bread or in combination with it. In place of whole nuts, nut-butter may be used; the latter should always be diluted with an equal amount of water.

Figs, raisins or dried currants can be used in the same way as dates. Lettuce and celery are good additions.

Tomatoes with Popcorn, Bread and Butter.

6. Prepare a salad with tomato and lettuce, or strain some canned tomatoes. The latter can be carried conveniently in a small Mason jar. Always open the jar a little, if left to stand in a store or office, so the air can circulate through it. Take one cup of tomato juice in combination with one-half pint or more of warm, buttered popcorn. Eat bread and butter with it, if desired.

Egg Sandwiches with Watercress and Olives.

8. Slice some hard boiled eggs and lay on buttered bread. Mix some olives and watercress with mayonnaise dressing, and serve with the bread. Egg sandwiches combine well with sliced or potted ham, or with anchovy or herring--butter, or with apples.

Cottage or Cream Cheese Sandwiches.

9. Spread thin slices of rye or black bread with cheese. Combine with apples or olives, with or without lettuce and mayonnaise dressing.

Cabbage Salad with Bread, Butter and Bologna.

10. Prepare the salad in the morning, mix with mayonnaise dressing and carry in a glass or jar. Prepare the bread with butter and thin slices of bologna or ham. Eat the cabbage salad as an entree or with the sandwiches. Hard boiled eggs are a good addition.

Potato Salad with Black Bread and Butter and Bologna.

11. Serve the salad as an entree. Prepare thin slices of pompernickle with butter and bologna or ham, and combine with hard boiled eggs. Nuts may be substituted for eggs.

Peanut and Olive Sandwiches.

12. Remove the stones and cut the olives into small pieces, mix with diluted peanut butter, and season with lemon.

Spread on rye bread.

Egg Sandwiches with Ham or Chipped Beef.

13. Chop some ham or beef very fine. Prepare some eggs for scrambling, mix with the meat and finish like scrambled eggs. When cold spread on sandwiches.

Raw Beef Sandwiches.

14. Wash some freshly cut round-steak, dry and scrape. Spread on buttered triscuit or soda cracker. Combine with lettuce and French dressing. Serve at once.

Sandwiches with Sausage.

15. Spread thin slices of rye or black bread with butter. Cover with liver sausage, blood sausage or metwurst. Goose fat or leaf lard can be substituted for the butter or be omitted. Combine with tart apples. Onions and lettuce is also a good addition.

Meat Sandwiches with Tomatoes and Cucumbers.

16. Cut some cold boiled or roasted lean meat into thin slices and lay on buttered bread. Eat cucumbers with it.

CHAPTER V.

FOOD COMBINATIONS AND MENUS.

DO NOT MIX.

Meat and Cheese.

Cherries and Milk.

Fancy Summer Fruits and Onions.

Fancy Summer Fruits and Cucumber.

Nuts and Excess of Starchy Food.

Potatoes and Tomatoes.

Potatoes and Tart Fruits.

Potatoes and Fresh Yeast Bread.

Potatoes and White Bread.

Potatoes and Underground Vegetables.

Cooked Greens and Raw Greens.

Meat and Dates or Figs.

Pork and Sago.

Cucumber and Sago.

Strawberries and Tomatoes.

Strawberries and Beans.

Bananas and Corn.

Fat Pork and Cucumbers.

Pork and Sweet Fruits.

Pork and Fancy Fruits.

Pork and Corn.

Meat and Fish.

Raw Fruits and Cooked Vegetables.

Milk and Cooked Vegetables.

Milk and Meat.

Fresh Raw Fruits and Cooked Cereals.

Cooked Vegetables and Nuts.

Cheese and Nuts.

Boiled Eggs and Nuts.

Boiled Eggs and Canned Corn.

Boiled Eggs and Bananas.

Boiled Eggs and Fresh Pork.

Boiled Eggs and Cheese.

Bananas and Pork.

Bananas and Cucumbers.

Skim-milk and Fruit.

Cheese and Bananas.

Beans and Bananas.

GOOD COMBINATIONS.

Raw Fruits and Raw Cereals.

Raw Fruits and Raw Cereals and Nuts.

Raw Fruits and Raw Greens and Nuts.

Raw Cereals and Nuts.

Raw Cereals and Raw Milk.

Raw Cereals and Raw Vegetables.

Boiled Cereals and Boiled Milk.

Boiled Cereals and Boiled Cream.

Raw Greens and Meats or Eggs.

Boiled Greens and Meats or Eggs.

Fats and Acids.

Meats and Acids.

Cheese and Apples.

Cheese and Rye.

Eggs and Salted Meat.

Eggs and Acid Fruits.

Eggs and Greens.

Nuts and Apples.

Nuts and Bananas.

Almonds and Rice.

Nuts and Raisins.

Nuts and Dried Currants.

The harmony and disharmony between the different foods as mentioned above are only stated in a general way. Certain combinations are absolutely harmful to every individual, others are either harmful to certain temperaments, or, to mix them would mean a waste in the animal economy of the body.

REMARKS.

Use only one rich protein food at any meal.

Exceptions: A few nuts which are rich in fat may be eaten at the end of a meal where lean meat is served.

Milk and milk soups may be taken at the beginning of a meal where meat is served, but they should never be mixed with the meat dish or used at the end of a meal where meat is served.

CHAPTER VI.

LAXATIVE FOODS.

Fruit juices, plums, tomatoes, apples, pears, grapes, figs, fruit-soups, fruit-gruels, raisins, gelatines, corn, oats, spinach, oranges, carrots, parsnips, bran, oil, butter, cream, olives, yolks of eggs, pecans, walnuts, Brazil nuts, cucumbers, onions, greens.

CONSTIPATING FOODS.

Skim-milk, liquid foods, fine flour bread, potatoes, tapioca, white of eggs, gluten, mush, lean meat and cheese made from skim-milk.

MENUS.

A menu which is one-sided or combined wrongly, that is, one in which either protein, carbohydrates, minerals or fluids are provided in excess, leads to waste of nervous energy as well as to waste of nutritive material. A wrong combination creates an abnormal appetite for too much or too little food.

Each person should learn by experience to select the kinds of food which yield him nourishment and avoid those which disagree.

MENUS FOR BREAKFAST.

People who feel the need of laxative foods during the spring season will find here a number of suitable breakfast menus to choose from:

1. Cooked spinach or yellow dock or mustard greens or dandelion leaves with rye or wheat bread and butter. Eggs or bacon, if desired.

2. Finely mashed boiled beets or turnips or potatoes or carrots or parsnips with plenty of parsley and bacon or ham or cornbeef or chipped dried beef.

3. Rhubarb salad and lettuce with French or mayonnaise dressing. Cornmeal cakes or muffins.

4. Mushroom salad with lettuce and French dressing. Bread and butter.

5. Cooked cereal of rice or wheat or rye with hot cream or butter and cucumbers cut in halves.

6. Sliced bananas and grapefruit with nut dressing or with mayonnaise dressing.

7. Cabbage salad with mayonnaise dressing, hard boiled eggs and bread with butter.

8. Strained canned tomato juice and bananas with lettuce.

9. Fish cakes with steamed potatoes, parsley and butter. Black crusts.

10. Baked or plain boiled cauliflower with cold boiled beef or chipped beef.

11. Boiled cauliflower with tomato sauce and stale bread with butter and grated cheese.

12. Tomato puree with fried parsnip balls, black toast with butter.

13. Radishes, green onions, whole wheat bread and butter.

14. Asparagus salad with ham hash, bread and butter.

15. Cream of potato soup with black toast or raw carrots or celery.

16. Salted mackerel with creamed potatoes, a glass of milk, celery.

17. Apple salad with mayonnaise dressing, a slice of stale bread and a glass of milk.

18. Lettuce with syrup dressing and German pancakes with bacon.

19. French rolls with butter and boiled ham, black malt coffee.

20. Warm apple pie with lettuce and cheese, black malt coffee.

21. Apple salad, corn bread, creamed chipped beef.

22. Shredded wheat with strawberries and milk or cream.

23. Lettuce, baked potatoes, fish salad with mayonnaise dressing.

24. Warmed-over macaroni with tomato puree and cold grated cheese.

25. Macaroni with cream sauce and frankfurter.

26. Codfish cakes with cream rice or apple rice or apple salad.

27. Omelet with lettuce and stewed prunes or syrup dressing.

28. Apple rice with bacon or eggs or fish croquettes, celery.

29. Boiled onions with black bread and butter and bologna or frankfurter.

30. Bread fritters with apple sauce or with lettuce and syrup dressing.

31. Bacon with string beans, bread and butter, stewed prunes.

32. Lettuce with mayonnaise dressing and baked potatoes with creamed beef.

33. Celery with French dressing and fried sweet potatoes with cranberry sauce.

34. Corned beef hash with eggs and triscuits with butter.

35. Lettuce with syrup dressing and buckwheat cakes.

36. Grated carrots with lettuce and unfired bread with butter or nut-cream.

37. Turnip salad with lettuce and unfired bread with butter or nut-cream.

38. Lettuce with French dressing and cornmeal patties with cranberry sauce.

39. Lettuce with French dressing and mashed potatoes with buttermilk and bacon.

40. Apple salad with lettuce and black bread with cheese.

41. Pear salad with cranberries and celery. Unfired bread with butter or nut-cream.

42. Lettuce with French dressing and baked potatoes and eggs.

WHAT SHALL WE DRINK WITH OUR MEALS?

This question is often asked. It depends entirely on the quality and combination of food which is eaten.

A diet consisting of a variety of solids and vegetables with excessive fluids gives the stomach nothing to do; the contents pass at once into the intestines. Such mixtures are ingested instead of being digested; they cannot be fully utilized because the stimuli upon the drainage of the body is lacking.

If dry foods are eaten, such as sandwiches, rice, macaroni, potatoes or dry cereals, without the addition of fruits, vegetables or soups, a small amount of liquid should be taken. Such simple foods do not form a perfect meal, therefore milk or broths are preferable to water. Water is best taken from five to fifteen minutes before the meal or from one to two hours after meals. Black malt coffee is sometimes beneficial if one-half cupful is taken after or with meals. It acts like a tonic, especially if the liver is sluggish.

CHAPTER VI.

MENUS FOR DINNER.

Select menus suitable for the season of the year. In the spring-time use more of eggs, lamb, fish, green peas, spring chicken and egg-foods in the form of pancakes, omelets and puddings. During the summer eat very little meat. Use nuts, fish, eggs and milk foods. As the weather gets colder use more protein foods and carbohydrates. During the winter use a larger amount of dried legumes, nuts and meats, and more fatty foods. Add fruits and vegetables which are in season.

1. Apple salad with lettuce and broiled steak, shredded wheat with butter.

2. Cream of pea soup. Beef or roast pork with potato dumplings, stewed prunes.

3. Broiled chops with young peas and creamed potatoes. Oranges.

4. Tomato salad with lettuce. Veal with mushrooms and rice. Toast and coffee.

5. Cream of tomato soup. Veal chops with peas, stewed prunes.

6. Broth with egg. Spinach, hard eggs, tongue. Grapes or oranges.

7. Sweet potatoes with roast beef, tomato puree, celery. Black toast with coffee.

8. Apple salad with watercress, fish with shredded wheat or bread and butter.

9. Tomato jelly salad. Beef croquettes with tomato sauce and rice, celery.

10. Cream of potato soup. Cold beef with stewed prunes, bread and butter.

11. Bean soup. Cabbage or sprouts with mutton, bread and butter.

12. Raw oysters with lemon and apple salad, whole wheat bread and butter, celery.

13. Boiled veal or mutton with caper sauce and stuffed peppers, celery.

14. Barley soup with cracker. Roast duck with apple stuffing. Grapes or oranges.

15. Macaroni with grated cold cheese and lettuce salad.

16. Rice with grated cold cheese and lettuce salad.

17. Baked fish, boiled potatoes with parsley. Black toast with butter and coffee.

18. Meat soup with bread and butter. Fish salad. Apples or oranges.

19. Clam chowder. Omelet with lettuce and fruit sauce.

20. Pea soup with fried bread. Roast goose with apple sauce.

21. Baked potatoes with kidney stew. Black toast with butter.

22. Potato salad with lettuce and fish, black crusts.

23. Apple salad. Roast chicken with cranberry sauce. Steamed pudding with wine sauce.

24. Rice or barley soup with crackers. Corned beef with cabbage and creamed potatoes.

25. Tomato or apple salad with lettuce. Nuts.

26. Rice with tomato sauce. Nuts.

27. Rice with almond butter. Almonds.

28. Banana salad with rye nuts and lettuce. Nuts.

29. Pineapple salad with lettuce. Nuts.

30. Beef or fruit soup. Macaroni with cream.

31. Apple salad with lettuce, smoked eel with black bread.

32. Corned beef, boiled eggs, potatoes and cabbage.

33. Knorr's pea soup with crackers. Stuffed peppers.

34. Roast pork ribs with apple filling. Oranges, black bread with butter, coffee.

35. Meat croquettes, beets, black bread and butter.

36. Roast chicken with sprouts. Cranberry sauce. Steamed rice pudding.

37. Green peas with dumplings and fried bacon, celery.

38. Tripe with tomato sauce and sprouts, triscuit with butter.

39. Apple salad with blood sausage, bread and butter.

40. Tomato salad with lettuce and fish, bread and butter.

41. Lamb stew with dumplings and green peas.
42. Lettuce salad. Mashed carrots and baked beans with lemon.
43. Pork with sauerkraut and dumplings.
44. Raw carrots and lettuce salad. Pork and lentils.
45. Beefsteak with eggs and potatoes, celery.
46. Pea soup with crackers. Fish with apple salad, celery.
47. Rice with frankfurters. Nuts.
48. Sour roast with potato dumplings and lettuce salad. Stewed prunes.
49. Broth with egg. Apple salad with onions and lettuce, pork chops.
50. Pea soup with toast. Fish with apple rice. Black coffee and crusts.
51. Apple salad with onions and lettuce, liver sausage, black bread.
52. Milk soup. Plum pudding with brandy sauce, celery.
53. Game or pork with sauerkraut and potato dumplings.
54. Tongue with mushroom sauce and baked potatoes. Crusts and coffee.
55. Apple salad with cottage cheese, olives, bread and butter.
56. Boiled beef with string beans, steamed potatoes with white sauce.
57. Baked oatmeal with cranberry sauce and celery.
58. Carrot salad with lettuce. Lima beans with cold pork. Oranges.
59. Fish with potato salad and black crusts. Grapes.
60. Roast mutton with peas and baked potatoes, celery.
61. Bean soup with raw carrots, bread and butter.
62. Barley soup with soda crackers. Swiss cheese and apple salad.
63. Lettuce salad with omelet and stewed prunes or cranberries.
64. Tomato and lettuce salad with pork tenderloin. Oranges, bread and butter.
65. Mashed carrots or beets with lemon, and fat or lean pork. Green grapes.
66. Pea soup with fried bread. Calves' liver with apple salad.
67. Lentil soup with fried bread. Codfish balls with apple sauce.
68. Rice and tomato soup. Boiled beef with horse-radish sauce and cabbage.
69. Milk soup. Bologna, toast and butter.
70. Salad of tomatoes or apple with mayonnaise dressing. Roasted chestnuts.
71. Calves' tongue with mushroom sauce and rice. Crackers with butter.
72. Lettuce salad. Fried eggplant with lemon and beefsteak, string beans.
73. Blue or white cabbage with cold or warm roast pork and baked potatoes or apples.

74. Cabbage rolls with potatoes and white sauce. Bread pudding.

75. Raw sweet corn and tomato salad with French dressing. Bread and butter.

76. Chicken soup with rice. Roast chicken with stuffed apples and cranberry compote, celery.

77. Green pea soup with fried bread. Breaded sour goose with potatoes and apple sauce.

78. Bean soup with cream. Apple dumplings with lemon sauce.

79. Celery and apple salad with mayonnaise dressing. Baked squash with lemon and beefsteak. Grapes.

80. Boiled cabbage with egg dressing. Bread pudding with stewed prunes or fruit sauce.

81. Apple and pineapple salad with whipped cream. Almonds and raisins.

82. Apples and lettuce salad. Buckwheat pancakes with syrup dressing. Nuts.

83. Corn bread, 3 to 6 ounces of canned strained tomato juice. Nuts.

84. Cream of corn soup with black crusts. Nuts.

85. Potato salad with cottage cheese and lettuce.

86. Boiled or steamed bread pudding with tomato sauce or fruit sauce.

87. Lentils with onions. Apple bread pudding, black coffee.

88. Tomato soup with crackers. Warm pop corn or roasted chestnuts.

89. Fresh codfish with horse-radish sauce and boiled potatoes. Black bread with butter.

90. Peanut roast with tomato sauce and celery.

91. Polenta with apricot or cranberry sauce and cheese.

92. Boiled whole wheat with butter or hot cream and cucumbers. Nuts.

93. Baked rolled oats with cranberry sauce, celery.

94. Smoked goose breast with apple salad and black bread.

95. String bean soup. Lima beans or cow beans with bacon. Oranges.

96. Asparagus salad. Spring lamb with caper sauce, bread and butter.

97. Cherry soup. German pancakes with lettuce and syrup dressing.

98. Blackberry soup. Cereal or bread omelet with lettuce and syrup dressing.

99. Milk soup with sago. German pancakes with gooseberry compote.

100. Wine soup with wafers. Fish-pudding with apple sauce.

101. Milk soup with buckwheat groats. Boiled fish with potatoes and currant sauce.

102. Plum soup with zwieback. Steamed or plain bread pudding.

103. Bread soup with apples. Liver pudding with tomato puree.

104. Celery-root salad with crusts. Plum pudding with wine sauce.

105. Bran or bread soup. Apple salad with grated cheese.

106. Milk or huckleberry soup. Unleavened apple pancakes.

107. Clabber milk with cream and grapenuts or stale bread. Nuts if desired.

108. Corn bread with apple salad and lettuce. Nuts.

109. Plain milk rice with currants. Nuts.

110. Oatmeal soup. Ham with kale and fried potatoes.

111. Bread dumplings with stewed prunes or pears, celery.

112. Fried herring with potato salad. Apple-bread pudding.

113. Buttermilk soup with dried fruit. Nuts if desired.

114. Meat cakes with mashed carrots or beets and lettuce salad.

115. Peas with codfish, butter and bread.

116. Vegetable pudding with tomato puree and yellow dock.

117. Bread fritters with lettuce and syrup dressing or stewed prunes.

118. Baked oats or barley with bologna. Nuts if desired.

119. Whole wheat or rice with bologna. Nuts if desired.

120. Plum salad with raw rolled rye or wheat. Walnuts.

121. String bean salad. Fish pudding with tomato puree or apple sauce, celery.

122. Salisbury steak with fried parsnip and lettuce salad.

123. Steamed mashed pumpkin with pickled tongue or corned beef. Black bread with butter.

124. Watercress salad. Pork tenderloin with tomato puree and roasted yellow turnips.

125. Lettuce salad with mayonnaise dressing. Apple or tomato rice with fish or boiled beef.

126. Lettuce or celery salad with mayonnaise dressing. Currant or cherry rice with fried eggs.

127. Asparagus with cream sauce and cold boiled ham and bread.

128. Empire salad. Bread pudding with wine sauce.

129. Kidney soup with rice and egg. Cooked celery-roots and kidney hash on toast.

130. Huckleberry soup with white of egg. Roman meal cakes with lettuce and syrup dressing.

131. Dried cherry soup with zwieback. Steamed or baked rice pudding with lettuce and syrup dressing.

132. Barley soup with prunes. Cold sliced beef with mustard sauce and string beans.

133. Asparagus salad. Broiled chicken with tomato puree, triscuit with butter.

134. Blackberries with one glass of rich milk and bananas. Nuts if desired.

135. Banana and apple salad with lettuce, French or mayonnaise dressing. Nuts.

136. Tomato and cucumber salad with lettuce, French or mayonnaise dressing. Fish with bread and butter.

137. Watercress salad with French dressing. Veal stew with mushrooms and rice.

138. Cabbage salad with mayonnaise dressing. Hard boiled eggs with whole wheat bread and butter.

139. Kidney soup with rice. Brown kidney stew on toast with asparagus.

140. Noodle soup. Boiled brisket with horse-radish sauce, bread and butter.

141. Bread soup with cream. Cold sliced boiled meat with string beans, triscuit with butter.

142. Cherry soup. Corn meal pudding with lemon sauce.

143. String bean soup. Fried left-over pudding with fruit sauce.

144. Blue fish with steamed potatoes, parsley and butter. Apple-bread pudding.

145. Spinach with egg. Fried fish with crust-potatoes and apple sauce. Oranges, toast with butter, black unsweetened coffee.

146. Green pea soup with fried bread. Pickled tongue with fried parsnips and lettuce salad. Green grapes.

147. Fish croquettes with apple salad. Steamed rice pudding with wine sauce. Black unsweetened coffee.

148. Apple snow on leaves of lettuce. Boiled white fish with drawn butter sauce and steamed potatoes, Roman meal cakes with apple sauce. Black unsweetened coffee.

149. Stuffed tomatoes with lettuce. Plum pudding with butter sauce, celery. Black coffee.

150. Lettuce and apple salad with grated Swiss cheese. Pumpkin pie with black coffee.

151. Artichokes with mayonnaise dressing. Broiled steak with baked potatoes and sprouts. Blue or red grapes.

152. Rice and tomato soup. Fillet of beef with mashed potatoes and stewed dried mushrooms. Apple tart with black unsweetened coffee.

153. Creamed onions. Fried chicken with cranberry compote and endive salad. Triscuit with butter, black unsweetened coffee.

154. Tomato and celery salad with mayonnaise dressing. Baked beans with lemon. Boston brown bread, coffee.

155. Apple sago with whites of egg and cream. Baked white fish with lemon and creamed potatoes. Apple pudding, black coffee.

156. Cantaloupe with lemon. Sliced bananas with whipped cream. Pecan or almond nuts.

157. Green pea broth with crackers and butter. Fried oysters with sauerkraut, bread and butter. Apple fritters with black unsweetened coffee.

158. Tomato and lettuce salad. Navy or butter beans with carrot puree and fried beachnut bacon. Toast with butter and black unsweetened coffee.

159. Broth with egg and crackers with butter. Macaroni and cheese with sprouts. Tomato gelatine.

160. Eggs with spinach and buttered toast. Cherry pie with black unsweetened coffee. Oranges.

161. Tomato puree and cabbage rolls with fried parsnips. Fruit gelatine.

162. Banana and date salad with lettuce. Pecans.

163. Barley soup. Baked fish and potato puree. Fried black toast with butter and unsweetened coffee.

164. Veal broth with sago. Veal with bread dressing, stewed prunes or rhubarb. Black coffee.

165. Watermelon. Meat croquettes with mashed or pickled beets, celery.

166. Cherries, apricot and lettuce salad. Nuts.

167. Cream of tomato soup. Corn bread with spinach and boiled eggs. Baked apples in gelatine.

168. Cream of celery soup. Cold boiled beef with olives and endive salad. Bread pudding with wine or fruit sauce.

169. Cream of potato soup. Smoked eel with apple and lettuce salad. Oranges, black toast and black unsweetened coffee.

CHAPTER VII.

MENUS FOR SUPPER.

1. Rice soup with crackers. Plum pudding with wine sauce.

2. Corned beef with sprouts, zwieback with butter and apple sauce.

3. Clam chowder with soda crackers and fruit.

4. Milk soup with black toast. Grapes.

5. Apple salad with bacon and black toast. Oranges.

6. Pea soup with crackers or raw celery. Grapes.

7. Apple salad with fish and black toast. Grapes or oranges.

8. Stewed prunes with cream and shredded wheat.

9. Artichokes with dressing. Creamed beef on toast.

10. Potato soup with shredded wheat and raw celery.

11. Barley soup with soda crackers and raw celery.

12. Sprouts with pickled tongue. Banana gelatine.

13. Lettuce with omelet and apple sauce.

14. Beef soup with rice. Boiled beef with sprouts, prunes.

15. Tomato soup with shredded wheat, raw celery.

16. Milk-rice with soda crackers or stale black bread.

17. Broth with egg and toast. Puffed wheat with butter and fried bacon.

18. Three-fourths to one pint of fresh milk with tomato toast.

19. Meat soup with rice and egg. Triscuit, butter.

20. String bean salad with mayonnaise dressing. Bran bread with butter, bacon.

21. Milk-or apple-rice with codfish cakes. Raw celery.

22. Cream of pea soup with soda crackers. Raw celery.

23. Date and lettuce salad with bread and butter.

24. Buckwheat gruel with cream and toast with honey or syrup.

25. Huckleberry pie with fresh milk or malt coffee.

26. Sago gruel with milk or cream and toast with apricot jam.

27. Baked bananas with black or bran bread and butter, malt coffee.

28. Blue grapes. Left-over steamed pudding with wine sauce.

29. Black stale bread with fig butter and rich fresh milk.

30. Fruit soup of plums or huckleberries, with whites of egg and toast with butter.

31. Bread soup with cream or butter, and soaked French prunes.

32. Whey or buttermilk soup, with soaked French prunes.

33. Stewed prunes with cream. Lemon pie with black malt coffee or milk.

34. Poached or soft boiled eggs, with bread and butter.

35. Apple or cranberry pie with hot or cold milk.

36. Baked apples with cream. Shredded wheat or bran bread with butter, bacon.

37. Warm chocolate pudding with cream and one glass of milk with toast.

38. Red fruit pudding with cream. One glass of milk with toast.

39. Potato soup with black bread, raw celery.

40. Apple or cranberry pie. Pine kernels.

41. Fruit or vegetable toast with fried bacon. Oranges.

42. Knorr's pea soup with cream and crackers. Raw celery.

43. Musk or watermelon. Creamed chipped beef, triscuit with butter.

44. Warm boiled custard with fruit sauce, black crusts or toast.

45. Barley soup with soda crackers. Creamed fish with baked apples.

46. Green pea soup with fried bread. Fruit cake and cereal coffee, raw celery.

47. Broth with egg. Steamed pudding with fruit or tomato sauce, raw celery.

48. Clam broth with crackers. Egg toast with fruit sauce.

49. Buckwheat gruel with cream. Fish with apple sauce and toast with butter.

50. Sago gruel with cream. Huckleberry pie with milk or coffee.

51. Baked bananas. Apple bread pudding with milk or coffee.

52. Blue grapes. Fried steamed pudding, or hominy cakes with fruit sauce.

53. Rice with milk. Black toast with fig butter or honey.

54. Blue plum soup with sago and whites of egg. Pumpkin pie with coffee.

55. Bread soup. Chops or beef with apple salad and mayonnaise dressing.

56. Pea broth. Tripe with tomato or whey sauce and toast with butter.

57. Melon with lemon or berries. Codfish cakes with bread and butter.

58. Cream of corn soup with tomato toast.

59. Rice flour with hot cream or milk. Toast with eggs.

60. Milk rice with soda crackers or toast.

61. Clear broth with crusts. Eggs and macaroni with fruit sauce.

62. Apple salad, puffed wheat with butter and fried bacon.

63. Broth with egg and cracker. Sprouts with lamb, toast with butter. Oranges.

64. Fresh milk with tomato toast.

65. Apple or tomato salad with mayonnaise dressing. Fish with lemon and toast with butter.

66. Apple and celery salad. Fruit cake with black coffee.

67. Raspberries or strawberries, dry toast or shredded wheat, one or two glasses of rich fresh milk.

68. Tomato or blackberry toast, with one or two glasses of rich milk.

69. Fruit gelatine with cream. Sandwiches, black coffee.

70. One or two glasses of sterilized blackberry juice with zwieback. Omelet with fruit sauce.

71. Clabber milk with cream and dry toast. Nuts if desired.

72. Lemon pie with fresh milk, or sand tart with fruit salad.

73. Raw huckleberries and zwieback with sweet butter. Nuts if desired.

74. Asparagus or artichokes with mayonnaise dressing. Sandwiches.

75. Boiled skim-milk with black bread.

76. Meat soup with barley. Apple salad or bread with Swiss cheese or cream cheese or cottage cheese.

For additional menus see recipes of soups, gelatines, salads, fish, sandwiches and egg foods.

Many of the above menus are suitable for children and for people of sedentary habits.

For those who require a liberal amount of nutritious food, it is easy to make up a number of additional menus from light protein foods for the evening meal, such as: Cream cheese, cottage cheese, Swiss cheese, fish, lamb chops, meat cakes (prepared from left-over cooked meats), eggs, pancakes (prepared with eggs or cream), fried egg-toast, sausages, legume soups, etc. Apples, tomatoes and prunes combine well with all the above mentioned foods.

CHAPTER VIII.

POOR MAN'S BILL OF FARE.

Suitable for people who perform hard manual labor, out of doors, and for those who are not steadily employed.

Sample Menu.

How to feed a family of five (2 adults and 3 children under 12 years of age) on $5.00 per week or 14 cents per person per day--71 cents per day for all.

BREAKFAST.

Cereal salad with apples and onions.

Cost in Cents.

Rylax or rolled wheat 2½■ cups 2½■ Apples 3 large 5 Cotton seed oil 3 tablespoons 2 Lemon ½■ 1 Onion 1 whole ½■

DINNER.

Lettuce with syrup dressing. Dried green peas with dumplings and fried bacon.

Lettuce 1 head 2 Syrup 3 tablespoons 1 Lemon or vinegar 2 tablespoons -- Cotton seed oil 3 tablespoons 2 Onion 1 whole ½■ Peas 1 pound 5 Flour 1½■ cups 3 Bacon ½■ pound 15

SUPPER.

Cream of tomato soup with dry toast.

Tomatoes 1 can 8 Soup stock 1 quart 5 Milk 1 quart 8 Butter 3 tablespoons 4 Flour 4 tablespoons ½■ Toast 7 large slices 4 --------
TOTAL 69 Cents

If porridge with milk is desired for breakfast, substitute a quart of milk in place of apples, oil, lemon and onion. Use one and three-fourths cup of rolled wheat or rye in place of two and one-half cups. If sugar is necessary, add fifteen prunes or five level tablespoons of sugar. During the summer, substitute carrots or cucumbers for the sweets. Raw, sweet or sub-acid fruits do not combine well with cooked cereals. Raw fruits and raw cereals is a better combination.

In order to reduce the cost of living to 10 cents per person per day or 50 cents per day for all, leave out the fat meat costing 15 cents, and some of the butter, replacing it by cooking oil. It is easy to modify the diet or add to it in a given direction. If more protein is required, a boiled egg or a few nuts may be added to the breakfast. If more fuel is needed, it can be added in the form of soup, fruits or fat. In comparing the value of 1 pound of legumes with 1 pound of lean meat and the additional fatty and green foods that are necessary with a meat diet, the housewife will realize that she must either have a big purse for the bills of fare with meat, or starve her family if they do not like legumes.

Ten cents per day is a small sum for a useful citizen to live on, yet thousands of people are compelled to do so every year, and for these the following pages might be of assistance.

Economical management, self-denial and abstinence from luxuries are the lessons to be studied. Look over the chapter on protein foods carefully. Never economize in these in order to buy cake, pastry or sweets. All who, for some reason or other, have to fight off starvation, will find that whole wheat bread and pure water or oatmeal porridge are the most perfect foods to keep them in fair health. They prevent diseases which might be the result of such conditions. To keep up on tea, coffee, sugar, white bread and liquor might result in dangerous breakdowns, insanity, murder and suicide. Coffee, tea and alcohol are medicines; they are valuable at times for the sick, when the system cannot digest food, or under conditions where not sufficient natural food can be obtained. On such occasions they may prevent disease and death.

HOUSEHOLD BOOKKEEPING

=====+======+==========+=======+========+==========+======+========== | | |Protein|Cereals | Green |Fruits|Stimulants |Income|Expenditure| Foods | Bread |Vegetables| Fats |and Misc. | | | |Potatoes| | Sugar| =====+======+==========+=======+========+==========+======+========== 1 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 2 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 3 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 4 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 5 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 6 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 7 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 8 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 9 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 10 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 11 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 12 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 13 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 14 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 15 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 16 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 17 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 18 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 19 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 20 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 21 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 22 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 23 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 24 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 25 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 26 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 27 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 28 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 29 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 30 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- 31 | | | | | | | -----+------+----------+-------+--------+----------+------+---------- Tot'l| | | | | | | =====+======+==========+=======+========+==========+======+==========

Monthly total receipts, $ ....

Savings, $ ....

Knowledge of bookkeeping is a necessity for systematic homekeeping. The experience gained from a household book with careful planning for one year is of more value than the experience gained from five years of unsystematic housekeeping. Wise management of a home will enable a family with a moderate income to enjoy comforts and pleasures, of which a family in better circumstances, but with poor and unwise management, is deprived.

"Time is money," therefore careful planning of the time that is expended for work, rest, recreation and outdoor life is as important as management of finances. Many women waste much valuable time with nonsensical details in the line of cleaning, cooking and fancy sewing. This abnormal amount of manual work and neglect of mental development is generally followed by worry and poor health, as the result of an anemic brain. In those conditions mental healers perform miraculous cures either by changing the activity of the mind or by paralyzing it to the extent of ignoring the plain facts of nature, and by denying the testimony of the senses.

The modern household is full of unwholesome things,--too many pictures, carpets, curtains and other ornaments, and too many salted, peppered, sugared and greasy artificial foods, with a lot of unnecessary dishes and utensils. A woman who enjoys spending all her time in drudgery, values herself below the poorest paid day-laborer.

To save time and strength means investing time and strength on more important subjects, such as harmonious conversations, out of door exercise, attending lectures, and the teaching of the laws of health and hygiene to the young, which cannot be begun too early. Unsystematic management of household work and the care of children has broken up many a home.

HOW TO FEED A FAMILY OF FIVE (2 ADULTS AND 3 CHILDREN) ON $3.50 PER WEEK OR 10 CENTS PER PERSON PER DAY DURING FALL AND WINTER.

Staple foods for two weeks. Cost in cents. Flour 10 pounds 35 Graham or whole wheat bread 3 loaves 15 Rye bread 1 loaf 10 Sugar 1 pound 05 Cereal coffee 1 package 20 Coffee beans ½■ pound 10 Bran 1 package 15 Roman meal 1 package 15 Rolled or steel-cut oats 1 package 10 Rice 2 pounds 10 Potatoes 4 pounds 20 Tomatoes 3 cans 25 Bacon ½■ pound 15 Dry peas 2 pounds 10 Dry beans 2 pounds 10 Lentils 1 pound 05 Corn meal 3 pounds 10 Dried prunes 4 pounds 25 Cheese ½■ pound 10 Onions 1 pound 05 Macaroni 1 pound 10 Salt 1 bag 05 Vinegar 1 pint 05 Cotton seed oil 2 quarts 50 Apples 6 pounds 25 Syrup 1 pint 05 Pumpkin 1 10 Eggs ½■ dozen 25 Rolled rye 1 package 15 Butter 2 pounds 45 Corn starch 1 package 10 Rolled wheat 1 package 10 ---- Total $4.95

SATURDAY.

=Breakfast.=--Roman meal cakes with lettuce and syrup dressing.

=Dinner.=--Hot skim-milk with black crusts. Macaroni with grated cheese.

=Supper.=--Meat soup with tomatoes and rice. Fried bread with apple sauce.

Cost of additional foods for Saturday: One gallon of skim-milk 5 cents, lettuce 5 cents, beef brisket 15 cents,--total 25 cents.

SUNDAY.

=Breakfast.=--Baked pumpkin, lettuce salad with raw rolled rye.

=Dinner.=--Warmed-over macaroni with soup stock, meat with tomato sauce.

=Supper.=--Hot skim-milk with black crusts or stale bread.

Cost of additional foods for Sunday: None.

MONDAY.

=Breakfast.=--Oatmeal porridge with butter or left-over boiled skim-milk.

=Dinner.=--Mixed boiled dinner of beans, potatoes and carrots.

=Supper.=--Soup from left-over scraps of tomatoes and meat, thickened with fat and flour, or pumpkin pie and black coffee or hash.

Cost of additional foods for Monday: Carrots and parsley 5 cents,--total 5 cents.

REMARKS: A portion of the skim-milk should be boiled on Sunday and balance be put in a pan for cottage cheese.

On Monday put one-half of the two pounds of beans in an earthen pot to bake before the carrots and potatoes are added. Preserve the baked beans with oil and keep in a cool place until Thursday.

TUESDAY.

=Breakfast.=--Rice with carrots and frankfurters.

=Dinner.=--Green pea soup. Codfish with butter sauce and potatoes with parsley.

=Supper.=--Left-over soup. Egg toast with stewed prunes or apple sauce.

Cost of additional foods for Tuesday: Frankfurters, 5 cents, fish, 15 cents,--total 20 cents.

WEDNESDAY.

=Breakfast.=--Corn meal mush or cakes with raw or stewed apples or prunes.

=Dinner.=--Cottage cheese with apple or potato salad and lettuce.

=Supper.=--Bread soup. Apple pancakes with lettuce salad.

Cost for additional foods for Wednesday: None.

THURSDAY.

=Breakfast.=--White or black toast with whey sauce (use whey which is drained from cottage cheese).

=Dinner.=--Lettuce salad. Raw carrots with baked beans. Brown bread with butter.

=Supper.=--Tomato and meat soup with toast. Celery.

Cost of additional foods for Thursday: Lettuce 5 cents, carrots 5 cents, parsley and celery 5 cents, Boston brown bread 10 cents, soup bone 5 cents,--total 30 cents.

FRIDAY.

=Breakfast.=--Oatmeal porridge with butter and syrup.

=Dinner.=--Milk soup with Roman meal. Fried herring and potatoes with parsley.

=Supper.=--Lentil soup with fried bread.

Cost of additional foods for Friday: Skim-milk 5 cents, herring 10 cents,--total 15 cents.

Total expenditure for the first week, 95 cents.

SATURDAY.

=Breakfast.=--Corn meal cakes with lettuce and syrup dressing.

=Dinner.=--Potato soup (prepared with fat, flour and skim-milk). Noodles with stewed prunes.

=Supper.=--Hot skim-milk with stale bread.

Cost of additional foods for Saturday: None.

REMARKS: Bake bread from one-half of the ten pounds of flour, mix with Roman meal instead of whole wheat flour.

SUNDAY.

=Breakfast.=--Bran muffins with stewed prunes.

=Dinner.=--Water rice with raisins or currants. Nuts.

=Supper.=--Corn starch pudding with stewed prunes and black crusts.

Cost of additional foods for Sunday: 1 pound of nuts 10 cents, raisins 5 cents,--total 15 cents.

REMARKS: Prepare the corn starch pudding on Saturday. Use balance of skim-milk with one-half water, a piece of butter, the yolk of an egg, some salt and a little sugar.

MONDAY.

=Breakfast.=--Rolled rye with butter and syrup.

=Dinner.=--Noodles with tomato sauce and liver.

=Supper.=--Potato soup with parsley and toast. (Prepare with fat, flour and left-over gravy from liver.)

Cost of additional foods for Monday: Liver 15 cents,--total 15 cents.

TUESDAY.

=Breakfast.=--Corn bread or fried mush with lettuce and syrup dressing.

=Dinner.=--Dried peas with flour dumplings and bacon sauce. Stewed prunes if desired.

=Supper.=--Corn meal porridge with skim-milk.

Cost of additional foods for Tuesday: Skim-milk 5 cents, lettuce 5 cents,--total 10 cents.

WEDNESDAY.

=Breakfast.=--Oat meal porridge with butter.

=Dinner.=--Lima beans with frankfurters and raw carrots.

=Supper.=--Stale bread with prune jam. Fresh milk diluted with barley water.

Cost of additional foods for Wednesday: Beans 5 cents, frankfurters 10 cents, fresh milk 10 cents, carrots and parsley 5 cents,--total 30 cents.

THURSDAY (Thanksgiving).

=Breakfast.=--Rolled wheat porridge with butter.

=Dinner.=--Apple salad with lettuce. Blood or liver sausage with rolled rye or black bread or baked oatmeal with cranberry sauce and celery.

=Supper.=--Tomato and lentil soup with fried bread.

Cost of additional foods for Thursday: Lettuce 5 cents, sausage 15 cents,--total 20 cents.

FRIDAY.

=Breakfast.=--Porridge from any kind of cereal with butter.

=Dinner.=--Cooked greens (pick some mustard or yellow dock on the street). Bread or flour dumplings with creamed fresh or salted codfish.

=Supper.=--Milk soup from stale bread and skim-milk.

Cost of additional foods for Friday: Fish 10 cents, skim-milk 5 cents,--total 15 cents.

Expenditure for staple foods $4.95 Additional expenditure for first week .95 Additional expenditure for second week 1.10 ---- Total $7.00

Staple Food for Two Weeks: Cost in Cents. Baking powder 1 can 15 Dried apples 2 pounds 15 Pearl barley 2 pounds 10 Flour 10 pounds 35 Sugar 1 pound 05 Rice 2 pounds 10 Eggs ½■ dozen 25 Apples 6 pounds 25 Leaf lard 2 pounds 10 Shoulder of mutton 3 pounds 15 Dried peas 2 pounds 10 Beans 2 pounds 10 Lentils 2 pounds 10 Bacon ½■ pound 15 Corn meal 3 pounds 10 Rolled rye 1 package 15 Oats 1 package 10 Wheat 1 package 10 Onions 1 pound 05 Cabbage 1 head 05 Lettuce 3 heads 05 Black bread 1 loaf 10 Whole wheat flour 2 pounds 10 Buckwheat flour 1 package 15 Potatoes 4 pounds 20 Cotton Seed Oil 2 quarts 50 Cheese ½■ pound 10 Apples 6 pounds 25 Butter ½■ pound 20 Tomatoes 3 cans 25 Milk delivered for two weeks 1 quart per day 1.25 Crackers 1 package 05 Nuts 2 pounds 20 ---- Total $6.05

SATURDAY.

=Breakfast.=--Mixed rolled rye and wheat porridge with butter and syrup.

=Dinner.=--Cabbage with mutton and bread and butter.

=Supper.=--Soup of mutton with rice and crackers. One-half quart of milk with barley water and toast for two children.

Cost of additional foods for Saturday: None.

REMARKS: Prepare sufficient bread for two weeks. If cabbage is left over, prepare it with fat, vinegar and flour and keep for Tuesday.

SUNDAY.

=Breakfast.=--Lettuce with syrup dressing and buckwheat cakes.

=Dinner.=--Rice soup with milk and raisins. Nuts.

=Supper.=--Left-over meat soup and bread for three. Milk and toast for two children.

Cost of additional foods for Sunday: None.

MONDAY.

=Breakfast.=--Oatmeal porridge with hot milk.

=Dinner.=--Lettuce with syrup dressing. Roman meal cakes. Hash of mutton.

=Supper.=--Baked apples in oil with black bread and residue of leaf lard with fried onions. One pint of milk and toast for two children.

Cost of additional foods for Monday: None.

REMARKS: Cut the leaf lard very fine, fry it in a pan with apples and a little oil.

TUESDAY.

=Breakfast.=--Cornmeal mush with hot milk.

=Dinner.=--Bean soup with bread. Cabbage and frankfurters.

=Supper.=--Pearl barley porridge with milk and cracker (for all).

Cost of additional foods for Tuesday: Frankfurters 5 cents,--total 5 cents.

WEDNESDAY.

=Breakfast.=--Three raw apples with black bread and lard.

=Dinner.=--Noodles and kidney stew. Bread if desired.

=Supper.=--Cream of green pea soup with bread and celery.

Cost of additional foods for Wednesday: Celery 5 cents, kidney 5 cents,--total 10 cents.

THURSDAY.

=Breakfast.=--Mixed rolled rye and wheat porridge with hot milk.

=Dinner.=--Mixed boiled dinner of beans, carrots and potatoes.

=Supper.=--Milk of soup for all.

Cost of additional foods for Thursday: Carrots and parsley 5 cents,--total 5 cents.

REMARKS: Keep one-half of the beans separate and bake for Sunday.

FRIDAY.

=Breakfast.=--Cornmeal pancakes with lettuce and syrup dressing.

=Dinner.=--Cream of corn soup. Meat croquettes and stewed dried apples. Bread.

=Supper.=--Bread soup with milk (for all).

Cost of additional foods for Friday: Canned corn 10 cents, Hamburg steak 5 cents, skim-milk 5 cents, lettuce 5 cents,--total 25 cents.

REMARKS: Prepare the corn soup with fat and flour, then add hot skim-milk. Use one pint of fresh milk for the bread soup and the balance skim-milk.

Total Expenditure for the week 50c.

SATURDAY.

=Breakfast.=--Oatmeal porridge with hot milk.

=Dinner.=--Baked noodles with milk and frankfurters.

=Supper.=--Mustard greens or yellow dock with lentils. Milk and toast for two children.

Cost of additional foods for Saturday: Frankfurters 5 cents, total 5 cents.

SUNDAY.

=Breakfast.=--Three raw apples and black bread with lard.

=Dinner.=--Lettuce salad with French dressing. Baked beans and bread.

=Supper.=--Milk toast for all.

Cost of additional foods for Sunday: Lettuce 5 cents, milk 5 cents,--total 10 cents.

REMARKS: Re-boil the skim-milk from Friday for cooking or baking.

MONDAY.

=Breakfast.=--Lettuce with syrup dressing. Cornmeal pancakes.

=Dinner.=--Milk soup with Roman meal. Bran biscuits with cheese and stewed dried apples.

=Supper.=--Cream of tomato soup with toast and celery.

Cost of additional foods for Monday: Celery 5 cents,--total 5 cents.

TUESDAY.

=Breakfast.=--Chopped apples with syrup dressing and raw rolled rye.

=Dinner.=--Cream of lentil soup. Tripe with tomato sauce and potatoes.

=Supper.=--Toast with apple sauce and hot milk diluted with barley water.

Cost of additional foods for Tuesday: Tripe 10 cents,--total 10 cents.

WEDNESDAY.

=Breakfast.=--Rolled wheat porridge with butter.

=Dinner.=--Mustard greens and unleavened pancakes with syrup or fruit sauce.

=Supper.=--Cream of pea soup with toast.

Cost of additional foods for Wednesday: Skim-milk 5 cents,--total 5 cents.

REMARKS: Flavor the greens with bacon. Use skim-milk and three eggs for the pancakes. Set part of the skim-milk for cottage cheese.

THURSDAY.

=Breakfast.=--Oatmeal porridge with hot milk.

=Dinner.=--Lima beans with potatoes and frankfurters or bologna.

=Supper.=--Apple pie with hot milk.

Cost of additional foods for Thursday: Frankfurters 5 cents,--total 5 cents.

FRIDAY.

=Breakfast.=--Buckwheat cakes with lettuce or yellow dock and syrup dressing.

=Dinner.=--Lentil and tomato soup. Cottage cheese with apple salad.

=Supper.=--Bread pudding with fruit sauce.

Cost of additional foods for Friday: Lettuce 5 cents,--total 5 cents.

Expenditure for staple foods $6.05 Additional Expenditure for first week .50 Additional Expenditure for second week .45 ---- Total $7.00

HOW TO FEED A FAMILY OF FIVE ON $5.00 PER WEEK OR 14 CENTS PER PERSON PER DAY DURING THE FALL AND WINTER.

Buy the same staple foods as suggested for the foregoing menus; add to it: Oranges, bananas, cream, peanut-butter, eggs, bacon, cheese, tomatoes, apples, rice, peas, celery, string beans, grapes or other fruits or vegetables.

HOW TO FEED A FAMILY OF FIVE (2 ADULTS AND 3 CHILDREN) ON $3.50 PER WEEK OR 10c. PER DAY DURING SPRING AND SUMMER.

Stale, whole wheat, graham and Cost in Cents. white bread 3 loaves 25 Flour 10 pounds 35 Stale black bread 2 loaves 15 Cereal coffee 1 package 20 Coffee beans ½■ pound 10 Bran 1 package 15 Roman meal 1 package 15 Cream of wheat 1 package 20 Rice 6 pounds 25 Potatoes 4 pounds 20 Tomatoes 3 cans 25 Bacon ½■ pound 15 Green dried peas 2 pounds 10 Lima beans 2 pounds 10 White beans 2 pounds 10 Corn meal 4 pounds 10 Dried prunes 2 pounds 10 Salt 1 bag 05 Vinegar 1 pint 05 Cotton seed oil 1 quart 25 Apples 6 pounds 25 Syrup 1 pint 05 Rolled rye 1 package 15 Rolled wheat 1 package 10 Corn starch 1 package 10 Butter ½■ pound 20 Eggs 2 dozen 35 Peanut butter 1 jar 25 Dried apricots 2 pounds 10 Onions 1 pound 05 ---- $4.85

REMARKS: Use plenty of parsley, pick green leaves such as mint, yellow dock, mustard greens and others on the road or in the country. Keep the eggs on ice or in salt water in a cool place.

SATURDAY.

=Breakfast.=--Mustard greens on toast.

=Dinner.=--Lettuce salad with baked beans and bread with butter.

=Supper.=--Rice and tomato soup with cracker or fried bread.

Cost of additional foods for Saturday: Lettuce 5 cents,--total 5 cents.

SUNDAY.

=Breakfast.=--Cereal salad with apples, onions and lettuce.

=Dinner.=--Steamed pudding with apricot sauce.

=Supper.=--Fresh milk and toast with tomato or apricot jam.

Cost of additional foods for Sunday: Milk 10 cents,--total 10 cents.

MONDAY.

=Breakfast.=--Cream of wheat porridge with butter and raw cucumbers.

=Dinner.=--Green pea soup with raw carrots. Left-over pudding.

=Supper.=--Buttermilk rice with prunes.

Cost of additional foods for Monday: Carrots 5 cents, buttermilk 5 cents,--total 10 cents.

REMARKS: Cook sufficient pea soup for two meals. (Use two-thirds of the two pounds of peas.)

TUESDAY.

=Breakfast.=--Mashed potatoes with buttermilk and bacon sauce. Black toast.

=Dinner.=--Apple salad with peanut dressing and raw rolled rye or wheat.

=Supper.=--Cream of pea soup with toast and celery or parsley.

Cost of additional foods for Tuesday: Fresh milk 10 cents,--total 10 cents.

REMARKS: Use a pint of milk for the left-over pea soup.

WEDNESDAY.

=Breakfast.=--Cornmeal mush with hot milk.

=Dinner.=--Lima beans with carrots, potatoes and parsley.

=Supper.=--Yellow dock (raw or cooked) and egg toast with stewed prunes.

Cost of additional foods for Wednesday: Carrots 5 cents,--total 5 cents.

THURSDAY.

=Breakfast.=--Mashed turnips or carrots and toast with butter.

=Dinner.=--Lettuce salad with unleavened apple pancakes.

=Supper.=--Meat soup of lamb with rice and tomatoes. Toast with butter.

Cost of additional foods for Thursday: Shoulder or neck of mutton 15 cents, lettuce 5 cents,--total 20 cents.

REMARKS: Cut the meat in five pieces, cover with a little hot vinegar for half an hour, pour off; then add soup stock and keep in gelatine until Saturday.

FRIDAY.

=Breakfast.=--Cream of wheat porridge and butter.

=Dinner.=--Cooked spinach with fish and baked noodles.

=Supper.=--Strawberries with toast and scrambled eggs.

Cost of additional foods for Friday: Fish 15 cents, strawberries 10 cents,--total 25 cents.

Total expenditure for the week 85c.

SATURDAY.

=Breakfast.=--Left-over noodles with tomato sauce.

=Dinner.=--Raw cabbage salad with mayonnaise dressing and lamb in gelatine. Bread.

=Supper.=--Cream of tomato soup with fried bread and celery.

Cost of additional foods for Saturday: Cabbage 5 cents, celery 5 cents,--total 10 cents.

SUNDAY.

=Breakfast.=--Creamed boiled cabbage with stale bread or toast.

=Dinner.=--Fruit salad of apricots or peaches and lettuce with rolled rye and nuts (4 to 8 walnuts per person).

=Supper.=--Pancakes or cornmeal patties with fruit sauce.

Cost of additional foods for Sunday: Nuts 10 cents, fruit 10 cents, lettuce 5 cents,--total 25 cents.

MONDAY.

=Breakfast.=--Rice soup of buttermilk or milk with prunes.

=Dinner.=--Mixed boiled dinner of lima beans, carrots and potatoes.

=Supper.=--Egg toast or pancakes with fruit sauce.

Cost of additional foods for Monday: Skim-and buttermilk 10 cents, carrots 5 cents,--total 15 cents.

REMARKS: Use part of the milk for pancakes. Leave some for clabber milk.

TUESDAY.

=Breakfast.=--Stale bread with peanut-butter and apples.

=Dinner.=--Clabber milk with zwieback, doughnuts or pancakes (prepared with eggs).

=Supper.=--String beans and meat stew with dumplings.

Cost of additional foods for Tuesday: String beans 10 cents, meat 10 cents,--total 20 cents.

WEDNESDAY.

=Breakfast.=--Cherries with corn bread or egg toast.

=Dinner.=--Yellow dock on toast. Steamed rice pudding with fruit sauce.

=Supper.=--Raspberries and fresh milk with toasted bread.

Cost of additional foods for Wednesday: Cherries 10 cents, raspberries 10 cents, milk 10 cents,--total 30 cents.

THURSDAY.

=Breakfast.=--Left-over yellow dock and Roman meal cakes or bran muffins.

=Dinner.=--Julienne soup with fried bread. Apple rice with peanut sauce. Raw celery.

=Supper.=--Asparagus with French dressing or butter sauce and frankfurters or chipped beef and bread.

Cost of additional foods for Thursday: Asparagus 10 cents, meat 5 cents, celery 5 cents,--total 20 cents.

FRIDAY.

=Breakfast.=--Rolled wheat porridge with butter.

=Dinner.=--Baked noodles with tomato sauce and lettuce.

=Supper.=--Milk soup with black crusts.

Cost of additional foods for Friday: Lettuce 5 cents, skim-milk 5 cents,--total 10 cents.

Expenditure for staple foods $4.85 Total Expenditure for first week .85 Total Expenditure for second week 1.30 ---- Total $7.00

Staple Foods for Two Weeks. (Cost in Cents.) Stale whole rye and wheat bread 5 loaves .40 Roman meal 1 package .15 Cream of wheat 1 package .20 Rice 6 pounds .25 Potatoes 4 pounds .20 Raw tomatoes 3 pounds .10 Bacon ⅛■ pound .15 Green dried peas 2 pounds .10 Cow beans 2 pounds .10 Lentils 2 pounds .10 Corn meal 4 pounds .10 Salt 1 bag .05 Vinegar 1 pint .05 Lemon ½■ dozen .10 Cotton seed oil 1 quart .25 Olive Oil 1 bottle .25 Apples 6 pounds .25 Rolled rye 1 package .15 Rolled wheat 1 package .10 Corn starch 1 package .10 Butter 1 pound .20 Eggs 2 dozen .45 Peanut butter 1 jar .25 Baking powder 1 can .15 Radishes 2 bunches .05 Green onions 2 bunches .05 Walnuts 2 pounds .25 Lettuce 3 heads .05 Celery 1 bunch .05 Carrots 2 bunches .05 ---- $4.70

A few staple foods, such as coffee, bran and a few cereals, are supposed to be left over from the last two weeks.

Use peanut butter in place of butter.

SATURDAY.

=Breakfast.=--Green onions and radishes with bread and butter.

=Dinner.=--Tomato salad and lettuce. Creamed horse beans with parsley. Bread.

=Supper.=--Rice and tomato soup. Celery.

Cost of additional foods for Saturday: None.

SUNDAY.

=Breakfast.=--Mashed carrots. Lettuce salad and horse beans.

=Dinner.=--Apple and lettuce salad. Nuts (4 to 8 per person).

=Supper.=--Lemon pie with black malt coffee.

Cost of additional foods for Sunday: None.

MONDAY.

=Breakfast.=--Cream of wheat with butter.

=Dinner.=--Lamb or beef stew with dumplings. Celery.

=Supper.=--Green pea soup with fried bread or left-over dumplings.

Cost of additional foods for Monday: Meat 10 cents,--total 10 cents.

REMARKS: Prepare enough pea soup for the next day.

TUESDAY.

=Breakfast.=--Fruit salad of apricots, peaches or plums, and lettuce with rolled raw wheat or rye.

=Dinner.=--Pea roast or steamed bread pudding with tomato sauce. Celery.

=Supper.=--Fresh berries and toast with milk.

Cost of additional foods for Tuesday: Fruit 5 cents, lettuce 5 cents, celery 5 cents, berries 10 cents, milk 10 cents,--total 35 cents.

WEDNESDAY.

=Breakfast.=--Roman meal cakes with lettuce and syrup dressing.

=Dinner.=--Buttermilk soup with rice and raisins. Nuts (4 to 6 per person).

=Supper.=--Egg toast and lettuce with fruit sauce.

Cost of additional foods for Wednesday: Raisins 5 cents, buttermilk 5 cents,--total 10 cents.

THURSDAY.

=Breakfast.=--Water or muskmelon. Raw rolled rye mixed with chopped apples and lettuce.

=Dinner.=--Cherries and unleavened pancakes with syrup dressing.

=Supper.=--Green grapes and black bread with cream cheese.

Cost of additional foods for Thursday: Melon 10 cents, cherries 10 cents, grapes 5 cents, cheese 10 cents--total 35 cents.

REMARKS: Leave one-half of the cream cheese for Saturday.

FRIDAY.

=Breakfast.=--Rolled rye and wheat porridge with hot milk and raw cucumbers.

=Dinner.=--Cucumber salad. Green peas with dumplings and creamed fish.

=Supper.=--Bread soup (with buttermilk).

Cost of additional foods for Friday: Fresh milk 10 cents, buttermilk 10 cents, peas 5 cents, cucumbers 5 cents, fish 10 cents,--total 40 cents.

Total expenditure for the week $1.30

SATURDAY.

=Breakfast.=--Stale bread with cream cheese and left-over raw greens.

=Dinner.=--Meat croquettes (of soup meat) with creamed beets and bread.

=Supper.=--Rice and tomato soup with soup stock. Celery.

Cost of additional foods for Saturday: Soup bone 5 cents, tomatoes 10 cents, beets 5 cents, celery 5 cents,--total 25 cents.

SUNDAY.

=Breakfast.=--Salad of chopped apples and celery with mayonnaise dressing and raw rolled wheat or rye.

=Dinner.=--Cherry-or currant-or apple-rice. Nuts.

=Supper.=--Tomato salad and egg toast.

Cost of additional foods for Sunday: Fruit 5 cents,--total 5 cents.

MONDAY.

=Breakfast.=--Corn meal mush with hot milk.

=Dinner.=--Tomato salad. Stewed lentils with creamed onions.

=Supper.=--Lentil and tomato soup with toast or bread.

Cost of additional foods for Monday: Milk 10 cents,--total 10 cents.

REMARKS: Dilute the left-over lentils and tomatoes with water, add onions. Cook for 20 minutes, run through a colander, mix with flour and fat, add hot milk.

TUESDAY.

=Breakfast.=--Creamed potatoes with frankfurters and parsley.

=Dinner.=--Cherries and corn meal pudding with lemon sauce.

=Supper.=--Milk soup of rice with black crusts.

Cost of additional foods for Tuesday: Cherries 5 cents, frankfurters 5 cents, skim-milk 5 cents,--total 15 cents.

REMARKS: Use left-over corn meal for pudding; add 4 to 5 eggs.

WEDNESDAY.

=Breakfast.=--Raw cabbage salad with mayonnaise dressing and bread with butter.

=Dinner.=--Meat stew with dumplings and lettuce salad.

=Supper.=--Bran muffins and tomato puree. Boiled skim-milk.

Cost of additional foods for Wednesday: Meat 10 cents, lettuce 5 cents, cabbage 5 cents,--total 20 cents.

THURSDAY.

=Breakfast.=--Cream of wheat gems and lettuce with syrup dressing.

=Dinner.=--Mixed boiled dinner of string beans, potatoes and pears. Cornbread.

=Supper.=--Corn starch pudding with boiled hot or cold milk and black crusts.

Cost of additional foods for Thursday: Beans 5 cents, milk 10 cents, pears 5 cents,--total 20 cents.

FRIDAY.

=Breakfast.=--Rolled rye porridge with butter and syrup.

=Dinner.=--Bread dumplings or fritters with pea puree or stewed pears.

=Supper.=--Creamed cabbage with frankfurter and bread.

Cost of additional foods for Friday: Frankfurter 5 cents,--total 5 cents.

Expenditure for staple foods $4.70 Total Expenditure for first week 1.30 Total Expenditure for second week 1.00 ---- Total $7.00

HOW TO FEED A FAMILY OF FIVE ON $5.00 PER WEEK OR 14 CENTS PER PERSON PER DAY DURING SPRING AND SUMMER.

Buy about the same staple foods as suggested for the foregoing menus. Use less bread and cooked porridge or mushes. Buy more starchy fruits, such as bananas, stone fruits, melons and raw vegetables; combine them with toasted bread or raw cereal flakes. For those who eat two meals per day and have a late breakfast, it is better to combine fruits with nuts for breakfast in place of cereals. Use rich milk or cream with fruits for supper in place of those foods suggested in menus for supper. For other combinations study menus.

SUGGESTIVE MENUS DURING THANKSGIVING WEEK.

WEDNESDAY.

=Breakfast.=--Fried sweet potatoes with fried bacon and apple sauce.

=Dinner.=--Stuffed turkey neck with cranberry sauce.

=Supper.=--Tomato soup with fried bread.

THANKSGIVING.

=Breakfast.=--Creamed onions with bread and butter.

=Dinner.=--String bean salad with French dressing. Turkey with apple dressing, celery, cranberry compote. Plum pudding with sauce. Black coffee.

=Supper.=--Apple pie with black coffee.

FRIDAY.

=Breakfast.=--A fast or some fruit juice.

=Dinner.=--Plain water rice with turkey gravy.

=Supper.=--Green pea soup with fried bread.

SATURDAY.

=Breakfast.=--Roman meal cakes with cranberry sauce.

=Dinner.=--Brown flour soup from turkey bones. Left-over plum pudding.

=Supper.=--String bean salad. Baked squash with fried bacon.

REMARKS: Cut the turkey into pieces and preserve in gravy.

SUNDAY.

=Breakfast.=--Apple salad with lettuce and mayonnaise dressing. Bread.

=Dinner.=--Green pea soup. Mince pie and cheese.

=Supper.=--Fruit cake with coffee.

MONDAY.

=Breakfast.=--Codfish cakes with apple-or tomato-rice.

=Dinner.=--Boiled onions. Turkey with steamed potatoes and gravy. Celery.

=Supper.=--Squash or pumpkin pie with black coffee.

TUESDAY.

=Breakfast.=--Buckwheat groats with hot cream.

=Dinner.=--Turkey hash or salad with tomatoes and lettuce.

=Supper.=--Huckleberry soup with sago or dumplings.

RECIPES FOR MIXED BOILED DINNERS.

They are much appreciated in many foreign countries by people of moderate means. The housekeeper who does her own work can save much time by introducing a few of these menus at her table. The preparation of foods in this manner requires less water, it is more of a steaming process, and fewer dishes and utensils are needed.

Dishwashing becomes a burden in many a large household and the intelligent homekeeper studies economy in all directions.

I ask in advance that you try the recipes; lay aside prejudice against some of the good old-fashioned dishes, to which you are not accustomed, and stop wasting your time over new and fashionable recipes that ruin your health. Simplicity and knowledge are a great help for a low purse.

I.

Lima Beans with Carrots and Potatoes.

Soak one pound of lima beans in rain or soft water over night, cook for half an hour, add salt, and then add five good sized carrots cut to the size of the beans. Cook both for half an hour, then add four or five potatoes and cook all together until done. Thicken the broth with corn starch, add chopped parsley and butter. A tablespoon of vinegar and sugar may be added to the sauce if the flavor is desired. The carrots may be cooked by themselves; when done, add the water to the beans and potatoes, pour a little diluted vinegar over the carrots, let stand 20 minutes, drain off the vinegar and add the carrots to the beans and potatoes. This is preferable for people who dislike the sweet taste of the carrots. Serve with pork, bacon, frankfurters or without meat. Bread is not needed at this meal, as potatoes and carrots furnish sufficient carbohydrates. If bread is desired, it should be eaten in place of dessert with a little unsweetened black coffee or malt coffee.

II.

Small White or Brown Beans with Carrots and Potatoes.

Prepare the same as the foregoing. The time for cooking beans depends on the quality. The carrots should not be added until the beans are nearly done.

III.

Dried Green Peas with Carrots and Pork.

Prepare the same as the foregoing. Young green peas or string beans may be used in place of dried ones. The latter are excellent during the summer in combination, with salted pickled herring or creamed chipped beef.

IV.

Green Dried Peas with Dumplings.

See recipe for bread or flour dumplings. Cook the dumplings in salted water and serve with the peas in place of meat or prepare a pea soup and boil the dumplings in the soup. This makes a perfect meal for dinner.

Use one-fourth to one-half a cup of dried peas per person, according to size and age of the individual. Green fresh peas may be substituted in the summer. Fried bacon is a good addition.

V.

Dumplings with Potatoes and Prunes.

Steam the potatoes. Prepare some nutritious dumplings from flour or bread with eggs. Heat some butter, bacon fat or oil, add finely chopped onions, fry until brown, remove from the fire and add two tablespoons of syrup and some lemon juice or vinegar. Pour the potatoes and dumplings on a dish, mix with stewed cold or warm prunes, pour the syrup sauce over it and serve. Serve with lettuce. The syrup sauce can be thickened with flour and strengthened with the water in which the dumplings have been cooked; the prune juice can be added in place of the syrup. Serve with fried bacon. Good during the summer.

VI.

Potatoes, Macaroni and Prunes.

Cook the macaroni until very tender, drain off the water, combine and serve in same manner as the foregoing.

VII.

Fried Dumplings.

Cut left-over dumplings into thin slices, fry in hot fat or butter until brown. Flavor with onions if desired.

PART FOUR

CHAPTER I.

DISEASE.

Disease is that condition of the body where there is any departure from the normal, in function, or structure. It may be local or general, and may tend to recovery, death or life-long suffering.

Many so-called forms of dyspepsia are brought about by improper eating, or by eating when not hungry or when tired. In such cases, a regulated life and the right selection, combination and preparation of foods is the only means to correct it.

ULCERATION OF STOMACH AND INTESTINE.

Causes: After effects from acute diseases, worry, envy, excesses of eating or drinking, bony displacements, anemia and overwork. The patient should consult a physician at once. If certain areas of the glandular structure of stomach or intestine have been destroyed once, the normal structure cannot be restored; but with good care and proper dietetic measures great improvement can take place. Excess of starchy foods is always harmful. Particles of food not well masticated can cause much disturbance. The presence of fats in large amounts or wrongly combined with other foods will also retard digestion; they cause the pyloric orifice to contract more, and leave the food contents in the stomach for a long time, and in this way cause fermentation and putrefaction.

Dyspepsia and indigestion are the beginnings of a disordered metabolism and if neglected the results are: Nervous prostration, insanity, consumption, pelvic disorders, difficult child-birth, weak offspring, different forms of tumors and cancers and a multitude of fashionable and epidemic diseases.

CONSTIPATION.

The recognized rule is that the bowels should be evacuated once per day. Nevertheless, there are a number of people whose bowels act only every second or third day, and whose health is not impaired thereby. Healthy people who live on natural foods, such as raw fruits, nuts and grains, or on simple cooked foods with a moderate amount of meat, as a rule will not find it necessary to resort to artificial means for evacuation of the bowels.

People, whose diet consists mainly of meats, cooked vegetables and potatoes mixed with fermentable substances, or those who mix meat with milk and sweets or soft puddings will find it absolutely necessary to have a daily evacuation of the bowels, in order to retain perfect health.

CHRONIC CONSTIPATION.

Different habits of diet have a great effect upon evacuations. People who suffer from chronic constipation without any particular ailment or disease may often be greatly benefited by adding a greater amount of fruits or vegetables to their diet. Others find it necessary to discard cooked fruits for a while and take oily substances. Some people are constipated from insufficient protein elements in their food. The original cause may have been mechanical obstruction. Morbid anatomy and morbid physiology go hand in hand. Therefore, if proper hygiene and diet does not correct the condition, the patient should consult a physician for special treatment.

MALARIA.

Malaria is a germ disease, but like many other germ diseases, the primary cause is lowered resistance, caused by poisoned air and adulterated food stuffs. Protection against adulterated food stuffs depends upon enforcement of pure-food laws, and the training of every housekeeper in the art of domestic science. Impure milk, whether poisoned by the milkmen or handled carelessly by the housekeeper, cannot be turned into good blood. The same is true of other food stuffs.

Dry, pure air is absolutely necessary for the patient who suffers with malaria. Dwelling places near which are stagnant pools, rain barrels, marsh land or stores where decayed fruits and vegetables are housed, are dangerous to people who are afflicted with malaria or any other germ disease. Mosquitoes are held responsible for both malaria and yellow fever. They breed in warm weather, wherever stagnant water is found. To prevent a disease that is spread by animal or vegetable parasites we must direct our effort against the breeding places of these disease carriers. Coal oil, poured upon the surface of stagnant water on streets, or near our homes, is a great help in preventing the multiplication of mosquitoes. Screens on dwelling houses, dry basements, plenty of sunshine in the home and the prevention of accumulation of vegetable refuse can do much toward protection from these parasites.

People who are afflicted with partial congestion of the portal circulation have stagnant and poisoned blood, and are more liable to contract malaria than those whose liver is in good working order. Many people are under the impression that they have liver trouble if they put more work upon this organ than it is able to do. Overtaxing of any part of the body will finally result in congestion and disease.

If mechanical obstructions are responsible for sluggish conditions of the liver, they should be remedied by anatomical and physiological adjustment. Deep breathing is of the greatest importance in all diseases affecting the abdominal organs. Fresh air at night is as important as during the day. During rainy weather have a fire going during the night in order to keep the air dry. Protect the body with warmer clothing after sunset, and wear light woolen underwear if necessary to avoid chills during sleep.

The diet should be light and nutritious. Avoid all rich condiments, spices, soft puddings containing milk and eggs, yeast breads and cakes. Some cases should avoid milk, cheese, shell-fish and other foods rich in protein.

THE FOLLOWING SUGGESTIONS MAY BE HELPFUL TO INVALIDS WHO SUFFER FROM CHRONIC AFFECTIONS OF THE LIVER AND INTESTINAL INDIGESTION.

1. Spend at least four hours per day out of doors.

2. Take short walks before and after dinner and before and after supper. Take deep breathing exercises by open windows before breakfast, and exercise the lower limbs while in bed.

3. Have breakfast at 9 a. m. and supper between 4 and 5 p. m.

4. Never work or eat when the hands and feet are cold.

5. Relax and breathe deeply with face down for 20 minutes, three times per day before meals.

6. During damp or rainy weather rest more, eat more greens, citrus fruits and fatty foods, and little or none of those foods which are rich in protein, such as cheese, whites of eggs, lean meats, nuts, beans, canned corn and milk foods, and select protein foods for the noon meal in the form of green pea or lentil soup, with or without tomatoes, or fat cold pork, fish or bacon in combination with apples, mashed beets, carrots or yellow turnips with lemon, hard yolks of eggs and fried bacon. Rice with tomato sauce and cold fat meat is also good. Black stale bread is best.

7. For breakfast use fats in the form of mayonnaise dressing with raw apples and tomatoes and plenty of onions, also fat meat if desired, and corn meal mush with eggs and cranberry sauce and celery; or the above mentioned green leaf vegetables. Celery

roots, raw or cooked, with lemon and toasted bread and butter or fried bacon is also good. Use raw carrots, cranberries and beets with greens and French dressing. Raw cabbage is also good.

8. For supper select your food according to your appetite. If you are warm, active and energetic, take some raw fresh milk with zwieback and tomato or cranberry juice, or suck the juice of one-half or one-fourth of a lemon or grapefruit with it, white and yellow skin and all, expectorate the residue. Bran tea, barley or oatmeal water with one-fourth sterilized cream is good. If you are cold and chilly eat a plate of warm soup made of tomatoes or plums, huckleberries, string beans or asparagus (treated with lemon), or potato soup, or eat green cooked leaf vegetables with lemon and fried bacon, toasted or puffed wheat, and butter.

9. During the dry, frosty season, when the sun is bright during the middle of the day, eat a moderate amount of those foods forbidden under No. 6, combine them rightly, and take walks in the sunshine after dinner.

10. Mornings and evenings eat about the same foods as suggested in the foregoing.

11. Dress the body according to the changes of temperature.

12. Avoid over-heated rooms, and stay in bed until the sun rises, if necessary.

13. Keep the bowels in good order by enemas.

14. Black malt coffee prepared with a few whole or crushed coffee beans is of medicinal value if taken in small quantities after meals, especially after the noon meal; it acts as a tonic to the liver. Raw cranberries may be substituted if desired.

The above mentioned suggestions are for extreme cases of liver degeneration. They also apply to many chronic, so-called incurable diseases where the protein and starches of the diet should be limited in quantity to the minimum, compatible with the requirements of the individual.

There are cases of liver trouble where there is no interference with the glycogenic and oxidizing action of the liver, and where an entirely different diet is required. Therefore, no patient should attempt to treat a disease by a book, without having his case diagnosed by a physician and receiving advice as to the special diet required.

TUBERCULOSIS.

It is one of the most fatal diseases that affects men and animals. It is due to a germ called the bacillus of tuberculosis. This germ, however, is not the primary cause for the development of the disease. Wrong environment, unclean air and food are the causes that multiply these germs. Hereditary weaknesses play an important part, but the disease itself is never inherited. Lowered vitality, infection through milk and meat, and careless spitting are in a large measure responsible.

Children of parents who suffer from tuberculosis may grow up into healthy and strong individuals, if the proper conditions are furnished. Tendencies to disease are universally manifest in the weaker structures, and this weaker resisting power is the exact measure of the power inherent in heredity.

Tuberculosis may affect the lungs or manifest itself in different parts of the body, and is known under the following names: Potts disease or curvature of the spine; hip joint disease, when it affects the hip joint; white swelling or knee joint disease; ankle joint disease; lupus or skin disease; scrofula, when it affects the glands of the neck; tuberculous ulceration, when it affects the inside of the intestine; tuberculous peritonitis, when it affects the outside of the intestine; and consumption, when the lungs are involved.

PREVENTION OF TUBERCULOSIS.

The House We Live In.

Sunlight is the best known disinfectant. The direct rays of the sun destroy tubercular germs and the majority of other micro-organisms. Plants cannot grow without sunshine. Human beings cannot enjoy health in dark dwelling places, without sunlight. The houses we live in should contain a large number of windows and glass doors, so as to permit all rooms to be permeated with sunlight. It is a pity that modern houses, with all their conveniences and sanitary arrangements, have so little provision for proper sterilization by sunlight.

Many new modern houses are provided with a lot of unnecessary closet room, pantries and double stairways, halls and other accessories, which shut up impure air and prevent proper ventilation. Instead of living in large, luxurious houses, our health and

comfort could be greatly improved by the investment of more space in artistically constructed gardens. Smaller houses, long and narrow in form, or wide and short, according to the location and size of the lot, could be daily disinfected and sterilized from cellar to attic by the rays of the glorious sun. A building of this kind may consist of two, four, eight, ten or more rooms, with one or three floors, and can offer comfort for one family, or be divided into apartments or flats. A house should be built on porous ground.

A lower floor, with parlor and spare bedrooms, is more easily ventilated and kept clean than a high basement with poor flooring, and no provision for proper airing or the admission of sunlight.

The mother of a family who has to do her own work in a two-story house could save much time and strength by having her kitchen and dining room on the upper floor, with hall and stairway and glass door in the center of the house, which would enable her to attend to the door from above. A house so constructed could easily be provided with porches for sleeping, and a place for the children to play during the morning hours, and in this way relieve the mother of many unnecessary steps.

Large, beautiful gardens call for work which is mixed with brains, while large houses with fashionable accessories call for slavery and compel one woman to become the servant of another woman.

All human beings are born with a pair of arms, which by gradual development enable them to care for their bodies in matters of feeding, dressing, hygiene and comforts. Assistants in the home are required for the child, the sick and the helpless.

Modern inventions relieve us partly of house-cleaning and laundry work, and modern methods of simple feeding and luxurious airing will relieve us from solving the servant problem and prevent diseases that are created by wrong living.

TREATMENT OF TUBERCULOSIS.

Clinical experience with hygiene and diet have proved that they are the most important factors in the treatment of disease.

A certain class of patients who are in the early stages of this disease may be benefited by a liberal diet, but the larger percentage of sufferers really have indigestion and can only gain benefit by cutting down their diet and by living upon plain, non-stimulating food. The amount of carbo-hydrate foods should be decreased and the amount of fats increased. Olive oil in combination with raw vegetables, acid fruits and raw eggs and fat meats should be given daily. They are best taken for breakfast. The heavier protein foods should be eaten at the noon meal in combination with a small amount of cereals and raw greens. The evening meal should consist of broths with egg, cooked green vegetables, toast and bacon, or of milk foods. If extra milk is required it should be given with a keen appetite. Food eaten without relish cannot be properly oxidized and assimilated.

People who are compelled to work while sick should take some extra milk between 10 and 12 a. m. and during the afternoon. Milk may be taken raw or boiled, according to the individual requirements. The bowels should be kept in order by enemas and laxative foods.

RICKETS.

This is a condition where there is interference with the nutrition of the bones. The bones, like other parts of the body, are injured by lack of nourishment; they become soft and yielding like wax, and are drawn by the muscles into deformity. The animal matter which enters into the composition of the skeleton is in great excess, and the earthy (or mineral matter) is deficient in proportion. Causes for such conditions are: Lack of lime and minerals in the food, before or after birth; impure or inferior milk; fermenting foods; excess of starchy foods, sweets and meats; insufficient greens, legumes and nut-foods in the mother's food, and overwork of the mother before or after birth of the child; damp and impure air and unhealthy dwellings. The first symptoms of this disease or a tendency to it can sometimes be detected in a child during the first year by soft and flabby muscles, excess of fat, difficulty and backwardness of learning to walk, and in cutting teeth, extremely narrow chest, continual digestive disturbances with constipation or greenish looking evacuations, and catarrh of the bowels. Softening of the bones of the head is often present.

The prevention and treatment of this disease demands careful regulation of the diet, sufficient sleep, pure air, dry, sunny dwellings, warm baths, massage and salt rubs. If the child perspires much on the upper part of the body during sleep, avoid feather pillows and keep the lower limbs warm by artificial heat if necessary. Avoid pressure on the head by placing a narrow pillow about two inches in width under the neck, and no pillow under the head. Keep the child in the lying position as much as possible. Do not carry it on the arm except when necessary, and never force it to stand or walk against its own will.

The diet should consist of milk and cream with well cooked strained pearl barley and steel cut oats or bran, a moderate amount of toast, calf's-foot jelly, eggs, strained legumes and fat meats. Raw greens, fruits and nuts should be given as soon as the child is able to digest them without difficulty. Always select the food in the right combination and never allow excesses of any kind. The bowels must be kept regular by enemas.

OBESITY.

Obesity is a constitutional disease, due to excess of food in general or to excess of wrong food and interference with the nerve supply controlling the oxidation processes.

Thousands of people who suffer from this "fat habit" could cure themselves by proper attention to hygiene and diet. A normal individual who lives right, thinks right and is engaged in useful work, does not need to carry useless fat around with him.

Do not take the advice of a friend who promises relief with dangerous drugs and salves, or excessive steam-baths and violent exercises. A diet suitable in quality and quantity to the particular constitution, useful activity, alternated with sufficient rest and recreation, and plenty of sunlight and dry, fresh air, are the only means to bring permanent results. A change of occupation is necessary at times. The dry diet, consisting of the necessary amount of proteins, with a large amount of raw greens or fruits and fats, and abstinence from tea and coffee and foods which are rich in starch and sugar, will bring relief to the majority of people who have a tendency to grow stout.

There are special conditions which require special treatment, such as tonic baths, massage, sun-baths, osteopathic treatments and special prescribed diets and exercises which cannot be discussed here.

CHAPTER II.

CARE AND FEEDING OF CONVALESCENTS.

Convalescence depends much upon the proper food. Fevers require that the patient's strength should be kept up. If the body has been overfed on certain articles, these must be stopped, and those elements which are needed must be administered in the form of food, water, air and so on. The fever is nature's method of throwing off disease,--and if properly guided it does not become dangerous. A physician should be sent for at once. The diet prescribed for the patient and the directions in regard to quantity, temperature and time of administration should be carried out in every detail, just like other directions in regard to nursing. Many a patient has been seriously injured or even killed through the administration of foods which were forbidden by the doctor. At times there is a special desire for a particular kind of food. It may be an indication that the system requires it, and such craving should always be reported to the doctor, and if possible the physician will suggest such a food or some substitute which will answer the purpose.

The temperature of the food should be tested before serving. Blood warm is generally the best. The tray should not be loaded with a variety of foods. The patient should not be tempted with food unless forced feeding is indicated.

If the tongue is coated, give a little water with lemon juice before breakfast, especially if milk foods are to be eaten. If the appetite is not keen, do not take milk foods for breakfast.

VOMITING.

If vomiting occurs or is continued for any length of time, it may be checked by giving cold weak tea or black coffee at frequent intervals, or a few drops of brandy in a tablespoonful of ice water. In many cases it is better for the patient to have his breakfast in bed for some time after recovery, especially if the exertion of dressing is tiresome or the temperature of the room is unsuited to the patient's condition. A mild warm room is preferable to an overheated one.

DIET.

Diet for the sick may be classified as liquid, semi-liquid and solid foods. A liquid diet is generally given only during acute illness or after operations. The kind of food, as well as the amount and intervals at which it should be given, are usually prescribed by the attending physician. Therefore, only a few suggestions are given.

If nourishment by enema is necessary, predigested substances are the best; peptonized milk and malt extracts or well prepared, strained gruels of bran and oats, or of bran alone, to which one to two teaspoonsful of brandy have been added. Black cereal coffee or weak black coffee are often excellent where stimulation is desired. The amount should be from one to three ounces at a time, and the temperature should be luke warm. It must be injected very slowly.

If the patient is of a nervous temperament, or suffers from irritability of the stomach, he should have as little animal food as possible, especially for breakfast. As a rule a well prepared water gruel satisfies the demands of the body until the noon hour. It acts as a sedative and rests the whole body, and in this way more nervous energy can be expended for digestion at the noon meal.

There are some exceptions; for example, if a patient has had a restless night and is exhausted, he may have a cupful of freshly prepared whey or bran-tea with milk or cream before his breakfast. As a rule such conditions should not appear during convalescence, and may be prevented by intelligent nursing and avoidance of unnecessary company.

The greatest care should be taken not to allow a patient to eat rapidly or to take large quantities at one time, and also to avoid foods which produce fermentation.

SUGGESTIVE MENUS.

1. Breakfast.

A cup of whey with or without lemon, and albumen water.

10 to 11 A. M.

Five to ten ounces of milk, diluted with gruel or tea.

Dinner.

Gelatine prepared from barley, rice, bran or legumes and a little zwieback.

3 to 4 P. M.

Cocoa or milk (5 to 10 ounces) with zwieback.

Supper.

Malt coffee with hot cream and milk-sugar and zwieback.

If food is required at 10 p. m. or during the night, whey, blackberry juice, broth, apple water, orange juice, egg-wine, tea, coffee or lemonade may be given if allowed.

2. Breakfast.

Water gruel prepared from barley or bran, rye or steel cut oats, cream of wheat or rice. Malt coffee with triscuit.

10 to 11 A. M.

Broth with the yolk of an egg or fresh milk with crackers or crusts.

Dinner.

Gelatine of wheat or toast with sterilized cream and zwieback or ryenuts.

3 to 4 P. M.

Milk, coffee, cocoa or eggnog with zwieback or crackers.

Supper.

Chicken or clam broth with one or two tablespoonsful of cream, ryenuts or zwieback.

Allow the patient to return to simple solid foods gradually. If he tires easily of one thing, as much variety as possible should be introduced into the diet, but as a rule no more than three or four articles should be served at one meal.

3. Breakfast.

Onion gruel, bread gruel, codfish gruel or cornmeal gruel.

10 to 11 A. M.

Milk or barley water with cream and toast.

Dinner.

Toast with poached egg. Asparagus with lemon or cream dressing.

3 to 4 P. M.

Malt coffee, black or with cream, zwieback or unleavened biscuits with butter.

Supper.

Strained pea soup or cream of tomato soup with zwieback or raw celery.

4. Breakfast.

Bread soup prepared with prunes or imported root beer. (Excellent for constipation.)

10 to 11 A. M.

Milk or veal broth with the yolk of an egg, and crusts or zwieback.

Dinner.

Puree of dried green peas, beachnut bacon, zwieback, raw celery.

3 to 4 P. M.

Cold water or malt coffee.

Supper.

Beer or wine gruel or boiled custard with zwieback.

5. Breakfast.

Gruel of Cook's flaked rice or shredded wheat with butter, or hot sterilized cream.

10 to 11 A. M.

Whey or broth.

Dinner.

Spinach on toast, two eggs, beachnut bacon.

3 to 4 P. M.

Raw bran, oatmeal water, almond milk or hot or cold water.

Supper.

Sago gruel prepared with blackberries, apples or huckleberries (strained), and zwieback with butter.

6. Breakfast.

Cereal gruel prepared with two-thirds water and one-third milk or one-fifth cream.

10 to 11 A. M.

Water, whey or tea of beans, peas, lentils or bran.

Dinner.

A raw or baked apple with fish. Lettuce with mayonnaise dressing.

3 to 4 P. M.

Water, bran water or milk.

Supper.

Soup of carrots, peas or asparagus with toast.

7. Breakfast.

Cereal coffee, bran or legume tea, one slice of whole wheat toast, or stale bread. One egg.

10 to 11 A. M.

Vegetable water or whey.

Dinner.

Green pea soup with raw celery. Raw oysters and crackers with butter.

3 to 4 P. M.

Almond milk, bran water or cold or hot water.

Supper.

Baked apple with sterilized cream. Cream of celery soup with toast.

8. Breakfast.

Milk or water gruel with crusts.

Dinner.

Apple salad and lettuce with sweet breads. Orange juice.

Supper.

Cream of tomato soup or clam broth with toast and raw celery.

9. Breakfast.

Melon. Codfish cakes, raw apples or ambrosia.

Dinner.

Pea or lentil soup. Squab on toast with tomato or apple salad and lettuce.

Supper.

Cream toast or fruit soup or whey soup.

10. Breakfast.

Lettuce or watercress or celery with or without dressing. Baked potatoes, one or two eggs and beachnut bacon.

Dinner.

Broth with egg. Cream cheese with apple salad, black toast, olives.

Supper.

String beans, creamed chipped beef, crackers or triscuit.

11. Breakfast.

Green grapes, banana salad with lettuce and French dressing.

Dinner.

Three ounces of strained tomato juice, young peas with bacon or white fish, triscuit with butter and black cereal coffee.

Supper.

Sliced pineapple with gelatine and cream. Black toast.

12. Breakfast.

Gluten gruel, cream of wheat, or whey gruel.

Dinner.

Beefsteak with egg and spinach. Toast with butter.

Supper.

Milk or fruit soup or green cooked vegetables with bacon.

13. Breakfast.

Asparagus with French or cream dressing, chipped beef or boiled codfish with one or two tablespoonsful of raw wheat or rye flakes.

Dinner.

Strained tomato juice with buttered toast, or a piece of cucumber. Lamb chops with sprouts and the yolk of an egg.

Supper.

Cook's flaked rice gruel with cream or butter and the yolk of an egg.

14. Breakfast.

Lettuce, creamed potatoes with parsley and boiled ham.

Dinner.

Tomato and lettuce salad with dressing. Scrambled eggs with string beans and bacon.

Supper.

Baked apples in gelatine with cold sterilized cream and unsweetened graham crackers.

15. Breakfast.

Fruit salad of peaches or apricots with almond cream and grapenuts or ryenuts.

Dinner.

Boiled beef or chicken with mushroom sauce and rice.

Supper.

Pea soup with buttered toast. Raw celery.

16. Breakfast.

Lettuce, egg toast with cranberry or apricot sauce.

Dinner.

Tomato soup. Lima beans with the yolk of an egg and lemon. Raw celery and parsley.

Supper.

Green grapes and black toast with butter or fruit pudding with sterilized hot or cold cream.

ADDITIONAL MENUS.

I.--Light Rice with Egg and Soda Crackers--233 Calories.

Wash two tablespoonsful of rice, boil rapidly in one pint of water with a little salt until the grains burst. Then boil slowly in the oven or on the stove (uncovered) until the rice is dry. Remove from the fire and add one teaspoonful of butter, the yolk of one egg and a few drops of lemon juice. Serve plain with two soda crackers or one small round zwieback.

Calories. Rice 2 tablespoons 100 Yolk of egg 1 48 Butter 1 teaspoon 35 Crackers 2 50 ---- 233

II.--Light Rice with Egg and Cranberry Sauce--263 Calories.

Prepare the same as No. I. Pour two tablespoonsful of cranberry sauce over the rice.

Cranberry Sauce, Sterilized--190 Calories.

Put one cup of cranberries into a pint jar, add two and one-half tablespoonsful of sugar and sufficient water to fill the jar; screw tight and cook in a water bath for 40 minutes or longer. Let cool and run through a colander.

III.--A Large Glass of Mixed Milk and Cream with Cranberry or Tomato Toast--525 Calories.

Heat two small round or one long zwieback and soften with two tablespoonsful of tomato or cranberry sauce. Serve on a plate and drink the milk with it.

Calories. Milk 8 ounces 165 Cream 4 ounces 230 Zwieback 2 small 100 Fruit Juice 2 tablespoons 30 ---- 525

IV.--Cream Toast of Whole Wheat Bread or Shredded Wheat--390 Calories.

Dissolve one tablespoonful of milk sugar in one-half or three-fourths cup of boiling water and pour over one slice of whole wheat bread or biscuit. Let stand a minute, then add four ounces of hot cream, and serve.

Calories. Cream 4 ounces 230 Biscuit 1 ounce 100 Milk Sugar 1 tablespoon 60 ---- 390

V.--Cornmeal with Egg and Cranberry Sauce--271 Calories.

Cook three tablespoonsful of cornmeal in one pint of water with a little salt, for 30 or 40 minutes.

Remove from the fire. Then add one teaspoonful of butter, the yolk of one egg and a few drops of lemon. Pour on a soup plate and serve with two tablespoonsful of cranberry sauce and one soda cracker or two black crusts.

Calories. Cornmeal 3 tablespoons 108 Yolk of egg 1 48 Butter 1 teaspoon 35 Crackers or Crusts 2 50 Cranberry Sauce 2 tablespoons 30 ---- 271

VI.--Apple Soup No. 1, with Two Black Crusts--440 Calories.

Heat a tablespoonful of olive oil and one of butter, mix with a tablespoonful of white flour, gradually add one pint of boiling water and stir.

When done, wash and grate one red Oregon apple with the skin. Add the grated apple to the soup, also a pinch of salt, a teaspoonful of sugar and a stick of cinnamon. Let all boil for about 10 minutes. Remove from the fire, add another teaspoonful of butter and a few drops of lemon; mix well, pour on a soup plate and serve with two crusts.

If the stomach is very delicate, the soup must be strained.

Calories. Apple 1 large 100 Flour 1 tablespoon 30 Olive Oil 1 tablespoon 100 Butter 1 tablespoon 105 Butter 1 teaspoon 35 Sugar 1 teaspoon 20 Crusts 2 50 ---- 440

VII.--Apple Soup No. 2, with Black Crusts--535 Calories.

Prepare as the foregoing. Add one-half cup of hot cream before serving; mix well. Omit the extra teaspoonful of butter, oil and lemon.

VIII.--Apple Soup No. 3, with Black Crust--488 Calories.

Prepare as No. 1. When done, dilute the yolk of one egg with a tablespoonful of water on a soup plate, stir well and gradually add to the soup, also add a teaspoonful of butter and a few drops of lemon.

IX.--Apple Soup No. 4, with Black Crusts--515 Calories.

Prepare as No. 2, omitting the sugar. This is good for diabetic patients.

X.--Apple Soup No. 5, with Black Crusts--468 Calories.

Prepare as No. 3, omitting the sugar. This is also good for diabetic patients.

XI.--Veal Soup with Sago. Zwieback with Butter--478 Calories.

Wash and soak three tablespoonsful of sago in one-half a cup of cold or warm water for several hours. Then boil it in one cup of water with a little salt. When the sago becomes too thick, add one cup of veal stock. Let it all boil together until the sago is done. Then remove from the fire, add a teaspoonful of butter and combine with the yolk of egg as directed for Apple Soup No. 2; also add a few drops of lemon. If flavoring is desired, boil a finely cut carrot and some parsley in the water before the sago is added. Remove the vegetables before serving. Celery is also good for flavoring. Onion does not combine well with sago. A great variety of vegetables in soup is not good for patients.

Use different ones each time, and the patient will relish it better.

Calories. Sago 3 tablespoons 90 Broth 1 cup 100 Butter 1 teaspoon 35 Yolk of egg 1 48 Zwieback 2 small 100 Butter 1 tablespoonful 105 ---- 478

XII.--Veal Soup with Cream. Crusts or Zwieback--453 Calories.

Prepare like the foregoing, omitting the lemon, butter and egg, and using three ounces of hot cream.

XIII.--Veal Soup with Green Peas and Zwieback.

Soak one-fourth of a cup of dry green peas in soft water over night. Boil them in about one pint of water until tender. Then add one cup of veal stock and more water if the peas are dry. Let all boil for one-half an hour longer, then strain.

If the soup is for very young children or invalids, do not press much of the pulp through. Put one zwieback on a soup plate, pour some of the soup over it, then add one or two ounces of hot cream and serve.

The broth may be mixed with the cream and served in a cup, and the zwieback eaten with it.

XIV.--Cream of Celery Soup No. 1--293 Calories.

Wash the celery stalks, scrape and cut into one-inch pieces. Boil in a very little water, with a pinch of salt. When tender, put the celery into one cup and the water into another cup. Squeeze the juice of one-half lemon on the celery stalks and let stand for 10 or 15 minutes. Heat a tablespoonful of butter and mix with a tablespoonful of mixed flour, and add the hot celery water. If there is not sufficient fluid, add more boiling water. When done, remove from the fire, add another teaspoonful of butter, then add the celery; mix well.

If the lemon makes it too sour, pour some boiling water over the celery, and let it drain through a colander. When ready to serve, combine the soup with the yolk of an egg, as directed in Apple Soup No. 3.

If vegetables cause fermentation, they are less liable to do so if treated with acids as directed above.

Calories. Celery 3 stalks 25 Butter 1 tablespoonful 100 Mixed Flour 1 tablespoonful 35 Yolk of Egg 1 48 Butter 1 teaspoon 85 ---- 293

XV.--Cream of Celery Soup No. 2--343 Calories.

Prepare and finish like the foregoing. Add one-half cup of beef, mutton or veal broth in place of hot water.

XVI.--Cream of Celery Soup No. 3, with Two Black Crusts. 436 Calories.

Prepare like No. 1, omitting lemon, egg and extra butter, and using three ounces of hot cream instead.

XVII.--Cream of Celery Soup No. 4, with Two Black Crusts.

Cook the celery as directed in No. 1. Add two teaspoonsful of cornstarch with water, and three ounces of hot cream.

XVIII.--Cream of Asparagus Soup with Black Crusts.

Prepare in the same manner as cream of celery soup, in four different ways.

XIX.--String Bean Soup, with or without Zwieback.

Select young, tender string beans, wash, trim and shred fine or break into one-half inch pieces. Cook in a very little water. Finish like Cream of Celery Soup, with or without lemon, egg or cream.

Add plenty of chopped parsley just before removing from the fire. This soup is very purifying to the liver and intestines, but should not be given to fever patients.

XX.--Cream of Cauliflower Soup with Black Crusts.

Prepare the same as Cream of Celery Soup. The use of lemon is important for people who suffer with gas and flatulent dyspepsia.

XXI.--Whey Gruel No. 1, with Zwieback.

Heat one and one-half cupsful of sweet or slightly sour whey to the boiling point. Melt a tablespoonful of butter, mix with a tablespoonful of mixed flour and add the hot whey gradually. Boil a few minutes. Remove from the fire, add the yolk of an egg and a few drops of lemon juice. If sour whey is used, add a tablespoonful of cane-sugar while it boils, or mix the gruel with a few soaked or stewed prunes or with dried currants. Add cream in place of egg and butter, if desired.

XXII.--Whey Gruel for Two Persons--503 Calories.

Wash one-fourth of a cupful or four tablespoonsful of sago several times with cold and warm water until the water becomes clear, then soak in one-half cup of cold or warm water for several hours over night. Bring two cups of whey to a boil with the peeling of

one-half a lemon or a piece of cinnamon bark. Stir in the sago, let boil 20 minutes, and add one-fourth teaspoonful of salt. Remove from the fire and add a teaspoonful of butter, the yolk of an egg diluted with a tablespoonful of cold water, and a few drops of lemon, or leave out the egg, butter and lemon, and add three ounces of hot cream. Mix well, pour on soup plates and serve with soda crackers or zwieback, or one-half of a raw red Oregon apple. One tablespoonful of sugar may be added if allowed. Sour whey may be used instead of sweet whey.

Calories. Sago ½■ cup 120 Whey 2 cups 200 Butter 1 teaspoon 35 Yolk of egg 1 48 Zwieback 2 100 ---- 503

XXIII.--Cornstarch Gruel with Whey.

Dissolve two tablespoonsful of cornstarch in a little cold water. Add one cup of water to a pint of whey, heat and stir in the cornstarch and boil 10 to 15 minutes. Finish the same as sago gruel. Rice flour, arrowroot, white flour or mixed flour may be used instead.

TABLE OF COMMONLY USED FOODS, GIVING CALORIC VALUE.

Almonds, 10 large 100 Apples, 1 medium 92 Bacon, 1 pound 2260 Broth, 1 cup 100 Bananas, 1 large 100 Barley, 1 tablespoon, raw 90 Beans, dried, ½■ cup, raw 300 Beefsteak, ½■ pound (round) 160 Bran, 1 cup 220 Butter, 1 tablespoon 105 Blue Fish, 1 pound 400 Carrots, 1 large 50 Celery, 12 stalks 100 Codfish, 1 pound 400 Cornmeal, 1 tablespoon 36 Crackers, 1 Uneeda 25 Cheese, 1 pound American 1800 Cream, ½■ cup from separator 230 Cucumbers, 1 large 40 Currants, 1 cup (dried) 700 Dates, 10 260 Eggs, 1 whole 60 Eggs, 1 yolk 48 Eggs, 1 white 12 Figs, 10 large white 600 Rice-flour, 1 tablespoon 55 Wheat-flour, 1 tablespoon 30 Mixed flour, 1 tablespoon 35 Cornstarch, 1 tablespoon 40 Gelatine, 1 tablespoon 80 Greens, 1 cup 40 Grapenuts, 1 tablespoon 30 Honey, 1 tablespoon 100 Kumyss, 8 ounces 100 Lamb chops, 1 small 100 Lemon, 1 whole 16 Lettuce, 1 head 40 Macaroni, 1 cup (raw) 300 Milk, 8 ounces 165 Oats, rolled, 1 cup (raw) 300 Oats, steel cut, 1 cup (raw) 900 Orange, 1 large 100 Oil, 1 tablespoon 100 Peanuts, 15 100 Peaches, 1 50 Peas, ½■ pound (dried) 350 Peas, green, 1 cup 150 Prunes, 5 (dried) 100 Potatoes, 1 large 100 Raisins, 10 large 100 Raspberries, 1 cup 60 Rice, 1 tablespoon 50 Syrup, 1 tablespoon 50 Sugar, 1 tablespoon 60 Tomatoes, 1 large 50 Walnuts, 8 100 Wheat, rolled, 1 cup (raw) 250 Whey, 1 cup 100

PART FOUR

APPENDIX.

MENTAL HYGIENE AND DIET.

Proper growth and activity of the brain and nervous system are promoted by a healthy flow of blood. Pure air and sufficient protein food properly combined and proportioned with carbo-hydrate and fatty foods, rich in phosphates and minerals, are essential. Choose more of the lighter form of protein and starchy foods, as fish, eggs, almonds, green peas, bacon, a moderate amount of lamb and beef, rice, sago, wheat, and vegetable gelatines. Foods rich in minerals are celery, apples, tomatoes, greens, oranges, and practically all the fresh fruits and vegetables, especially the small berries. Melons and starchy vegetables in large quantities are suitable for muscular workers. Use as little as possible of so-called pure chemical substances, such as refined sugar and flour.

Avoid poisonous beverages, tobacco and all forms of drugs. Sleep at least nine hours in a well ventilated room, facing east or south. Avoid constipation. Combine mental work with moderate amounts of useful and enjoyable exercise, or physical work. Protect the eyes from strong artificial light. Keep the feet warm. Relax before and after meals. A certain amount of manual labor is absolutely necessary for the brain-worker. It favors deep breathing and creates a demand for more air and water, and thus improves digestion, oxidation and nutrition. The body poisons are carried off quicker and nervous headaches and despondency are avoided. Short walks out of doors before retiring are very beneficial for people who suffer with cold hands and feet.

“THE IMMIGRANT.”

All who leave the land of their birth should make themselves acquainted with the art of living and the peculiarities of the new country in which they intend to live.

To depart entirely from their old customs and habits is as dangerous as to neglect the study of the new environment or the failure to adopt necessary changes.

In some States the climatic conditions of the United States are very changeable; we have extreme heat and cold, and excess of rain with wind storms and dryness changing within a short time. West of the Rocky Mountains we have a mild sea air. In the Southern States and near the Pacific Coast we have low districts where malaria and catarrhal conditions are easily acquired.

Tropical fruits and vegetables which are looked upon as luxuries in Northern Europe are necessary articles of food in the country where they grow, therefore the stranger should make himself acquainted with such foods and by degrees learn to eat them.

In countries where the days are extremely hot and the nights are cold, the selection of foods should be made accordingly. Fats produce more than twice the amount of energy than carbohydrates, therefore they are more suitable during the early part of the day. During the middle of the day select foods of the protein class, in proper proportion with fruits and raw greens. For the evening meal use the stimulating sub-acid and sweet fruits in combination with light protein and cereal foods.

HEALTH HINTS FOR BUSY PEOPLE.

1. Keep the feet warm, the head cool and the stomach not too full.

2. Take walks out of doors daily and breathe deeply.

3. Do not wear tight shoes or tight corsets.

4. Masticate your food thoroughly. Select, combine and prepare it rightly. Do not overeat.

5. Avoid fresh breads, inferior cakes and pastry.

6. Do not eat unless you are hungry.

7. Do not over-indulge in athletic or any other kind of exercise.

8. Remember that natural feeding, pure air and sufficient sleep call for natural breathing and natural exercise.

9. Unnatural feeding and late hours create disease or nervousness.

10. Don't take drugs for sleeplessness.

11. Tired feeling in the morning is the result of nerve starvation and auto-intoxication.

12. The house we live in should be constructed for health and comfort, rather than for style.

13. Sleep by open windows. Night air is as pure as day air. Protect yourself from dampness by an open fire if necessary.

14. Do not dress and wash in a cold bath room. Have your wash bowl in the bed room.

15. Sewer gas from a small pipe in a well ventilated bed room is not harmful, as it is carried off in the air. Have the stopper placed in the hole when not in use.

16. Dress by an open fire or in a sunny room. A chill before breakfast produces indigestion and a desire for unnecessary hot foods.

17. Never sleep by night lamps or any other artificial light. They are injurious to the eyes and absorb oxygen.

18. Teach a growing child that selecting and preparing his food is an important occupation.

19. Do not allow a child to fill his body with trash.

20. Pure water is as important as pure food. If you boil your water the minerals are deposited on the bottom of the kettle instead of in the system for bone-making material.

21. Milk is a food, not a drink; it should never be taken in addition to, or at the end of, a heavy meal.

22. Many people object to boiled milk on account of a theory that it tends to constipate. Do not dwell on theories; find out the effect for yourself. Potatoes, toast and many other cooked foods are constipating also. Why not object to those?

23. Raw foods are more nutritious than cooked foods, if they are pure and fresh and can be digested without difficulty.

24. A change from cooked to raw foods might produce diarrhœa or constipation. The latter condition is generally not dangerous. Constipation from cooked foods is more dangerous.

25. A daily evacuation of the bowels is not always a sign that the stomach and intestines are in good working order. The bowels can be forced to move by the eating of too rich foods.

26. Some people are clearer in mind on a vegetarian diet, while upon others it has no such effect at all.

27. A healthy individual does not need to confine himself to a special system of diet. Avoid dangerous experiments carried on for orthodox reasons.

28. Rich soaky cooked nut foods are not health foods. If you want to be a vegetarian, live on raw foods.

29. Some people thrive on raw foods while others do not. The best time to begin with raw foods is in childhood.

30. Hot house plants cannot digest raw foods. Open your doors and windows and learn to breathe first. Fresh air and sunshine are necessary for the change of food.

31. If your teeth are poor, substitute a food-chopper or grinder for your foods.

32. The most perfect foods, such as apples, tomatoes, wheat, oats, rye, legumes and nuts seldom disagree with a healthy individual, provided they are used wisely.

33. Sunlight is a great disinfectant. Dark rooms are a breeding place for tuberculous germs.

34. Daily out-of-door exercise in the sunshine will increase health and reduce the coal bill. Without exercise our food can be of little benefit to us.

35. By natural feeding, overwork is not possible. The body demands rest when its strength is exhausted.

36. Artificial stimulants are deceivers. They make a man feel strong when he is weak. They produce artificial heat and will-power and an abnormal temperature; they lead to overwork, abnormal development and degenerate brains and bodies.

37. Natural will-power can direct its force wherever it is wanted, be it for work or rest; it can sustain on bread and water for many days.

38. Without substance there can be no power. Substantial food, fresh air, water and natural exercise develop strong bodies and minds.

39. Artificial sweets, white bread and poisonous beverages develop butterflies that crave excitement and artificial life.

40. The world is full of people that are without substance, power or principle. They earn their living the easiest way they can. Wrong feeding is responsible for such conditions.

41. Social reformers and humanitarians cannot solve problems until they have learned how to feed the race.

42. Many people are under the impression that if a certain food is recommended as especially healthful, over-indulgence must be beneficial.

43. All natural foods are wholesome; over-eating produces discomfort and disease.

44. Some fruits and vegetables have high medicinal values. Specific foods prescribed in large quantities are useful for certain ailments, but not for a healthy individual.

45. Each individual is a law unto himself. Two different people afflicted with a disease of the same name may require entirely different treatment. Human beings cannot be standardized like inert machines.

46. Canned fruits out of season are not a necessary article of food; they are of value as a medicine.

47. If certain foods do not agree, or produce indigestion, study their combination and preparation carefully, also the proportion, and time of the day when most suitable. If this does not prove satisfactory, leave them alone.

48. Don't buy cheap or inferior food of any kind.

49. Don't always believe your dealer as to the quality of the product. Investigate for yourself.

50. Don't use fruits in excess if you lead a very active life. The right proportion is the key note to maintain balance.

51. Excessive fruits and rest is a prescription for sickness.

52. If no great hunger is felt at a meal, do not eat nuts or any kind of foods classed as protein. Neither stuff yourself with liquid foods. A fast or fruits or fruit juices are the best under such conditions.

53. Do not offer a guest more food than he desires. It may be polite, but it is an unwholesome fashion.

54. Drink sufficient pure natural water between your meals. There is danger in over-drinking as well as in under-drinking.

55. A definite employment, practical and loving sympathy with our fellow men and faith in the almighty power of creation is a good prescription for imaginary diseases.

56. There is a great medicinal force in a mind of peace. If you suffer from chronic ailments brought on by overwork, seek rest and solitude, and exercise your soul. The latent powers within you can be awakened by right study. Give up wrong thoughts and habits.

57. Hard arteries are the result of high-pressure life.

58. Restlessness and sleeplessness are the result of an acid or toxic condition of the blood.

59. The liver is the great filter and germ destroyer of the body. Co-operate with nature and treat your liver right. Germs are not attracted to healthy people.

60. Many lung diseases are often the result of an abused liver.

61. Mouth-breathing is the result of structural and functional derangement.

62. Children that are allowed to sit with cold feet in the school room cannot keep their health or study their lessons.

63. A destructive or mischievous child can be corrected by proper food and sufficient suitable employments.

64. Defective teeth and eyesight are often the result of improper feeding. Glasses cannot make up the deficiency.

65. Cleanse the mouth and teeth on arising and after each meal.

66. If you wish to prevent colds, stop overloading your stomach.

HYGIENE ECONOMY AND SANITATION.

The pantry shelf with its contents is responsible for many acute diseases and ptomaine poisoning by unhygienic and careless handling and preservation of foodstuffs.

A closet for the preservation of food should be located on the north or east side of the house if possible. It should have several long and narrow windows from top to bottom, so as to allow plenty of air and light. The shelves should be constructed of wire, zinc or wooden slats, and be removable.

Raw fruits and vegetables should never be kept in the same closet with cooked food. Milk and butter should not be kept near meat or other cooked foods. Potatoes, carrots and underground vegetables should be kept out of doors or in a dry basement. They may be preserved in a box with dry sand.

Onions should not be left in a paper bag; hang them up in the sun or keep them in a flat box in a dry place. Onions which have been cut should never be used again for food, unless the cut side has been preserved in vinegar or oil.

All raw foods which have a thick skin have better keeping qualities than those with a thin skin; therefore, fancy summer fruits should be eaten while fresh on the same day they were picked. No more should be bought than can be eaten the same day, or else they should be preserved by sterilization.

Green vegetables should be used fresh if possible, and not kept longer than three or four days. Never keep them in the house or pantry.

Apples or other winter fruits should be kept in a dry store room out of doors, in the attic or in a dry basement.

The white film that often gathers around grapes is a breeding place for diphtheria germs. Wash thoroughly before eating all fruits which have been stored in houses or at the market. Do not prepare more raw food than can be eaten at one meal. Never allow it to stand after it is cut.

Many housekeepers think it important to scald their dishes, but do not know that it is far more important to sterilize or reboil cooked foods which have stood on the shelf for 18 or 24 hours and sometimes longer. Such foodstuff is dangerous long before the process of fermentation can be detected by the sense of smell or taste.

Some foods begin to undergo changes immediately after cooling; therefore, cooked foods left over, with the exception of a few, should be reboiled before serving again. Rice or other cereals should be stirred over the fire for a while and then baked in the oven until they are thoroughly sterile. The care of milk has been discussed in the chapter on food. Soups which are preserved with fat will keep wholesome for several days without reboiling. Fruits and fruit juices should not stand longer than 24 hours. Eggs are best preserved in bran or lime-water or on ice if kept for a week or longer. Boiled or thoroughly roasted meats will keep wholesome for 36 hours in a cold place. During the summer meat should not be kept from one day to another.

If left-over meat is cut from the bone and cooked up in gravy or soup stock or preserved in gelatine (with fat to cover it), it can be kept wholesome for 4 or 5 days and longer, according to the manner of preservation. Half cooked chops and beefsteak should never be kept in the same manner they are served. They should be cooked thoroughly in fat or gravy before being put away. All meats should be freshly cut and cooked the same day after delivery, or be preserved by partly cooking or roasting, until the next day. Many housekeepers keep roasts, chops and beefsteak until it looks blue and green with putrefaction before it is cooked. Never buy meat which has an unnatural color. Be sure that your butcher does not use poisonous substances to keep the meat from decomposition. Visit your butcher often and investigate how often he gets a fresh supply of meat. This is of more benefit than to save time by telephoning.

Never allow sliced bacon to lie in the ice box or pantry for several days. It becomes rancid and is unfit for food. Buy your bacon in bulk and slice it with a sharp knife when wanted.

Do not keep sliced meat of any kind longer than one day in cold weather. Do not keep it in hot weather without preserving it in gravy or fat or by sterilization.

Do not keep a tight cover on a dish, jar or bottle which contains raw or cooked food, unless the air within is sterile.

Allow cooked food to stand open until it is cool, then put the cover over two-thirds of its opening or cover with a cheese-cloth or a colander.

If milk or cream is delivered in bottles, remove the cover immediately after delivery. If the air where it stands is dusty, protect the milk with cotton or cheese-cloth. Treat boiled milk in the same manner.

Cooked foods which have poor keeping qualities should not be kept for further use, or no more should be prepared than can be eaten at one meal. To this class belong cooked underground or leaf vegetables, custards, soft puddings, milk and egg foods and gelatines. Damp or rainy weather is more favorable for decomposition of foodstuffs than dry weather.

Whites of eggs should not be kept longer than 18 or 24 hours. They must be preserved in a very cold place and be utilized at the earliest opportunity. They are like all proteins, more dangerous than starches if left to ferment, whether the fermentation begins on the pantry shelf or in the stomach. White of egg can be used in many different ways. It may be beaten to a froth and served on fruit-soups or fruit pies, or it can be taken in place of broth at the beginning of a meal. Add a tablespoon of water and a few drops of lemon or orange or apple or cranberry juice to one white of an egg and beat up with a fork, or drink without beating. White of egg can also be utilized for brancakes.

If a variety of left-over food is on hand which cannot be combined into one dish, it is better to serve different food to each member rather than to divide each article for all; the latter custom may be more polite, but it is not wise to mix a great variety of foods at one meal.

Left-over skim-milk is best utilized for cheese, pancakes, whey gruel, whey or milk sauce, or be boiled and served with stale rye or corn bread. Vegetables prepared with milk do not make a good combination. Soft puddings prepared with skim-milk, sugar and eggs, are not very wholesome unless the necessary amount of fat is added in the form of butter or suet. Skim-milk and fruit is not a good combination.

Left-over potatoes can be utilized in many different ways: for fish-cakes, pancakes, hash, potato-dumplings, creamed potatoes or for salad. Fried cooked potatoes are not a good food for the noon meal, especially for children or people doing active work.

Baked legumes if preserved with fat meat or oil can be kept on hand for a week and be rebaked two or three times per week.

PRESERVATION OF EGGS FOR THE WINTER.

Put one layer of common salt or bran one inch deep on the bottom of a wooden pail or washtub. Then grease the eggs with parafine or oil and place them with the small end down, so that they will not touch the bottom of the tub. Fill with enough salt to cover the eggs one inch.

PRESERVATION OF EGGS. No. 2.

Preserve the eggs with salicylic acid, which can be bought in the drug store. Follow directions on package.

CHILDREN.

A child should have his face and hands washed before and after each meal. He should not be allowed to carry foodstuffs and candy about the house, or touch carpets and furniture with sticky and greasy fingers. If he requires food between meals, give him four or five meals per day, but have him eat his food in the proper place.

The breeding of flies, mosquitoes and other disease carriers is greatly favored by allowing children to eat at any and all times without napkins or special preservation of their dress or without cleaning their hands before and after eating or before and after playing with animals and pets.

The American child is given too much consideration at the table. There is a great difference between the saying “I don’t like a certain food” and “I don’t want it,” because there are things which taste better.

To leave one’s plate half full of foodstuffs and ask for or accept another food is fashionable, but before the law of our Creator it is unclean and disrespectful.

The physiological laws of our bodies are based on very economical plans; nature utilizes everything and wastes nothing. Cooked foodstuffs, whether they are wasted within our bodies by over-indulgence, or in the garbage can, create decomposition and germs.

Cooked green foods and mushes are neither wholesome foods for chickens or pet animals. Natural food is dry, and animals which are fed on dry food produce a better quality of milk, eggs and flesh than animals which are fed upon slops.

DISHWASHING.

Dishwashing is a work which takes up so much time in every household, that it is a subject which should receive some attention.

The housekeeper who serves a considerable amount of raw food saves much time and strength by relieving herself of greasy dishes and saucepans.

Scrape off the fragments from plates and utensils and prepare one basin with hot soapsuds and another with rinsing water of clear hot or cold water. People whose time is valuable can save much work by placing the dishes from the drain-board upside down on a shelf prepared from wooden slats, or set them in a wire basket and let them dry without wiping.

If the dishes are not washed immediately after each meal, place the silverware and knives in a high bowl or quart measure and let them soak in hot or cold water. Remove all foods from metallic utensils immediately after the meal is over. Never allow metallic spoons to stand in fruit sauce, salt or in any kind of prepared food. Acids dissolve metal and in this way may produce poisoning.

In contagious diseases all dishes should be sterilized. Burn up all particles of left-over food, put the dishes into a narrow pail and boil with plenty of water and soda for an hour or longer.

DISINFECTION OF EXCRETA.

Use solutions of carbolic acid or chloride of lime. Mix with equal quantities of the excreta and allow it to stand for several hours before it is disposed of.

WHITEWASH FOR WOODWORK.

Soak one-fourth of a pound of glue in cold water over night. Dissolve some lime with cold water, add a few handsful of salt. Heat the glue until it is dissolved and add to one bucket of whitewash. This makes a smooth and healthy paint. Use for rough or smooth woodwork, twice per year in laundry, basement or cellar or pantry.

INDEX

PART I.

CHAPTER II.

STUDY OF FOODS.

Apples, 27

Almonds, 21

Asparagus, 19

Apricots, 26

Boiled Milk, 35

Berries, 25

Blackberries, 26

Bananas, 27

Bread, 41

Brazil Nuts, 21

Beans (dried), 18

Beans (green), 18

Barley, 31

Cereals, 29

Cabbage, 19

Cauliflower, 19

Celery, 19

Carrots and Parsnips, 19

Corn, 20

Cucumbers, 21

Chestnuts, 22

Cherries, 26

Cranberries, 29

Compotes or stewed fruits, 28

Cheese, 32

Certified Milk, 35

Cream, 35

Cocoanuts, 22

Desserts, 40

Dates, 29

Eggs, 32

Fish, 34

Fats, 37

Fruits, 23

Fruit Jellies, 28

Figs, 29

Grapes, 24

Grapefruit, 27

Hazelnuts, 22

Lentils, 18

Lemons, 27

Lettuce, 21

Limes, 27

Legumes, 18

Muffins, 41

Meat, 32

Muskmelon, 29

Milk, 34

Nuts, 24

Nut-Butter, 22

Nectarines, 27

Oats, 31

Oranges, 27

Peanuts, 22

Plums, 28

Pineapples, 27

Peaches, 26

Pears, 26

Pancakes, 41

Peas (dried), 18

Peas (green), 18

Pine Kernels, 22

Rice, 31

Raspberries, 26

Rye, 30

Sago, 31

Soups, 42

Sugar, 38

Strawberries, 25

Spices, 39

Turnips, 19

Tapioca, 31

Tomatoes, 20

Vegetable Foods, 17

Wheat, 30

Watermelons, 29

Walnuts, 22

PART II.

PREPARATION OF FOODS.

CHAPTER I.

GREEN VEGETABLES.

Artichokes, 46

Asparagus, 46

Beets, 46

Beet Greens, 46

Black Carrots, 50

Carrots, 47

Celery Roots, 50

Carrot Puree, 47

Corn, 52

Cucumbers (stewed), 50

Cauliflower, 49

Cabbage, 52

Cabbage Rolls, 54

Egg Plant, 50

Kale, 53

Kohlrabi, 52

Mushrooms, 51

Mustard Greens, 50

Mixed Vegetables, 48

Okra, 50

Onions, 51

Peas, 48

Peas and Codfish, 48

Peas and Carrots, 48

Peas with Lamb, 48

Peppers (stuffed), 51

Parsley, 51

Parsnips, 53

Potatoes, 55

Potatoes, Creamed, 55

Potatoes, Sweet, 55

Potatoes, Steamed, 56

Potatoes, Mashed, 56

Potato Salad, 55

Potato, French, 56

Potato Balls, 56

Crust Potatoes, 56

Potato Pudding, 56

Potato and Apple Puree, 56

Sauerkraut, 54

Squash, 53

Spinach, 49

Spinach, Saxon Dish, 50

String Beans, 49

Sprouts, 52

Tomatoes, 53

Tomatoes, Stewed, 54

Tomatoes, Stuffed, 54

Tomato Puree, 53

Turnips, 53

Turnip Puree, 53

Vegetable Oysters, 53

CHAPTER II.

LEGUMES AND MEATS.

Breaded Goose, 61

Brains, 61

Bean and Lentil Puree, 58

Beans (baked), 57

Beans, Lima, 58

Bean Puree, 58

Baked Lentils or Peas, 57

Bacon, boiled, 63

Bacon, fried, 63

Bacon, fat, 63

Calves' Liver, fried, 60

Calves' Liver, steamed, 60

Chipped Beef, 61

Chicken Gelatine, 59

Hash, 60

Ham Hash, 62

Hamburg Steak, 60

Kidney Hash, 60

Leaf Lard, 63

Lamb in Gelatine, 59

Meat Cake, 62

Pork Cutlets, 59

Pea Puree, 58

Ribs of Pork with Apple Filling, 63

Salisbury Steak, 61

Sour Roast, 59

Tripe, 60

Tongue, 61

Turkey Roasted, 62

Turkey Stewed, 62

Turkey in Gelatine, 62

Turkey Neck, 63

Turkey Dressing, 63

Veal Cutlets, 59

CHAPTER III.

FISH, CHEESE AND EGGS.

Codfish Cakes, 65

Fish, boiled, 64

Fish, fried, 64

Fish Cakes, 65

Herring, 64

Shell Fish, 64

Cottage Cheese, 65

Eggs, boiled, 65

Eggs, scrambled, 66

Eggs, scalloped, 66

Omelet, 66

CHAPTER IV.

SOUPS.

Asparagus Soup, 74

Bean Soup, 67

Buttermilk Soup, 73

Buttermilk with Rice, 73

Blackberry Soup, 69

Buttermilk Soup, 73

Beer Soups, 72

Barley Soups, 74

Bread Soups, 75

Bran Soups, 75

Beef Soup, 69

Beef Soup, 70

Carrot Soup, 74

Clam Chowder, 71

Clear Soup, 70

Cream of Bean Soup, 68

Cream of Pea Soup, 68

Cream of Tomato Soup, 68

Cherry Soup, 69

Huckleberry Soup, 68

Kidney Soup, 71

Knorr's Pea Soup, 72

Milk Soup, 72

Milk Soup, 73

Milk Soup, 73

Mixed Vegetable Soup, 75

Oatmeal Soup, 71

Pigeon Soup, 71

Potato Soup, 71

Plum Soup, 69

Pea Soup, 68

Spinach Soup, 74

Soup Stock, 70

Soups with Caloric Value--

Tomato Soup, 68

Vegetable Soup, 70

CHAPTER V.

CEREALS, NOODLES AND DUMPLINGS.

Almond-Rice, 79

Apple-Rice, 79

Apricot-Rice, 79

Brown Rice, 80

Bread and Milk, 78

Barley, 78

Bran Mush, 76

Bran and Rye Mush, 77

Buckwheat Groats, 76

Boiled Whole Wheat, 77

Baked Cornmeal Dumplings, 82

Bread Dumplings, 81

Cornmeal Mush, 77

Cherry Rice, 79

Currant Rice, 80

Carrot Rice, 80

Cracker and Milk, 78

Direction for Boiling Rice, 78

Dumplings, 81

Dumplings, 82

Dumplings, 83

Macaroni in Cream, 80

Macaroni in Soup Stock, 80

Milk-Rice, 78

Noodles, 80

Polenta Italian Dish, 77

Rice Cream, 79

Rice Flour, 77

Raw Whole Wheat, 77

Rylax with Prune Jam, 76

Rolled Wheat, 76

Rolled Oats with Cranberry Sauce, 76

Rhubarb Rice, 80

Steel Cut Oats, 76

Tomato-Rice, 80

CHAPTER VI.

BREADS, CAKES AND PUDDINGS.

Apple Pancakes, 92

Apple Bread Pudding, 95

Bran Muffins, 86

Bran Bread, 86

Black Bread Pudding, 96

Baked Bread Pudding, 95

Boston Brown Bread, 86

Biscuits, 85

Bread Omelet, 90

Buckwheat Cakes, 92

Cherry Pancakes, 92

Coffee Cake, 85

Cereal Omelet, 90

Corn Bread, 89

Cornmeal Pudding, 94

Crusts, 89

Black Bread, 84

Doughnuts, 90

Egg Toast, 91

Fried Bread, 89

Fish Pudding, 93

Flour Bread Pudding, 94

Frosting, 87

Fruit Cake, 88

German Pancakes, 91

German Potato Cakes, 91

Hominy Cakes, 90

Imperial Sticks, 89

Light Whole Wheat Bread, 84

Light Graham Bread, 85

Liver Pudding, 93

Mixed Flour, 88

Meat Pudding, 93

Matzoon Pudding, 93

Matzoon Cake, 93

Pop Over, 86

Pastry, 87

Plain Cake, 87

Potato Pudding, 93

Plum Pancakes, 92

Plum Pudding, 97

Plain Bread Pudding, 94

Pompernickle, 84

Roman Meal Bread, 85

Rice Fritters, 91

Rye Nuts, 88

Rice Flour Pudding, 95

Rice Pudding, 94

Roman Meal Cakes, 92

Suet Pudding, 96

Steamed Bread Pudding, 96

Sago Pudding, 94

Strawberry Short Cake, 88

Sand Tart, 87

Unleavened Pancakes, 91

Uncle Tom's Pudding, 96

Sun Dried Bread, 88

Snow Balls, 90

Whole Wheat Bread, 84

White Bread, 85

White Muffins, 86

Vegetable Pudding, 95

CHAPTER VII.

SAUCES AND SALAD DRESSINGS.

Almond Sauce, 99

Butter Sauce, 98

Bacon Sauce, 100

Cream Sauce, 99

Caper Sauce, 99

Cherry Sauce, 100

Dried Currant Sauce, 100

Dried Cherry Sauce, 101

Flavoring of Meatless Sauces, 100

Horse Radish Sauce, 99

Lemon Sauce, 100

Mint Sauce, 100

Milk Sauce, 100

Mustard Sauce, 99

Mushroom Sauce, 99

Olive Sauce, 99

Tomato Sauce, 98

White Wine Sauce, 101

Red Wine Sauce, 101

COLD DRESSINGS.

French Dressing, 101

Mayonnaise Dressing, 101

Mayonnaise Dressing, 102

Mayonnaise Dressing, 103

Syrup Dressing, 103

CHAPTER VIII.

SALADS.

Anchovy Butter, 105

Anchovy Salad, 106

Apple Salad, 107

Asparagus Salad, 107

Apple and Banana Salad, 108

Boiled Vegetable Salad, 104

Banana Salad, 107

Banana and Grape Salad, 109

Beet Salad, 109

Cereal Salad, 110

Carrot Salad, 109

Celery Root Salad, 109

Cranberry and Pear Salad, 109

Cranberry and Banana Salad, 108

Cranberry and Celery Salad, 108

Celery Salad, 106

Cabbage Salad, 106

Cheese Salad, 105

Cucumber Salad, 104

Dried Fish Salad, 106

Dandelion Salad, 106

Egg Salad, 105

Empire Salad, 105

Fish Salad, 104

Fruit Salad in Gelatine, 108

Herring Salad, 107

Yellow Dock Salad, 106

Lettuce Salad, 104

Mushroom Salad, 107

Meat Salad, 103

Mixed Spinach Salad, 109

Olive Salad, 107

Orange Salad, 107

Pineapple Salad, 108

Pineapple and Orange Salad, 108

Radish Salad, 107

Radish Salad, 109

Rhubarb Salad, 107

Raw Corn, 109

Spinach Salad, 105

Tomato Salad, 104

Tomato and Watercress Salad, 104

CHAPTER IX.

GELATINES AND TOASTS.

Banana Gelatine, 112

Buckwheat Gelatine, 113

Bean Gelatine, 115

Bread Gelatine, 115

Bran Gelatine, 114

Barley Gelatine, 113

Beer Gelatine, 112

Blanc Mange, 112

Calves' Foot Jelly, 112

Coffee Gelatine, 114

Cereal Coffee Gelatine, 115

Chocolate Gelatine, 115

Fruit Gelatine, 111

Gelatine Pudding, made with Sour Milk, 111

Lentil Gelatine, 116

Oat Gelatine, 114

Pea Gelatine, 114

Pineapple Gelatine, 112

Rice Gelatine, 113

Rye Gelatine, 114

Snow Pudding, 113

Tomato Gelatine, 113

Wine Gelatine, 115

Whipped Sweet Cream, 112

Whipped Sour Milk, 111

TOASTS.

Apple Toast, 117

Apricot Toast, 116

Barley Toast, 116

Clam Toast, 117

Celery Toast, 117

Cream Toast, 117

Egg Toast, 118

Milk Toast, 117

Oyster Toast, 117

Prune Toast, 116

Rice Toast, 116

Rye and Bran Toast, 116

Spinach Toast, 117

Tomato Toast, 116

Water Toast, 116

CHAPTER X.

FRUITS, PUDDINGS AND GRUELS.

Apple Sauce, 120

Apple Snow, 121

Apricot Sauce, 121

Apple Tapioca, 122

Ambrosia, 120

Apple Pudding, 122

Apple Sago, 125

Arrowroot Gruel, 127

Boiled Custard, 124

Blackberry Sago, 125

Bread Gruel, 125

Beer Gruel, 122

Baked Apples, 120

Baked Peaches, 120

Berry Tapioca, 122

Baked Apples in Oil, 121

Barley Gruel, 126

Currant, Raspberry or Peach Pudding, 123

Cornmeal Gruel, 126

Codfish Gruel, 126

Chocolate Cornstarch, 124

Cornstarch Gruel, 128

Dried Fruits, 119

Fig-Butter, 119

Gluten Gruel, 127

Gooseberry Pudding, 121

Gooseberry Compot, 121

Ground Dried Dates, 120

Ground Dried Prunes, 120

Lemon Filling for Pie, 123

Mixed Flour Gruel, 127

Milk Gruel, 128

Nut Gruel, 127

Onion Gruel, 125

Oatmeal Gruel, 126

Peptonized Gruel, 128

Peaches and Whipped Cream, 123

Plain Junket, 123

Rice Gruel, 124

Raisin and Currant Butter, 119

Rhubarb Pudding, 122

Sago Gruel, 128

Soaked Fruit, 119

Strawberries with Cream, 123

Stewed Blackberries, 121

Stewed Huckleberries, 121

Tomato Tapioca, 122

Wine Gruel, 123

Wine Gruel, 124

Wheat Gruel, 126

CHAPTER XI.

FLUIDS.

Apple Barley Water, 133

Albumen Water, 133

Almond Milk, 134

Bean Tea, 136

Coffee, 135

Cocoa, 135

Cocoa Shells, 136

Egg Wine, 135

Fruit Lemonade, 134

Flaxseed Tea, 133

Irish Moss, 133

Lemon Whey, 133

Lemonade with Egg, 134

Milk Eggnog, 134

Pea and Lentil Tea, 136

Raw Green Pea Juice, 133

Strawberry Milk, 134

Tea, 135

Water Eggnog, 133

Quoted from Farmers' Bulletin No. 142, by W. O. Atwater, Ph. D. U. S. Department of Agriculture.

TABLE I.--_Average composition of common American food products._

---------- | | | | | | | =Fuel= =Food Materials (As Purchased)= |=Refuse=|=Water=|=Protein=|=Fat=| =Carbohydrates= |=Ash=| =Value= | | | | || | =per lb.= ---------- =Animal Food.= | | | | | | | | % | % | % | % | % | % |=Calories= Beef, fresh: | | | | | | | Chuck ribs | 16.3| 52.6 | 15.5 | 15.0| -- | 0.8 | 910 Flank | 10.2| 54.0 | 17.0 | 19.0| -- | .7 | 1,105 Loin | 13.3| 52.5 | 16.1 | 17.5| -- | .9 | 1,025 Porterhouse steak | 12.7| 52.4 | 19.1 | 17.9| -- | .8 | 1,100 Sirloin steak | 12.8| 54.0 | 16.5 | 16.1| -- | .9 | 975 Neck | 27.6| 45.9 | 14.5 | 11.9| -- | .7 | 1,165 Ribs | 20.8| 43.8 | 13.9 | 21.2| -- | .7 | 1,135 Rib rolls | -- | 63.9 | 19.8 | 16.7| -- | .9 | 1,055 Round | 7.2| 60.7 | 19.0 | 12.8| -- | 1.0 | 890 Rump | 20.7| 45.0 | 13.8 | 20.2| -- | .7 | 1,090 Shank, fore | 36.9| 42.9 | 12.8 | 7.3| -- | .6 | 545 Shoulder and clod | 16.4| 56.8 | 16.4 | 9.8| -- | .9 | 715 Fore quarter | 18.7| 49.1 | 14.5 | 17.5| -- | .7 | 995 Hind quarter | 15.7| 50.4 | 15.4 | 18.3| -- | .7 | 1,045 Beef, corned, canned, pickled, | | | | | | | and dried: | | | | | | | Corned beef | 8.4| 49.2 | 14.3 | 23.8| -- | 4.6 | 1,245 Tongue, pickled | 6.0| 58.9 | 11.9 | 19.2| -- | 4.3 | 1,010 Dried, salted, and smoked | 4.7| 53.7 | 26.4 | 6.9| -- | 8.9 | 790 Canned boiled beef | -- | 51.8 | 25.5 | 22.5| -- | 1.3 | 1,410 Canned corned beef | -- | 51.8 | 26.3 | 18.7| -- | 4.0 | 1,270 Veal: | | | | | | Breast | 21.3| 52.0 | 15.4 | 11.0| -- | .8 | 745 Leg | 14.2| 60.1 | 15.5 | 7.9| -- | .9 | 625 Leg cutlets | 3.4| 68.3 | 20.1 | 7.5| -- | 1.0 | 695 Fore quarter | 24.5| 54.2 | 15.1 | 6.0| -- | .7 | 535 Hind quarter | 20.7| 56.2 | 16.2 | 6.6| -- | .8 | 580 Mutton: | | | | | | | Flank | 9.9| 39.0 | 13.8 | 36.9| -- | .6 | 1,770 Leg, hind | 18.4| 51.2 | 15.1 | 14.7| -- | .8 | 890 Loin chops | 16.0| 42.0 | 13.5 | 28.3| -- | .7 | 1,415 Fore quarter | 21.2| 41.6 | 12.3 | 24.5| -- | .7 | 1,235 Hind quarter, without tallow | 17.2| 45.4 | 13.8 | 23.2| -- | .7 | 1,210 Lamb: | | | | | | | Breast | 19.1| 45.5 | 15.4 | 19.1| -- | .8 | 1,075 Leg, hind | 17.4| 52.9 | 15.9 | 13.6| -- | .9 | 860 Pork, fresh: | | | | | | | Ham | 10.7| 48.0 | 13.5 | 25.9| -- | .8 | 1,320 Loin chops | 19.7| 41.8 | 13.4 | 24.2| -- | .8 | 1,245 Shoulder | 12.4| 44.9 | 12.0 | 29.8| -- | .7 | 1,450 Tenderloin | -- | 66.5 | 18.9 | 13.0| -- | 1.0 | 895 Pork, salted, cured, and pickled: | | | | | | | Ham, smoked | 13.6| 34.8 | 14.2 | 33.4| -- | 4.2 | 1,635 Shoulder, smoked | 18.2| 36.8 | 13.0 | 26.6| -- | 5.5 | 1,335 Salt pork | -- | 7.9 | 1.9 | 86.2| -- | 3.9 | 3,555 Bacon, smoked | 7.7| 17.4 | 9.1 | 62.2| -- | 4.1 | 2,715 Sausage: | | | | | | | Bologna | 3.3| 55.2 | 18.2 | 19.7| -- | 3.8 | 1,155 Pork | -- | 39.8 | 13.0 | 44.2| 1.1 | 2.2 | 2,075 Frankfort | -- | 57.2 | 19.6 | 18.6| 1.1 | 3.4 | 1,155 Soups: | | | | | | | Celery, cream of | -- | 88.6 | 2.1 | 2.8| 5.0 | 1.5 | 235 Beef | -- | 92.9 | 4.4 | .4| 1.1 | 1.2 | 120 Meat stew | -- | 84.5 | 4.6 | 4.3| 5.5 | 1.1 | 365 Tomato | -- | 90.0 | 1.8 | 1.1| 5.6 | 1.5 | 185 Poultry: | | | | | | | Chicken, broilers | 41.6| 43.7 | 12.8 | 1.4| -- | .7 | 305 Fowls | 25.9| 47.1 | 13.7 | 12.3| -- | .7 | 765 Goose | 17.6| 38.5 | 13.4 | 29.8| -- | .7 | 1,475 Turkey | 22.7| 42.4 | 16.1 | 18.4| -- | .8 | 1,060 Fish: | | | | | | | Cod, dressed | 29.9| 58.5 | 11.1 | .2| -- | .8 | 220 Halibut, steaks or sections | 17.7| 61.9 | 15.3 | 4.4| -- | .9 | 475 Mackerel, whole | 44.7| 40.4 | 10.2 | 4.2| -- | .7 | 370 Perch, yellow, dressed | 35.1| 50.7 | 12.8 | .7| -- | .9 | 275 Shad, whole | 50.1| 35.2 | 9.4 | 4.8| -- | .7 | 880 Shad, roe | -- | 71.2 | 20.9 | 3.8| 2.6 | 1.5 | 600 Fish, preserved: | | | | | | | Cod, salt | 24.9| 40.2 | 16.0 | .4| -- |18.5 | 325 Herring, smoked | 44.4| 19.2 | 20.5 | 8.8| -- | 7.4 | 755 Fish, canned: | | | | | | | Salmon | -- | 68.5 | 21.8 | 12.1| -- | 2.6 | 915 Sardines | [1]5.0| 53.6 | 23.7 | 12.1| -- | 5.3 | 950 Shellfish: | | | | | | | Oysters, "solids" | -- | 88.3 | 6.0 | 1.3| 3.3 | 1.1 | 225 Clams | -- | 80.8 | 10.6 | 1.1| 5.2 | 2.3 | 340 Crabs | 52.4| 36.7 | 7.9 | .9| .6 | 1.5 | 200 Lobsters | 61.7| 30.7 | 5.9 | .7| .2 | .8 | 145 Eggs: Hens' eggs | [2]11.2| 65.5 | 13.1 | 9.3| -- | 0.9 | 685 Dairy products, etc.: | | | | | | | Butter | -- | 11.0 | 1.0 | 85.0| -- | 3.0 | 3,410 Whole milk | -- | 87.0 | 3.3 | 4.0| 5.0 | .7 | 310 Skim milk | -- | 90.5 | 3.4 | .3| 5.1 | .7 | 165 Buttermilk | -- | 91.0 | 3.0 | .5| 4.8 | .7 | 160 Condensed milk | -- | 26.9 | 8.8 | 8.3| 54.1 | 1.9 | 1,480 Cream | -- | 74.0 | 2.5 | 18.5| 4.5 | .5 | 865 Cheese, Cheddar | -- | 27.4 | 27.7 | 36.8| 4.1 | 4.0 | 2,075 Cheese, full cream | -- | 34.2 | 25.9 | 33.7| 2.7 | 3.8 | 1,885 | | | | | | | =Vegetable Food.= | | | | | | | | | | | | | | Flour, meal, etc.: | | | | | | | Entire-wheat flour | -- | 11.4 | 13.8 | 1.9| 71.9 | 1.0 | 1,650 Graham flour | -- | 11.3 | 13.3 | 2.2| 71.4 | 1.8 | 1,645 Wheat flour, patent roller process | | | | | | | High-grade and medium | -- | 12.0 | 11.4 | 1.0| 75.1 | .5 | 1,635 Low grade | -- | 12.0 | 14.0 | 1.9| 71.2 | .9 | 1,640 Macaroni, vermicelli, etc.: | -- | 10.3 |

13.4 | .9| 74.1 | 1.3 | 1,645 Wheat breakfast food | -- | 9.6 | 12.1 | 1.8| 75.2 | 1.3 | 1,680 Buckwheat flour | -- | 13.6 | 6.4 | 1.2| 77.9 | .9 | 1,605 Rye flour | -- | 12.9 | 6.8 | .9| 78.7 | .7 | 1,620 Corn meal | -- | 12.5 | 9.2 | 1.9| 75.4 | 1.0 | 1,685 Oat breakfast food | -- | 7.7 | 16.7 | 7.3| 66.2 | 2.1 | 1,800 Rice | -- | 12.3 | 8.0 | .3| 79.0 | .4 | 1,620 Tapioca | -- | 11.4 | .4 | .1| 88.0 | .1 | 1,650 Starch | -- | -- | -- | -- | 90.0 | -- | 1,675 Bread, pastry, etc.: | | | | | | | White bread | -- | 35.3 | 9.2 | 1.3| 53.1 | 1.1 | 1,200 Brown bread | -- | 43.6 | 5.4 | 1.8| 47.1 | 2.1 | 1,040 Graham bread | -- | 35.7 | 8.9 | 1.8| 52.1 | 1.5 | 1,195 Whole-wheat bread | -- | 38.4 | 9.7 | .9| 49.7 | 1.3 | 1,130 Rye bread | -- | 35.7 | 9.0 | .6| 53.2 | 1.5 | 1,170 Cake | -- | 19.9 | 6.3 | 9.0| 63.3 | 1.5 | 1,630 Cream crackers | -- | 6.8 | 9.7 | 12.1| 69.7 | 1.7 | 1,925 Oyster crackers | -- | 4.8 | 11.3 | 10.5| 70.5 | 2.9 | 1,910 Soda crackers | -- | 5.9 | 9.8 | 9.1| 73.1 | 2.1 | 1,875 Sugars, etc.: | | | | | | | Molasses | -- | -- | -- | -- | 70.0 | -- | 1,225 Candy[3] | -- | -- | -- | -- | 96.0 | -- | 1,680 Honey | -- | -- | -- | -- | 81.0 | -- | 1,420 Sugar, granulated | -- | -- | -- | -- | 100.0 | -- | 1,750 Maple sirup | -- | -- | -- | -- | 71.4 | -- | 1,250 Vegetable:[4] | | | | | | | Beans, dried | -- | 12.6 | 22.5 | 1.8| 59.6 | 3.5 | 1,520 Beans, Lima, shelled | -- | 68.5 | 7.1 | .7| 22.0 | 1.7 | 540 Beans, string | 7.0| 83.0 | 2.1 | .3| 6.9 | .7 | 170 Beets | 20.0| 70.0 | 1.3 | .1| 7.7 | .9 | 160 Cabbage | 15.0| 77.7 | 1.4 | .2| 4.8 | .9 | 115 Celery | 20.0| 75.6 | .9 | .1| 2.6 | .8 | 65 Corn, green (sweet) edible portion | -- | 75.4 | 3.1 | 1.1| 19.7 | .7 | 440 Cucumbers | 15.0| 81.1 | .7 | .2| 2.6 | .4 | 65 Lettuce | 15.0| 80.5 | 1.0 | .2| 2.5 | .8 | 65 Mushrooms | -- | 88.1 | 3.5 | .4| 6.8 | 1.2 | 185 Onions | 10.0| 79.8 | 1.4 | .3| 8.9 | .5 | 190 Parsnips | 20.0| 66.4 | 1.3 | .4| 10.8 | 1.1 | 230 Peas (Pisum sativum), dried | -- | 9.5 | 24.6 | 1.0| 62.0 | 2.9 | 1,565 Peas (Pisum sativum), shelled | -- | 74.6 | 7.0 | .5| 16.9 | 1.0 | 440 Cowpeas, dried | -- | 13.0 | 21.4 | 1.4| 60.8 | 3.4 | 1,505 Potatoes | 20.0| 62.6 | 1.8 | .1| 14.7 | .8 | 295 Rhubarb | 40.0| 56.6 | .4 | .4| 2.2 | .4 | 60 Sweet potatoes | 20.0| 55.2 | 1.4 | .6| 21.9 | .9 | 440 Spinach | -- | 92.3 | 2.1 | .3| 3.2 | 2.1 | 95 Squash | 50.0| 44.2 | .7 | .2| 4.5 | .4 | 100 Tomatoes | -- | 94.3 | .9 | .4| 3.9 | .5 | 100 Turnips | 30.0| 62.7 | .9 | .1| 5.7 | .6 | 120 Vegetables, canned: | | | | | | | Baked beans | -- | 68.9 | 6.9 | 2.5| 19.6 | 2.1 | 555 Peas (Pisum sativum), green | -- | 85.3 | 3.6 | .2| 9.8 | 1.1 | 235 Corn, green | -- | 76.1 | 2.8 | 1.2| 19.0 | .9 | 430 Succotash | -- | 75.9 | 3.6 | 1.0| 18.6 | .9 | 425 Tomatoes | -- | 94.0 | 1.2 | .2| 4.0 | .6 | 95 Fruits, berries, etc., fresh:[5] | | | | | | | Apples | 25.0| 63.3 | 0.3 | 0.3| 10.8 | 0.3 | 190 Bananas | 35.0| 48.9 | .8 | .4| 14.3 | .6 | 260 Grapes | 25.0| 58.0 | 1.0 | 1.2| 14.4 | .4 | 295 Lemons | 30.0| 62.5 | .7 | .5| 5.9 | .4 | 125 Muskmelons | 50.0| 44.8 | .3 | -- | 4.6 | .3 | 80 Oranges | 27.0| 63.4 | .6 | .1| 8.5 | .4 | 150 Pears | 10.0| 76.0 | .5 | .4| 12.7 | .4 | 230 Persimmons, edible portion | -- | 66.1 | .8 | .7| 31.5 | .9 | 550 Raspberries | -- | 85.8 | 1.0 | -- | 12.6 | .6 | 220 Strawberries | 5.0| 85.9 | .9 | .6| 7.0 | .6 | 150 Watermelons | 59.4| 37.5 | .2 | .1| 2.7 | .1 | 50 Fruits, dried: | | | | | | | Apples | -- | 28.1 | 1.6 | 2.2| 66.1 | 2.0 | 1,185 Apricots | -- | 29.4 | 4.7 | 1.0| 62.5 | 2.4 | 1,125 Dates | 10.0| 13.8 | 1.9 | 2.5| 70.6 | 1.2 | 1,275 Figs | -- | 18.8 | 4.3 | .3| 74.2 | 2.4 | 1,280 Raisins | 10.0| 13.1 | 2.3 | 3.0| 68.5 | 3.1 | 1,265 Nuts: | | | | | | | Almonds | 45.0| 2.7 | 11.5 | 30.2| 9.5 | 1.1 | 1,515 Brazil nuts | 49.6| 2.6 | 8.6 | 33.7| 3.5 | 2.0 | 1,485 Butternuts | 86.4| .6 | 3.8 | 8.3| .5 | .4 | 385 Chestnuts, fresh | 16.0| 37.8 | 5.2 | 4.5| 35.4 | 1.1 | 915 Chestnuts, dried | 24.0| 4.5 | 8.1 | 5.3| 56.4 | 1.7 | 1,385 Cocoanuts |[6]148.8| 7.2 | 2.9 | 25.9| 14.3 | .9 | 1,295 Cocoanuts, prepared | -- | 3.5 | 6.3 | 57.4| 31.5 | 1.3 | 2,865 Filberts | 52.1| 1.8 | 7.5 | 31.3| 6.2 | 1.1 | 1,430 Hickory nuts | 62.2| 1.4 | 5.8 | 25.5| 4.3 | .8 | 1,145 Pecans, polished | 53.2| 1.4 | 5.2 | 33.3| 6.2 | .7 | 1,465 Peanuts | 24.5| 6.9 | 19.5 | 29.1| 18.5 | 1.5 | 1,775 Pinon (Pinus edulis) | 40.6| 2.0 | 8.7 | 36.8| 10.2 | 1.7 | 1,730 Walnuts, black | 74.1| .6 | 7.2 | 14.6| 3.0 | .5 | 730 Walnuts, English | 58.1| 1.0 | 6.9 | 26.6| 6.8 | .6 | 1,250 Miscellaneous: | | | | | | Chocolate | -- | 5.9 | 12.9 | 48.7| 30.3 | 2.2 | 2,625 Cocoa, powdered | -- | 4.6 | 21.6 | 28.9| 37.7 | 7.2 | 2,160 Cereal coffee infusion (1 part | | | | | | | boiled in 20 parts water)[7] | -- | 98.2 | .2 | -- | 1.4 | .2 | 30

[1] Refuse, oil.

[2] Refuse, shell.

[3] Plain confectionery not containing nuts, fruit, or chocolate.

[4] Such vegetables as potatoes, squash, beets, etc., have a certain amount of inedible material, skin, seeds, etc. The amount varies with the method of preparing the vegetables, and cannot be accurately estimated. The figures given for refuse of vegetables, fruits, etc., are assumed to represent approximately the amount of refuse in these foods as ordinarily prepared.

[5] Fruits contain a certain proportion of inedible materials, as skins, seeds, etc., which are properly classed as refuse. In some fruits, as oranges and prunes, the amount rejected in eating is practically the same as refuse. In others, as apples and pears, more or less of the edible material is ordinarily rejected with the skin and seeds and other inedible portions. The edible material which is thus thrown away, and should properly be classed with the waste, is here classed with the refuse. The figures for refuse here given represent, as nearly as can be ascertained, the quantities ordinarily rejected.

[6] Milk and shell.

[7] The average of five analyses of cereal coffee grain is: Water 6.2, protein 13.3, fat 3.4, carbohydrates 72.6, and ash 4.5 per cent. Only a portion of the nutrients, however, enter into the infusion. The average in the table represents the available nutrients in the

beverage. Infusions of genuine coffee and of tea like the above contain practically no nutrients.

TABLE II.--_Food consumption of persons in different circumstances, and proposed dietary standards._

(Quantities per man per day.)

---------- =No. of= | =Actually Eaten= | =Digestible= | | =Studies= |---------+-----+-------+---------+-----+-------+ =Fuel= |=Nutritive= =Incl. in Av'ge=| =Protein= | =Fat= | =Carbohydrates= | =Protein= | =Fat= | =Carbohydrates= | Value=| Ratio=

---------- =Persons with Active Work.= | | =gms= |=gms=| =gms= | =gms= |=gms=| =gms= |=Calories= | _I_: Rowing clubs in New England | 7 | 155 | 177 | 440 | 143 | 168 | 427 | 3,955| 5.6 Bicyclists in New York | 3 | 186 | 186 | 651 | 171 | 177 | 631 | 5,005| 6 Football teams in Connecticut and | | | | | | | | | California | 2 | 226 | 354 | 634 | 208 | 336 | 615 | 6,590| 6.6 Prussian machinists | 1 | 139 | 113 | 677 | 128 | 107 | 657 | 4,270| 7 Swedish mechanics | 5 | 189 | 110 | 714 | 174 | 104 | 693 | 4,590| 5.3 | | | | | | | | | =Persons with Ordinary Work.= | | | | | | | | | | | | | | | | | | | Farmers' families in Eastern United | | | | | | | | | States | 10 | 97 | 130 | 467 | 89 | 124 | 453 | 3,415| 8.2 Mechanics' families in United States | 14 | 103 | 150 | 402 | 95 | 143 | 390 | 3,355| 7.5 Laborers' families in large cities | | | | | | | | | of United States | 12 | 101 | 116 | 344 | 93 | 110 | 834 | 2,810| 6.3 Laborers' families in United States | | | | | | | | | (more comfortable circumstances) | 2 | 120 | 147 | 534 | 110 | 140 | 518 | 8,925| 7.6 Russian peasants | -- | 129 | 33 | 589 | 119 | 31 | 571 | 3,165| 5.4 Swedish mechanics | 6 | 134 | 79 | 523 | 123 | 75 | 507 | 3,380| 5.5 | | | | | | | | | =Professional Men.= | | | | | | | | | | | | | | | | | | | Lawyers, teachers, etc., in United | | | | | | | | | States | 14 | 104 | 125 | 423 | 96 | 119 | 410 | 3,220| 7.1 College clubs in United States | 15 | 107 | 148 | 459 | 98 | 141 | 445 | 3,580| 7.8 German physicians | 2 | 131 | 95 | 327 | 121 | 90 | 317 | 2,680| 4.3 Japanese professor | 1 | 123 | 21 | 416 | 113 | 19 | 403 | 2,345| 4 | | | | | | | | | =Men with Little or no Exercise.= | | | | | | | | | | | | | | | | | | | Men (American) in respiration | | | | | | | | | calorimeter | 11 | 112 | 80 | 305 | 103 | 76 | 296 | 2,380| 4.5 Men (German) in respiration | | | | | | | | | apparatus | 5 | 127 | 80 | 302 | 117 | 76 | 293 | 2,430| 4 | | | | | | | | | =Persons in Destitute Circumstances.=| | | | | | | | | | | | | | | | | | | Poor families in New York City | 11 | 93 | 95 | 407 | 86 | 90 | 895 | 2,845| 6.9 Laborers' families in Pittsburg, Pa. | 2 | 80 | 95 | 308 | 74 | 90 | 299 | 2,400| 6.8 German Laborer's family | 1 | 52 | 32 | 287 | 48 | 30 | 278 | 1,640| 7.2 Italian mechanics | 5 | 76 | 38 | 396 | 70 | 36 | 384 | 2,225| 6.6 | | | | | | | | | =Miscellaneous.= | | | | | | | | | | | | | | | | | | | Negro families in Alabama and | | | | | | | | | Virginia | 39 | 86 | 145 | 440 | 79 | 188 | 427 | 3,895| 9.3 Italian families in Chicago | 4 | 103 | 111 | 391 | 95 | 105 | 379 | 2,965| 6.5 French Canadians in Chicago | 5 | 118 | 158 | 345 | 109 | 150 | 335 | 3,260| 6.2 Bohemian families in Chicago | 8 | 115 | 101 | 360 | 106 | 96 | 3499 | 2,800| 5.3 Inhabitants Java village, Columbian | | | | | | | | | Exposition, 1893 | 1 | 66 | 19 | 254 | 61 | 18 | 246 | 1,450| 4.7 Russian Jews in Chicago | 10 | 137 | 103 | 418 | 126 | 98 | 405 | 3,135| 5 Mexican families in New Mexico | 4 | 94 | 71 | 613 | 86 | 67 | 595 | 3,460| 8.7 Chinese dentist in California | 1 | 115 | 113 | 289 | 106 | 107 | 280 | 2,620| 4.9 Chinese laundryman in California | 1 | 135 | 76 | 566 | 124 | 72 | 549 | 3,480| 5.7 Chinese farm laborer in California | 1 | 144 | 95 | 640 | 132 | 90 | 621 | 3,980| 6.2 United States Army ration, peace | -- | 120 | 161 | 454 | 110 | 153 | 440 | 3,730| 7.1 German Army ration, peace | -- | 114 | 39 | 480 | 105 | 37 | 466 | 2,275| 5.2 | | | | | | | | | =Dietary Standards.= | | | | | | | | | | | | | | | | | | | Man at hard work (Voit) | -- | 145 | 100 | 450 | 133 | 95 | 437 | 3,270| 4.9 Man at moderate work (Voit) | -- | 118 | 56 | 500 | 109 | 53 | 485 | 2,965| 5.5 Man with very hard muscular work | | | | | | | | | (Atwater) | -- | 175 | [8] | [8] | 161 | [8] | [8] | 5,500| 7.2 Man with hard muscular work (Atwater)| -- | 150 | [8] | [8] | 138 | [8] | [8] | 4,150| 6.2 Man with moderately active muscular | | | | | | | work (Atwater) | -- | 125 | [8] | [8] | 115 | [8] | [8] | 3,400| 6.2 Man with light to moderate muscular | | | | | | | | | work (Atwater) | -- | 112 | [8] | [8] | 103 | [8] | [8] | 3,050| 6.1 Man at "sedentary" or woman with | | | | | | | | | moderately active work (Atwater) | -- | 100 | [8] | [8] | 92 | [8] | [8] | 2,700| 6.1 Woman at light to moderate muscular | | | | | | | | | work, or man without muscular | | | | | | | | | exercise (Atwater) | -- | 90 | [8] | [8] | 83 | [8] | [8] | 2,450| 6.1

[8] Fats and carbohydrates in sufficient amounts to furnish, together with the protein, the indicated amount of energy.

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Constipation and its correction by exercise

C. O. Benson

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TRANSCRIBER'S NOTE

Italic text is denoted by _underscores_.

Some minor changes to the text are noted at the end of the book.

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Constipation and Its Correction by Exercise

C. O. Benson

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CONTENTS

Page

Causes of Constipation 7

Exercises for the Prevention and Correction of Constipation 20

CONSTIPATION AND ITS CORRECTION BY EXERCISE

Constipation or dyskinesia is one of the important influences in making people old before their time. The breaking down of the faculties and functions supposed to be due to old age is in reality due to the accumulation of waste and bacteria in the intestines. A habit of life which keeps the bowels clean will set "old age" back to the time when men will enjoy perfect health to the utmost limit of a normal span of years (at the present time the normal span is fifty-eight years).

There are many people who think they are quite normal, though they never had a regular daily movement of the bowels without the aid of laxatives in years. Yet, these same persons will not let the gasoline line on their automobile stay clogged one day.

The body is a very delicate organism and it must be taken care of in a thoughtful fashion. A poisoned night is spent if a day is missed without a bowel movement, for the body cannot carry waste a great length of time without serious injury to it. Under a normal life the bowels should move at least once a day without artificial aid.

Results of Constipation

When food remains too long in the body it decays, putrefies, and develops into very active poisons. With this decaying comes a depressing feeling caused by these wastes being absorbed into the blood. Then, to make matters worse, this putrification retards the bowel action, thus keeping the poisons in the body. Thus, constipation results. Some of these poisons are not so harmful, yet others are very capable of infecting the body, and these enter the blood stream via the intestines and reach other organs where they may cause a chronic disease.

Constipation brings many other ills besides that of poisoning and infecting the body. If this decay occurs too frequently, very serious infections may develop. Frequently diseases associated with old age, such as rheumatism, kidney trouble, and disturbances of the gall bladder are the result of a constipated condition which has run for years. The retained masses of putrefied food in the digestive tract many times displaces and distends the bowels with the ultimate result that it reacts on the nervous system and the circulation of the liver, and causes much suffering. Appendicitis is often traced to the continuous constipated condition.

Other results of constipation can be dizziness, offensive breath, headache, loss of pep and vitality, bad temper, poor complexion, stomach disorders, skin eruptions, sleepless nights, loss of appetite, stupor, and piles.

CAUSES OF CONSTIPATION

Lack of Exercise

One who leads an inactive life must expect to have a flabby body. Lack of exercise lowers the tone of the whole body and especially the abdominal viscera. This is an unhealthy way to live, for it offers no incentive to the stomach and intestines for the vigorous digestion of food. A good workout daily will stimulate and tone the intestines for better functioning.

Unless your work involves a great deal of outdoor walking, a daily walk cannot be over-estimated in the treatment of constipation. Learn to stride along with the head and chest up, breathing deeply. Walking in this fashion will do as much good the last ten minutes as the first ten. This exercise will stimulate the appetite and increase the physical and mental tone of the body. It is a life-enriching as well as life-purifying habit.

Learn to take a few workouts in the gym every week, that is, if you are physically able. However, before you plan your workout have your health doctor plan your program and limitations and what it should include.

In the back of the book will be found exercises that will aid in the correction of constipation. These exercises will be found very beneficial if used daily.

Improper Diet

One of the chief causes of constipation is improper diet. Correct feeding alone may cure constipation. Even this rule has its exception, for there is a form of constipation associated with proper diet. This brings out the point that it is essential to have a health examination frequently by your family doctor, for he will give you correct knowledge of the condition of your body immediately.

Before taking up the matter of food, it must be remembered that the purpose of this book is to give exercises to cure constipation and not to plan a diet. Your doctor will give you a correct diet. However, it is essential that the food should be chewed until it is almost a pulp before swallowing. This will aid the stomach and whole digestive tract in assimilating the food.

The spirit of happiness and cheerfulness is important when eating. It cannot be over-emphasized. In fact, laughter during the meal time is very good for the digestive tract in digesting the food. This buoyancy of the mind will aid a great deal in the correction of constipation. It is the only exercise that can be used successfully while eating. Do not be downcast while eating, as this will prevent normal digestion.

The typical breakfast is usually orange juice, eggs, toast or rolls and coffee. This breakfast will satisfy hunger and supply energy, but it does not meet the demands of health. It is true that this breakfast includes the necessary nutriments, but it does not contain bulk or roughage, which are sometimes desirable in order to give the bowels something to work upon.

In order to give the body foods with roughage bran may be used in moderation. However, bran does not agree with everyone. The indulgence in this food should depend upon the advice of your physician.

Fruit will cure constipation quicker than any constipation remedies ever advertised. Oranges, orange juice, figs, dates, and prunes are very good for the prevention as well as the correction of constipation. It is a very excellent idea to have some form of fruit for every meal. It cannot be over-emphasized.

Vegetables are an absolute necessity in everyone's diet. Nature gives us food values that cannot be estimated in importance. They clean the interior of the body and act as a broom in the digestive tract, that is, if they are eaten twice a day. They are a mechanical necessity to the intestines. Their bulk is absolutely needed to stimulate the intestines to activity.

Foods which contain no mechanical stimulation such as purées and gruel are open to objection. Pastries are very constipating due to the pasty element, for the secretions of the digestive tract cannot assimilate them. The psychic effect of a monotonous diet may cause poor digestion resulting in constipation. Such foods as eggs, milk, cheese--particularly cottage, pot smearcase and cream, white rice, tea, chocolate are said to be constipating because they seem to slow up the action of the intestinal tract.

On the whole, eat foods that originally gave the human race its vigor, and you will get all the food values, the sunshine, and fresh air, which that food has absorbed during the days of its growth.

Laxatives

Laxatives do not cure constipation. They may serve to make it chronic. Yet one fourth of the people use them regularly. They only give artificial stimulation to the bowel movements. Every laxative, no matter how innocent in itself, is a habit forming drug for the bowels. They lash the bowel into action once or twice or a few times. After that the bowels will refuse to work without a laxative administered. The dose becomes larger and larger until heroic doses are consumed. NO LAXATIVE OR ANY FORM OF BOWEL WASHING SHOULD BE TAKEN UNLESS ADVISED BY A PHYSICIAN.

Posture

Poor posture ranks on a par with lack of exercise and improper diet in the cause of constipation. Poor posture aids in the slipping of the abdominal organs out of their respective places, resulting in a tangled mass which will act as an interference on the normal bowel action. As a general rule, poor posture hinders deep breathing. Thus, there is no compressing movement upon the organs of the abdominal regions, such as is found in a normal upright person. Deep, vigorous breathing is an aid to a normal bowel movement. Good posture is an absolute necessity for the freedom of the bowel acting.

During Defecation

Faulty posture during defecation causes insufficient emptying or difficulty in moving the bowels at all. Many closet seats are too high. The proper altitude is one that brings the knees a little higher than the posterior.

A high closet seat can be remedied by using a footstool to support the feet, thus bringing the body into proper posture.

Hurried Defecation

A normal defecation ordinarily takes about two to three minutes, but owing to the abuse of resisting the call, ordinary defecation is not always secured in the normal time. Thus residue is left in the large intestine. This offers difficulty when a call comes some later hour, for the residue becomes hard and dry. This residue in the colon results in the condition known as

Irregularity in Answering Call

Irregularity in answering nature's call causes irregularity of bowel action. Nature's call means that enough waste is in the colon to cause automatic processes to set in action the bowel movement.

If for any reason the bowels are not permitted to move at once, the call usually disappears in a few minutes and may not reappear for some time. Thus, the wastes lie in the colon with the water in them being absorbed by the intestine, causing the wastes to become dry. Due to these wastes remaining in the intestine distention is produced in the colon and defecation may become difficult or impossible without mechanical aid.

The water of the waste which is absorbed into the blood stream affects the body, causing lower vitality and fatigue affecting the nerves.

Treatment

Hygiene is an important factor in restoring the body to a condition of health. The various abuses of the body that make for constipation should be corrected. General habits, and especially that of neglecting nature's call, should be corrected. Without good hygiene the treatment of constipation cannot be successful.

Proper Diet

See your doctor and have him make out a proper diet. However, the diet should contain a sufficient amount of roughage, such as vegetables, fruits, and bran. Milk should be used for its vitamin qualities and nourishment.

Rules for Proper Eating

1. Do not eat too much.

2. Do not study your food while eating.

3. Enjoy what you eat.

4. Chew your food until it swallows itself.

5. Eat regularly.

6. Do not eat when tired.

7. Take a brisk short walk after eating, as this is an aid to the digestive processes.

Laxatives and Enemas

These should be used only upon the consent of your doctor. They do not cure, and if possible should be avoided.

Mental Attitude

Patience is necessary, and the feeling "I can't" should be changed to "I will." This feeling can do more than drugs. Do not hurry defecation.

Regularity

Visit the toilet at least once a day--not to read but to move the bowels. Aim to establish a habit by visiting the toilet the same time every day.

Use of Water

Most people drink too little water. Six glasses of water a day is the minimum and eight are better. Even more should be taken in hot weather. Avoid ice water, for it chills the stomach. If ice water is the only water available, sip it slowly.

Water should be taken freely between meals. A glass at each meal will help digestion, and there is nothing that so helps the bowels as a glass or two of water before retiring.

Bathing

After taking the exercises described in the back of the book a bath should be taken. Take a shower or tub bath for two minutes with the temperature between 95° and 100° F. for cleansing purposes. This should be followed by a quick cold rub over the entire body. Dry with a rough towel until the skin glows. This should be followed by a cold wet towel rubbed on the abdomen for a few minutes until it attains a reddish glow. Then dry the body thoroughly, dress quickly, and you will have a keen appetite for the morning meal.

Exercises

The effectiveness of certain exercises in overcoming constipation has been scientifically proved. Diet alone will not cure constipation. Diet and exercise should be used together, and the victim of constipation should not neglect either. Suitable diet and proper exercises can usually be relied upon to cure the most obstinate case of constipation. They will very frequently banish that tired feeling and make one tingle with energy and vitality.

Every one needs exercise other than his work, for work tires the same old muscles and the same old back day after day, while it neglects the vital muscles around the waist. Work wearies, while exercise refreshes. Exercise builds up the muscular system and makes work easier. Exercise may be harmful if too vigorous, and if the patient is not accustomed to it. These exercises as described below should be indulged in mildly at first, and as the body becomes accustomed to exercise increase the dosage.

Monotony in doing the same old exercise cannot be condemned too vigorously. It is better to spread the dosage of work around the different parts of the body rather than to concentrate too vigorously on the muscles of the waist. The continuous repetition of certain movements results in fatigue, which causes atonic conditions about the parts involved.

Regular exercises in the open air and getting the abdominal muscles and organs in first rate condition is the first step in securing longevity of life and renewed vitality. This will increase the appetite and strengthen the voluntary muscles of defecation. Vigorous exercise diverts the thoughts from business and household cares and relieves an important factor in constipation. Hill climbing, walking, running, horseback riding, and all forms of games are the best forms of exercise for the cure of constipation. It so happens in many cases that the individual is not physically fit for such activities, and then the following exercises cannot be used to advantage until the patient is able to participate in recreative exercises and games.

In the following exercises that of raising both legs to a right angle from the lying position is purposely omitted because of the severe action on the abdomen and the paralyzing effect on the sensitive nervous systems of that region. Often an exaggerated condition of constipation comes from this type of exercise.

In the following exercises it must be remembered that good posture is necessary for the proper effect on the vital organs.

EXERCISES FOR THE PREVENTION AND CORRECTION OF CONSTIPATION

EXERCISE 1

Position: Lying on back on floor, hands on sides, legs straight.

Action: Arch the body upward, forming a bridge with the weight resting on the heels and shoulders.

Remarks: This is an excellent exercise before retiring. It can be done ten to twenty times without fatigue.

EXERCISE 2

Position: Feet apart, arms side shoulder level.

Action: Twist the body to the right side, bend slightly forward, keeping the knees straight and touch the right foot with the left hand, the right arm being stretched straight up over the body toward the ceiling. Exhale and draw abdomen well in. Repeat exercise twisting the body to the left side and touching left foot with right hand.

EXERCISE 3

Position: Lying on back on floor, hands by sides, legs straight with the weight of from two to four pounds on the abdomen.

Action: Breathe slowly and deeply. The abdomen should rise and fall rhythmically as you breathe.

EXERCISE 4

Position: Body erect and on toes.

Action: Full knee bend, extend arms forward. Exhale and draw abdomen in. Rise to normal position, keeping abdomen in. Raise the chest and then inhale.

EXERCISE 5

Position: Feet apart, arms side shoulder level. Twist the body to the right side, lean slightly over the right knee; inhale. Return to normal position, then repeat to the left side.

Remarks: All twisting is done above the hips.

EXERCISE 6

Position: Stand erect with chest up, chin in.

Action: Bend or sway from side to side, moving from the hips only.

Remarks: The arms should wave loosely like the branches of a tree.

EXERCISE 7

Position: Lying on back on floor, hands by sides, legs straight.

Action: Draw the right knee to the chest and exhale. As the right knee is returned to its normal position the left knee is drawn to the chest.

Remarks: A variation of this exercise for those whose abdominal muscles are weak, the knee may be lifted to the chest and compressed to it by both arms being wrapped around it.

EXERCISE 8

Position: Lying on back with the body well relaxed.

Action: Expand the chest, pulling it well up and letting the abdomen become hollow. Count six. Then make the chest small, pushing down and making the abdomen large and count two.

Remarks: Do this three to five times without breathing; then take several slow, long breaths. Repeat this exercise from fifteen to twenty times. A variation of this exercise may be done by getting down on all fours like a cat, and doing this exercise.

EXERCISE 9

Position: Stand erect with hands resting on hips.

Action: Raise the right knee until it is at right angles with the body, with the toes pointing towards the floor. Extend the foot forward until knee is straight and stretch. Return leg to normal position and repeat with the left leg.

EXERCISE 10

Position: Stand erect with hands resting on hips.

Action: Stationary run, with high knee action, that is, bring your knees up well in front of you and land on the balls of the feet.

EXERCISE 11

Position: Same as Exercise 10.

Action: Draw the right knee to the chest and squeeze with both arms. Raise on toe of the left foot. Replace the right leg and continue exercise by repeating with the left leg.

Remarks: An alternate compression and stretching movement is given the abdominal organs.

EXERCISE 12

Position: Stand erect with fingers interlaced behind the neck.

Action: Draw the abdomen in; lift the chest and look straight up towards the ceiling directly above you. Turn your head slowly to the right and then to the left.

Remarks: Do this exercise about six times. This is a very good exercise before taking the morning shower or bath.

EXERCISE 13

Position: Stand erect with the hands above the head.

Action: Bend body forward and touch toes with the hands. Exhale and draw in the abdomen. Return to the normal position and inhale.

EXERCISE 14

Position: Lying on back with the hands tightly closed on the shoulders.

Action: Lift the chest and take a deep breath. Put your head back; then bend the body to the right. Stretch the left arm forward and the right sideward. Stretch vigorously. Exhale and return to the normal position. Repeat to the left side.

Remarks: This is an excellent first exercise in the morning workout. It can be done while lying in bed. Yawn, stretch, and grunt as much as you wish for the circulation is stimulated.

EXERCISE 15

Position: Sitting on chair directly below the chandelier or light fixture.

Action: Keeping head directly underneath chandelier, make a circle with the abdomen from right to left, or from left to right. Crumple down, then straighten up and you are making your circle.

Remarks: Do this ten to twenty times. It is one of the best exercises for the cure and prevention of constipation. It may take some time before one can make the circle in a real circular fashion.

EXERCISE 16

Position: Feet together, standing with the hands above the head.

Action: Twist the body to the left side. Place the left hand on the hip, and with the body in that twisted position, touch the outside of the left heel with the right hand and exhale. Return to normal position and repeat to the right side.

Remarks: Knees should be straight during the entire exercise. It may be impossible to touch the heel, but stretch down as far as possible. In returning to the normal erect position, bring the hand out and up.

EXERCISE 17

Position: Lie on the back in form of a cross with arms extended.

Action: Carry right foot up to the left until it touches the left hand. Repeat, using left foot touching right hand.

Remarks: A difficult variation of this exercise may be done by doing the exercise in a standing position.

EXERCISE 18

Position: Lying on back with arms above head on floor keeping knees straight.

Action: Assume a sitting position and touch toes with hands; exhale. Return to sitting position, keeping abdomen in; then slowly return to the normal position. Stretch and then inhale deeply.

EXERCISE 19

Position: Body erect, hands on hips, feet apart with knees straight.

Action: Bend to right, then to left.

Remarks: Do not bend too far backwards. Repeat this exercise about a dozen times.

EXERCISE 20

Position: Body erect, chest up, feet apart.

Action: Turn head and shoulders to right as far as possible. Then swing arms, head and shoulders in the opposite direction.

Remarks: Waist muscles should be as lax and lifeless as possible. Let them twine around the body as if tied to the body with strings. This should be a daily exercise and can be used by people of all ages. It is very beneficial.

EXERCISE 21

Position: Stand erect with hands on hips.

Action: Bend right and reach towards floor or ground. Reverse movement to left.

Remarks: In reaching towards floor bring the hand only to the knee at first and then with each successive stretch bend a little lower until ground is reached. This exercise is very helpful in preventing or curing constipation and torpid liver.

EXERCISE 22

Position: Stand erect, hands on hips, feet apart.

Action: Swing hips as far to right as possible then to left. Keep head as nearly as possible in starting position.

Remarks: Hold hips a second or two in each position: _i. e._, right or left.

EXERCISE 23

Position: Body erect, hands on hips.

Action: Bend forward very slowly, hinging only at hips, while keeping back straight and face to front. Bend low enough so that back is parallel to floor. Return to normal position slowly.

Remarks: You will not like this exercise at first, but it is a very helpful exercise. Repeat exercise three to five times.

EXERCISE 24

Position: Stand erect with hands high above the head.

Action: Bend to right and bring hands to floor near the right foot, going down slowly. Reverse movement and swing hands directly over head and down to floor near left foot.

Remarks: Repeat in each direction four or five times. Combine deep breathing with this exercise; exhale as you bend in one direction and inhale as you reverse movement.

EXERCISE 25

Position: Stand erect with hands on hips, feet together.

Action: Bend forward until back and legs are at right angles. Turn right by pivoting at waist and swing head and shoulders around in a large circle until they have been returned to starting position. Reverse movement and swing around in opposite direction.

Remarks: Keep knees straight. Do not bend too far backwards. This is a very strenuous but very effective waist strengthener and liver stimulating exercise. (Do not use until you are accustomed to exercising.)

EXERCISE 26

Position: Stand erect.

Action: Take a full breath, hold it, reach out right and left, close fists tightly and tense arms. Repeat two or three times. Now take another deep breath and reach as far as you can with the feet while tensing the muscles of the legs.

Remarks: This is an excellent exercise in beginning the morning workout.

EXERCISE 27

Position: Lying on back very lax and lifeless.

Action: Take a full, deep breath very smoothly through the nostrils and at the same time expand the abdominal muscles as much as possible. Hold breath a few seconds, relax waist and abdominal muscles very slowly and then draw in and upward and exhale. Repeat five to ten times or oftener.

Remarks: One of the best exercises a frail, weak person can take and quite as valuable for strong folk.

EXERCISE 28

Position: Stand erect, arms on level with shoulders.

Action: Swing right foot around to a position two feet from left side of left foot thus twisting the legs. At the same time swing head and shoulders as far around to right as possible while keep the arms straight and in line with each other. Reverse and swing as far as possible to the left.

Remarks: Repeat exercise eight to sixteen times. This is a good exercise to strengthen and make flexible a good many muscles of the body.

EXERCISE 29

Position: Stand erect, hands on hips.

Action: Right foot raised backward, bend forward until back and legs are at right angles, exhale. Return to normal position. Repeat exercise four times to both sides.

EXERCISE 30

Position: Stand erect with chest up, chin in.

Action: Expand chest and abdominal muscles suddenly while bringing hands up quickly above head at the same time taking a deep breath just as quickly as possible through the nostrils. Hold breath a few seconds then exhale very slowly as you lower hands to starting points. Repeat three to five times. Now take breath very slowly while bringing arms up laterally till hands meet above head. Bring arms back to sides very quickly and suddenly exhale completely through mouth. Repeat three to five times.

Remarks: Another part can be added to the above exercise by taking a deep breath and counting fifty without taking more breath.

The above exercises should be indulged in as you arise in the morning. They will give you pep and vitality that is needed to carry on a successful day. They will give the abdominal organs the workout that will prevent and correct constipation.

These exercises are in reality liver regulators. You will undoubtedly discover after doing these exercises that you feel better in every way.

It is essential to take several deep, long breaths between each exercise. Do not do the same exercises every morning. Pick out five and do them vigorously for fifteen minutes. There are enough exercises for six days of the week; thus you will not become tired of the monotony of exercises.

TRANSCRIBER'S NOTE

Obvious typographical errors and punctuation errors have been corrected after careful comparison with other occurrences within the text and consultation of external sources.

Some hyphens in words have been silently removed, some added, when a predominant preference was found in the original book.

All misspellings in the text, and inconsistent or archaic usage, have been retained.

Page 19. “rythmically” replaced by “rhythmically”.

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Untitled

Thomas Cradock Hepworth

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THE MAGIC LANTERN

AND ITS MANAGEMENT.

THE MAGIC LANTERN

AND ITS MANAGEMENT

INCLUDING

FULL PRACTICAL DIRECTIONS FOR PRODUCING THE LIME LIGHT, MAKING OXYGEN GAS, AND PREPARING LANTERN SLIDES

BY

T. C. HEPWORTH

LATE LECTURER ON SCIENCE TO THE ROYAL POLYTECHNIC INSTITUTION, LONDON.

[Illustration]

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PREFACE.

During the past few years, the introduction of a dry-plate photographic process of such a nature that it can be practised successfully by amateurs of both sexes has aroused an amount of interest in the camera and its capabilities, such as few scientific instruments can command. The Magic Lantern is now closely allied with the camera, for there is no means of showing the perfection of a photographic picture so well as by its aid. But many persons are deterred from adopting the latter contrivance because they fancy that there must be innumerable difficulties to surmount before they can hope to master its management. It is for these that the following pages have been written, in which I have tried to place clearly before the reader what can be done, and how to do it. I have also tried to indicate the educational value of the lantern, and have pointed out in a necessarily brief manner how various branches of knowledge can be illustrated by its aid. The numerous personal inquiries addressed to me after my lectures, and the numbers of letters constantly received, asking for information regarding the lantern, its management, and the preparation of lantern slides, have convinced me that there is room for a manual, humble though it be, dealing with these subjects.

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CONTENTS.

THE HISTORY OF THE MAGIC LANTERN.

PAGE

The introduction of mineral oil lanterns.--The advance caused by the aid of photography.--The optical system of a modern lantern.--Educational value of the lantern 1-12

THE LIME-LIGHT.

Different forms of lime-jets.--Precautions to be observed in their use 12-16

DISSOLVING VIEWS.

The old method and the new.--The biunial lantern.--The dissolving-tap and its management.--Coincident discs.--'Effects'--The application of the double lantern to spectrum analysis 17-22

MAKING OXYGEN GAS.

Necessary precautions.--The purifier.--Explanatory diagram.--Practical details.--The retort.--The gas-bag.--Iron bottle for compressed gas.--Pressure-boards. --Lime cylinders 22-33

THE SCREEN OR SHEET.

Arrangement adapted to a sitting-room.--Public exhibitions. --Method of hanging a large sheet.--Sheets on frames 33-37

PICTURES FOR THE LANTERN.

Photographic slides.--Home-made pictures.--Drawing pictures on ground-glass.--The slide-painter's easel.--Mounting slides 37-43

ON THE COLOURING OF PHOTOGRAPHIC TRANSPARENCIES.

The process described.--Oil-colours employed.--Apparatus required.--Mixed tints.--How to lay on the colour.--Finishing touches.--Painting in water-colours 43-55

SHOWING SOLID AND OPAQUE OBJECTS ON THE LANTERN SCREEN.

Chadburn's opaque lantern.--The aphengescope.--Showing coins, medals, etc.--The opaque lantern in a law court.--The physioscope 56-61

THE LANTERN MICROSCOPE.

Photographic microscopic slides.--The solar microscope.--A sketch lecture 61-65

MECHANICAL OR MOVING PICTURES.

Comic slips.'--Beale's choreutoscope.--The dancing skeleton 66-69

CONCLUDING REMARKS.

The management of the lantern in public.--Signals between lecturer and operator 70-75

THE MAGIC LANTERN

AND ITS MANAGEMENT.

There is no optical instrument so well known or so highly held in popular estimation as the Magic Lantern. It is somewhat unfortunate that its old appellation, given to it when it was nothing more than a mere toy, should have stuck to it so long. And more than one attempt has been made by those conversant with its capabilities as a scientific instrument, and as an important aid to education, to give it a name more consistent with its real value. The late Mr. Dalmeyer was, I believe, the first to re-christen it the 'Optical Lantern;' and there is evidence that others are adopting the term, and that in time the old name will sink into oblivion.

With regard to the early history of this deservedly favourite contrivance, but little is known. Its invention has been ascribed to Friar Bacon, but the evidence on this point is of the most legendary character. It seems, however, certain that the first to give an intelligent description of it was Kircher--a Jesuit who lived two and a half centuries ago, and who published a work entitled 'Ars Magna Lucis et Umbræ,' or 'The Great Art of Light and Shadow.' The body of the lantern, as described by Kircher, consisted of a room several feet across, furnished with an opening in which a lens was placed. The source of light was an oil-lamp, and the pictures for exhibition were of the roughest kind. Indeed, we may presume that the effects produced fell far short of those attained by the cheapest toy lantern of our schoolboy days. Even if we search the columns of an Encyclopædia or any similar book of reference of forty years ago, we shall not find any great improvement on the description afforded by Kircher. The magic lantern will there be found described as 'an optical toy, by which glass pictures executed with coloured varnishes can be thrown upon a wall or screen.'

But from this time a gradual improvement began. First, the old oil-lamp was replaced by the argand burner; then came gas; finally the brilliant lime-light--and some time in the near future, perhaps, will come electricity. The improved means of obtaining light have naturally led to larger pictures being thrown on the screen; for the size of such pictures is governed only by the amount of light available. Thus, supposing we own a modern lantern constructed with one of the improved three or four-wick lamps, and that it will give us a good picture of about six feet diameter, by using the same lantern, and without any change whatever in its optical arrangements, save fitting it with a lime-light jet, the disc can be increased to fifteen feet diameter. A picture of the same size could be produced with the original lamp, provided that the operator retired to the necessary distance from the screen, but the light would be so attenuated that the picture would be but a ghost of what it ought to be. It will therefore be understood that the enlarged image formed by the lantern lens can be made to fall at any point in front of that lens, and may be of any size; but to render it practically available its size, and therefore its distance from the lens, must be regulated by the amount of light at disposal.

During the past few years two circumstances have combined to render the optical lantern more popular than ever: one being the introduction of photographic transparencies representing scenes from the remotest parts of the earth, and the other the construction of metal-bodied lanterns of improved character, and burning mineral oil. As a good paraffine lamp is compared with a farthing rushlight, so is one of these lanterns to the toy of our boyhood. The light given, although it falls far short of the brilliance of the lime-light, is much more intense than could have been hoped for some years ago from oil. But its brilliance is not all due to the paraffine, but quite as much to the careful ventilation and general construction of the flame-chamber. There is, too, no danger in the use of this form of lantern, for the reservoir containing the paraffine is far below the combustion-chamber, and therefore it cannot become unduly heated.

The lenses, too, in this new form of lantern, although placed in the same position as those in the old-fashioned magic lantern, are of a very different stamp. And this leads me to a brief consideration of the optical system comprised in these instruments.

[Illustration: FIG. 1.

L, Light; _c_, _c_, Condensing lenses; _o_, _o_, Objective lenses.]

There are two sets of lenses: one being known as the condenser, and the other as the objective. The condenser is made up of two or more glasses, the usual form consisting of two plano-convex lenses placed face to face. The duty of this condenser is to take up as much as possible of the light afforded by the lamp, and to change the direction of the rays so that they are cast through the picture or slide placed in front of it. A glance at Fig. 1. will show how this is accomplished, and how the rays indicated by the dotted lines would be lost if not turned to account by the condenser. The use of the objective, on the other hand, is to magnify the image of the picture, and to present it in as perfect a form as possible on the screen placed for its reception. Its distance from the picture is governed by the distance of the lantern from the screen, and can be regulated to a nicety by the focusing screw attached to it. It is generally acknowledged by all acquainted with the requirements of the lantern that the photographic camera lens (known as the quarter-plate portrait lens) fulfils admirably this duty; and this particular form of lens, which is by no means expensive, is generally fitted to modern lanterns of the mineral-oil type. The condensers vary from four to three inches in diameter; perhaps the best size is three and a half inches. The relative positions of condenser, light, slide, and objective are indicated in the diagram to which attention has just been called, Fig. 1.

The optical lantern always inverts the image of any picture projected by it, an inconvenience readily obviated by placing the slide on the stage upside down. At the same time the picture must have its front turned towards the condenser, not away from it, otherwise every part of the slide suffers reversal on the screen. In some cases this does not matter, but when any wording, such as that on a signboard, for instance, is contained in the picture, it reads backwards. Such accidents can be prevented by a white label, easily seen in semi-darkness, placed in a certain position on the picture. If such a precaution had been observed at a certain exhibition at which I was present, General Garfield would not have been shown standing on his head--not a dignified position for the President of the American Republic.

The first lanterns, constructed to burn mineral oils, were very different to those of modern make, and took their pattern from the cumbrous instruments which before them were provided with colza-oil lamps. The reservoir for the oil was carefully kept in a cistern at the back of the lantern, and bubbled through a pipe to the lamp on the same principle that water is supplied to an earthenware poultry fountain. It was doubtless thought necessary in those days to maintain the paraffine in the cistern at a height equal to or above the wick, as in the case of colza and other heavy oils. But paraffine is more of the nature of a spirit--for it volatilizes very readily--and in modern lamps for lanterns the reservoir is kept some inches below the point of combustion. By the time that the

liquid reaches this point, it has become so heated in the course of its passage along the metal wick-holders that it issues as a gas. This can be readily proved by turning down the wicks after the lantern has been burning some time, when the flames will remain above the wick-holders, although the wicks themselves have been turned down quite out of reach. In the older lanterns, too, the glass chimney was thought to be indispensable, but now this has been done away with, and with it the cylindrical wick has also gone. The modern combustion-chamber is made of charcoal iron, and is closed at one end with a thin pane of glass, just outside which the condensing lenses are placed, and at the other end by a silver-plated reflector. The necessary air to promote combustion is admitted by suitable orifices below, and a draught is established by a long iron chimney above.

There is no great difficulty in managing one of these lanterns. The loosely plaited cotton wicks should in the first instance be carefully cut parallel with the wick-holders. After this they do not require much attention. It is a far better plan to remove the charred end of the wicks by scraping them along with the back of a knife, than to be always cutting them afresh. However, any loose strands that may project from the cotton should be certainly snipped off with scissors.

After lighting the lantern--which is best done with a long wax taper--each wick should be turned down quite low, and the combustion-chamber closed. In about two minutes, by which time the front glass and the lantern generally will have become warmed, the wicks should be turned up to their highest; that is to say, to a pitch just short of smoking-point. If the wicks are turned low for any length of time the lamp will be sure to smell. It will also smell if, in the process of charging with oil, some of the liquid has been smeared against any part of the lantern which may afterwards become heated. The best oil only should be used.

I have already hinted at the educational value of the optical lantern, but those who have not experimented with it have but a faint idea of its capabilities in this respect. I am of the opinion that every school and college should possess one, and that both pupils and teachers would soon discover its many advantages. Now that it is manufactured in such a portable and efficient form, and can be so easily managed, there is no possible hindrance to its adoption, unless it be its old name of 'magic lantern,' which is associated with things too childish for consideration. But this objection cannot hold good when it is pointed out how many different branches of knowledge can be illustrated by its use.

The schoolmaster of a London Board School once told me of some of his difficulties in teaching such a subject as geography. Most of the children had never seen the sea, and many of them had never even travelled so far as the Thames. What notion could such waifs have of a mountain, a valley, a cliff, or even of a rock? The value of the optical lantern at once becomes apparent here. But better informed children in high-class schools, although they see many places beyond the London streets, can yet reap much advantage from the mode of instruction which I am advocating; and as the range of knowledge increases, so will some such means of illustration be forced upon teachers. The labour and expense of tracing a dozen diagrams on glass, in the way hereafter explained, is considerably less than that involved in drawing a single large diagram for the schoolroom wall. By this easy method the illustrations in any book can be roughly copied and rendered available for an entire class.

In the higher branches of knowledge the lantern can also give its help. Botany, zoology, and natural history generally can be illustrated by diagrams, photographs, and in many cases by natural preparations. The revelations of the microscope can be transferred to the lantern, and the most complex organisms can be seen clearly defined and magnified many hundred times their natural size. It is possible, too, to show by the lantern many interesting experiments in chemistry and electricity which cannot be shown to a large number of persons in any other way. Let me cite for instance the formation of crystals, which can actually be watched in progress, highly magnified, by the simple expedient of smearing a piece of glass with a solution of sal ammoniac and placing it in the lantern. There are several adjuncts which may be fitted to a first-class lantern which I have not space to notice in detail. With the lantern-microscope ordinary microscopic slides can be utilized, and tanks for containing the living denizens of our ponds and ditches may be employed. The marvels of polarised light may be demonstrated with the lantern-polariscope. By another special device called the 'aphengescope' and which is made to fit on the lantern, opaque objects can be thrown on the screen. It is possible, for instance, to utilize ordinary photographs or diagrams on card, to show the moving works of a watch, sections of fruit, and many other objects as explained in a subsequent chapter.

The lantern, at the time of exhibition, should stand firmly. It can, if it be a small one burning oil, be placed on a box standing upon a table. I myself prefer to place it on a photographic tripod-stand, and this I effect by screwing on to the top of the stand a base-board upon which the lantern firmly fits. For large lanterns, such as the lime-light biunial, a far more solid arrangement is requisite. My own method is this. The lantern screws on to the top of its travelling-box, at the lower corners of which are sockets to admit four wrought-iron legs. These legs are bent outwards, and what I may call their toes are turned out, and have a hole into which a screw may be inserted and driven into the floor. The lantern is fastened to the box by two hinged pieces at the back, so that the nozzles

can be raised to any extent desired.

THE LIME-LIGHT.

The lime-light consists of a jet of mixed hydrogen and oxygen gases under pressure, ignited, and forced upon a cylinder of lime, which it renders white-hot. The heat given by these gases is second only to the heat of the electric arc, and will melt that most refractory of metals, platinum. Even the lime block cannot withstand the great heat to which it is exposed, but is quickly pitted under the action of the flame. Hence lime-light jets are furnished with an arrangement by which the lime cylinder can be turned at frequent intervals, so as to offer a fresh surface for the gases to play upon.

There are three kinds of jet used for the lantern. Firstly, a jet in which a stream of oxygen is forced through the flame of a spirit-lamp on to a cylinder of lime. This form is perfectly safe, and although it presents an immense improvement upon any form of oil arrangement, does not afford sufficient light to illuminate a screen more than about nine feet in diameter. Secondly, there is what is known as the blow-through jet. In this case the jet is connected with the house gas, and the oxygen meets it at the point of ignition, and is _blown through_ it on to the lime. This form of jet is also safe; indeed, it is often called 'the safety jet,' and affords plenty of light even for professional use. It is the one that I recommend the amateur to work with. Thirdly, there is the mixed jet, in which the two gases in separate bags are both under pressure, and mix together before reaching the external orifice. This form of lime-light gives the most light of any; but such care is requisite in dealing with it, that I shall say no more about it, considering it unfit for casual acquaintance.

A beginner might fancy that it would be a simple thing to mix the two gases in one bag, put it under pressure, and use them thus. So it would, and a beautiful light would be the result. Probably a beautiful explosion would be another result, for the two gases mixed form a most terrible compound, and a bag so charged would be almost equal in danger to a live shell.

With the spirit jet, or the 'blow-through,' the operator need have no fear of danger. Oxygen is not an explosive, and, although the best supporter of combustion, is not itself capable of being ignited. The spirit jet I should not recommend, except in situations where coal gas is not obtainable, so in my directions for using the lime-light, let it be understood that I am considering the employment of the blow-through, or safety jet.

Let us suppose, then, that we are preparing for an exhibition. The gas is made, and is at hand in the gas-bag; our lantern--and I will, for simplicity's sake, consider it a single lantern only--is raised on its stand-table, or other support, at a convenient height from the ground, and we wish to have a private rehearsal in order to see that all is right. The first thing is to attach the hydrogen terminal of the jet, marked H, by flexible tubing to the nearest gas-bracket. Now take a cylinder of lime from its box, clear out the hole in the centre with a bit of wire, or a match, and place it on the pin provided for it above the jet. See that it turns freely, and so adjust the pin that the lime is distant from the jet nozzle about the sixteenth of an inch. Light the gas, and turn it down so that the flame is about an inch high. This can be done with advantage an hour or more before the lantern is really required, for the lenses and body of the lantern will by this means get thoroughly warmed, and any moisture upon the glasses, which would show as a blemish on the sheet, will be removed.

In all cases the hydrogen should be lighted first, if only to thoroughly warm the lime. Now the oxygen-bag can be put between the pressure-boards, and connected by another tube to the tap marked O. A half-hundred-weight having been put on the boards, the gas-bag tap may be turned on to the full. We may now attend to the jet. Turn on the hydrogen so that it flames up some inches over the lime, then gradually turn on the oxygen. At first it is air only that comes away, but presently with a characteristic little snap the two gases come together, and the brilliant lime-light is produced. A little care in adjustment of each tap alternately will soon show us the amount of gas from each which will give the best result.

It will soon be apparent to the operator that the spot of light on the lime must be exactly in the axis of the system of lenses, or the effect upon the sheet will be spoiled. The vertical movement of the jet is governed by a little screw, which holds it to the post on which it is fixed, which post stands upon an iron tray gliding between grooves. We must raise or lower the jet until the right place is found, when the screw can be brought home, and the jet is fixed. Even now, most probably, we shall find that the outer margin of the disc is ill-defined. This shows that the light is either too near or too far from the condenser. By moving the jet on its tray bodily backwards and forwards, we shall soon be able to find its correct position, and when found, that position will hold good to the end of the exhibition. We can now put a picture on the slide-stage, and focus it by means of the screw on the front lens. If the lime is properly adjusted and centred, our picture will be illuminated equally well in every part.

DISSOLVING VIEWS.

So far, we have considered the production of a brilliantly illuminated picture with a single lantern. For many years after the lime-light came into use, this was all that was required of it. But suddenly the beautiful effect known as dissolving views was contrived--an effect which, at the time of its introduction, made a wonderful sensation--and the method of producing which was for a long time kept secret. The old way of dissolving one picture into another, and the way which must still be adopted if oil-lanterns are in question, was to use two lanterns, side by side, and by a kind of see-saw arrangement in front of the lenses, to gradually uncover one nozzle whilst the other was being closed. This was easily done by furnishing each end of the see-saw with a screen of tin, the edge of each being cut into teeth like a comb. The one picture was thus caused to mingle with the other until the first lantern was quite closed, when the new design became perfectly disclosed. It soon became evident that the same effect could be produced more simply and economically with the lime-light lanterns, by contriving a special form of gas-tap which would slowly turn off the gases supplied to one lantern, while it as slowly admitted the gases to the other. By this arrangement nearly half the gas supply is saved, and therefore very little more is wanted for a dissolving-view apparatus than for a single lantern.

Dissolving view, or biunial lanterns, as they are generally termed, are now made in very compact form. The two systems of lenses, one above the other--not side by side as of old--are fitted into one mahogany case, lined with tin, and furnished with doors, so that the lights can be tended when necessary. At the back of the arrangement is placed the dissolving-tap, which is connected by indiarubber tubing with the lime-jets, and has two nozzles by which the hydrogen and oxygen respectively can be supplied to it. The dissolver is also furnished with by-passes, so that when the gases are turned from one lantern, just sufficient remains to keep the jet turned down 'to the blue.'

The management of a pair of lanterns like this is, of course, much more onerous than that of a single lantern; but when once understood presents no difficulty. Before lighting up, be quite sure that all connections--and there are many--are quite secure, and that each place where indiarubber tubing fits on to metal is secured with twine. Now light the hydrogen in both lanterns, which you can do by placing the dissolving-tap in an upright position. Move the dissolver until the upper jet seems on the point of going out; but prevent it doing so by opening the hydrogen by-pass, and adjust this little tap so that the flame remains about one inch high when the other lantern is being used. Move the dissolver backwards and forwards a few times, so as to see that it works well, and that the hydrogen flares up in each lantern alternately.

We can now pay attention to the oxygen supply. First see that the bag is properly adjusted between the pressure-boards, and that the weight--one 56 lb. weight is sufficient to begin with--is in its place, above the upper board. Attending to the lower lantern first, turn up the hydrogen, and very gently admit the oxygen by turning the tap attached to the jet. When the light has been satisfactorily established, the oxygen by-pass must be turned in the same way that the other by-pass was just now treated, so as to admit a small amount of gas passing to the lantern not in use. If this be not done, the sudden inrush of the oxygen is sure to cause a small explosion, which will blow the light out. This does not indicate any danger whatever, but is inconvenient and undesirable during an exhibition. The upper lantern may now be attended to with the same precautions; and if all has been done well, the light will move from jet to jet alternately, as the dissolver is worked.

In using a double lantern, it is necessary to make both pictures coincident on the sheet. If one picture overlaps the other at every change, it has a most slovenly appearance. Such an error can be avoided by manipulating certain screws fitted to the metal front of the lantern, by which the two discs thrown upon the sheet can be adjusted until they quite coincide. These screws allow the lower nozzle to be pointed slightly upwards, and the upper one to point downwards, so that the images cast by each may be made to meet at the screen.

The double lantern is mainly employed for dissolving views; but its use does not stop here. A great many beautiful "effects" can be compassed by its means, a few of which I may here describe. Statuary slides form very beautiful pictures if photographed direct from the marble; but their effect is much enhanced if, by means of the auxiliary lantern, a glow of colour is thrown upon the screen at the same time. A few squares of differently tinted glasses, each mounted like an ordinary slide, with a mask of oval or round shape, are all that is needed. Again, a wintry scene in one lantern may be much improved by the effect of falling snow, produced by working a special form of slide in the other lantern. This slide consists merely of a frame containing a roller at the top with the handle projecting outside. As the handle is rotated, a long ribbon of black paper pierced with needle-pricks is rolled up upon it, and each prick makes a descending spot of light upon the screen, which together look exactly like falling snow. Sunset and moonlight effects, windows lighted up in night-scenes, ripples upon water, can all be managed by specially-devised 'effect' slides in the

second lantern. These effects can be much extended when a triple lantern is employed; but as this instrument is not often found--out of the hands of professional operators--we need not further allude to it.

But the double lantern can be used with great advantage from an educational point of view, in a manner that was first suggested by the present writer. I mean in the demonstration of the main features of Spectrum Analysis. Let me cite one example. A slide prepared and coloured so as to represent the continuous solar spectrum, marked with the principal _Frauenhofer_ lines, is placed, say, in the lower lantern. We now wish to show the bright lines given by an incandescent metal, say _sodium_. A slide, all blackened out but the double D line due to sodium, and so placed on the glass that it will exactly register with the D line in the coloured spectrum slide, is placed in the upper lantern. The dissolver is now brought into play, and can be so adjusted that while the continuous spectrum has all but faded away, the two brilliant sodium lines stand out boldly in their proper place. The spectra of all the other metals can be treated in exactly the same manner, keeping the continuous spectrum in the lower lantern for constant comparison and reference.

MAKING OXYGEN GAS.

There is very little danger incurred in the use of the lime-light if only the operator be intelligent in its employment. But there are certain dangers connected with the preliminary making of the oxygen gas, so that that part of the work should only be entrusted to a careful worker, and one who, knowing where the greatest care is required, will take every precaution against disaster. I have myself made several thousand feet of oxygen on different occasions, and have never yet met with any mishap; but as I know of cases where serious accidents have occurred, I have endeavoured to find out why they have happened, and I now consider myself forewarned, and therefore forearmed, against their repetition. The articles required for making the gas comprise a retort in which to generate it, a gas-stove to furnish the necessary heat, a wash-bottle or purifier, an indiarubber gas-bag, and several feet of tubing. Beyond these is wanted the mixture of chlorate of potash and peroxide of manganese in powder, which forms the charge of the retort, from which the gas is generated on the application of heat.

I have found that the best proportions of chemicals to use are four parts (by weight) of chlorate to one of manganese. Before being mixed together, both should be most carefully picked over, and most probably both will yield a small crop of bits of straw and wood-chips, which are not only injurious, but would in sufficient quantity prove actually dangerous if permitted to remain. The larger crystals of the chlorate, and any lumps which may be found in the manganese, should be rubbed down to powder by gentle pressure with the wooden spoon used for mixing the compound, about two pounds of which will yield sufficient gas for an evening's show. The mixture can now be funnelled into the retort, the nozzle of which, after being blown through to see that the passage is clear, can be screwed into its place.

The purifier, or wash-bottle, is made of tin, or may consist of a wide-mouthed bottle with an indiarubber cap, fitted with inlet and outlet tubes of metal or glass. In either case the vessel is three-parts filled with water, the inlet tube dipping some inches below the surface. This tube is subsequently connected by three or four feet of indiarubber tubing with the retort. As the gas is given off, it bubbles through this water, which not only cools it, but catches the particles of solid matter which are sure to be blown from the retort. The outlet tube is connected with the gas-bag. In the annexed illustration the relative positions of the retort, purifier, and gas-bag are shown, but in practice certain modifications are desirable. It is as well, for instance, to stand a chair between the retort and purifier, upon which the connecting rubber tube may rest, otherwise the water evolved from the crystals of potash will condense in the tube and obstruct the passage of the gas. Again, the gas-bag, instead of being on the same level, should be laid on a table, so that any water accidentally driven from the purifier may not be forced into it. The rubber tubes should have an orifice of nearly half an inch, and should on no account contain an inside coil of wire. Previous to making gas the bag should be warmed for an hour or so in front of a fire, so as to make it soft and pliable. The cock should then be opened, and the bag rolled tightly up so as to expel any air. The tap should then be closed.

[Illustration: FIG. 2.

Diagram showing relative positions of _g b_, Gas-bag; _w b_, Wash-bottle; and _r_, Retort.]

When all is ready, and every junction made except that between the bag and the pipe leading from the purifier, the gas-stove may be kindled, but turned down almost to its lowest point. If this precaution be not observed, the oxygen will come off with such rapidity as to be quite out of control, and will probably blow the connections away. In two or three minutes the gas will commence to bubble through the purifier, at first intermittently, but the bubbling will gradually become more regular, until it is evident that oxygen is

coming over in earnest. The brightening of a spark at the end of a blown-out match, held to the end of the purifier-tube, will announce the fact that all the air has been driven out of the pipes, and that gas has taken its place. Now is the time to connect the gas-bag with the purifier. With a quick movement the indiarubber tube should be slipped over the nozzle of the bag with one hand, while the tap is turned on with the other. The gas should now come over regularly until the bag is nearly half full, and this will occupy about fifteen minutes. The action will then probably flag a little, when the flame feeding the stove may be increased. When the bag is nearly full the flame can be raised, if occasion should require, to its utmost.

Some care is requisite in finishing the operation. When the bag is quite full and as tight as a drum, it should be disconnected before anything else is done. Of course at the moment of taking the tube from it, the tap must be turned. The next thing is to detach the retort from the purifier _before the gas is extinguished in the stove_. This is a most important point, for if the retort were cooled by putting out the gas first, the water might be sucked into the retort from the purifier, and a small steam-boiler explosion would be the result. In an hour or so the retort will be cool enough to handle, when the nozzle can be unscrewed and the vessel washed out with several changes of hot water. It can then be dried and put away for the next occasion. The retort-nozzle and its indiarubber tube should also be washed out, or it may get clogged.

Particular care must be taken to purchase the chlorate and manganese of some reliable dealer. Accidents have been reported owing to lamp-black, bone-black, etc., having been supplied in error for the manganese, which is a black powder much resembling them. I find that the best plan is to buy several pounds of each at a time, and to test a small quantity of the mixed ingredients in a test-tube over a spirit-flame. If the gas comes off with a slight sparkling of the ingredients all is right; but if there is anything approaching to an explosion, the manganese is at fault. One accident which I heard of was due to connecting the retort to the wrong side of the purifier; the gas had no outlet, and the retort exploded, breaking all the windows of the room in which it was.

Retorts are made either of copper or iron. I have tried both, and much prefer the latter, which have also the advantage of being cheaper than the copper ones. A good retort should serve for at least fifty charges, and even then a new bottom can be put into it, and it will do duty for another fifty. But no retort will last long unless properly treated. I am quite satisfied that the spent charge if allowed to remain has the effect of eating into the metal; it should, therefore, be washed out soon after use. The thickness of a retort after much use can be gauged by tapping it with the back of a knife when empty.

The oxygen gas is most usually stored in an indiarubber bag. These vary very much in quality, and the cheapest kinds are to be avoided. The rubber should be soft and pliant, and should be covered outside with stout twill. A good bag will almost last a lifetime if it be only used occasionally. I have had one for many years, which looks shabby enough with constant use, but seems to be as gas-tight and as efficient generally as the first day I had it. Even then it had been in use for some months by a friend.

[Illustration: FIG. 3.

Iron bottle for compressed oxygen gas.]

A bag full of gas is not the most portable thing that could be named, and various attempts have been made to replace it by some contrivance of a more convenient character. There is, too, the danger of accidental injury, which can readily occur if the bag is carelessly handled. In very cold weather, for example, some bags get quite stiff and hard, and have to be almost thawed before they can be used. Neglect of this precaution will lead to cracks, which will eventually turn into holes. Metal gas-holders--miniature copies of the big reservoirs seen at gas-works--which serve as travelling-boxes for the rest of the apparatus--are recommended by some, but are seldom used. Perhaps the most convenient arrangement--which, however, is only suitable for a single lantern--is to employ an iron bottle in which the oxygen is greatly compressed. Such a bottle charged with gas can be obtained from several dealers, and I have had some little experience of their use. A bottle measuring three feet in length, and about seven inches in diameter, will hold about eight feet of compressed gas--sufficient for an ordinary evening's work. At the end of the bottle is an opening closed with a tap which can only be opened by a special form of key. Into this orifice is screwed a nozzle, upon which an indiarubber tube can be readily fitted. When a bottle of this kind is used, the amount of oxygen which reaches the lime must be directly controlled by this tap, and not by the tap attached to the jet, which must remain fully opened. The reason of this is that the gas issues with such force, that, unless controlled in the way I have stated, it will blow off the tubing by its pressure. I found it so difficult to regulate the supply, that I had an independent screw-tap made to fit on to the bottle. This screw-tap is of the same pattern as those used on steam engines to control the supply of steam to the cylinder, and with it I can adjust the oxygen supply with the greatest nicety. My chief objections to the bottle system--which presents many advantages in the matter of portability--are, firstly, that you cannot charge the bottle yourself--it must always go back to the dealer for that purpose--and you are therefore

dependent for one of your first requisites upon others; and secondly, you do not know how much gas you are using, for you cannot see it diminish as you can when you employ a bag. For these and other reasons I still prefer bags to store my gas, and shall continue to do so until some improvement comes about.

[Illustration: FIG. 4.

Gas-bag and pressure-boards.]

The gas-bag is wedge-shaped, and the thin edge of the wedge has in its centre a gas-cock for the entrance and exit of the gas. The object of the bag being in this form is, that it can conveniently be placed between the pressure-boards. These, in their simplest form, consist of two boards strongly put together--the size of the bag which is used--which are hinged together at one end. At the centre of this end, and between the hinges, is cut an oval opening through which the gas-cock is thrust. A shelf on the upper board serves as a support for the weights. At least two weights are required--one being sufficient at first, when the bag is full; the other being added later on when the pressure becomes reduced. The weighted gas-bag should always be placed as near the lantern as circumstances will allow--in order that it may be under the eye of the operator--and the tube from it which supplies the lantern should be guarded, so that it is not accidentally stepped upon.

The lime-cylinders are sold in air-tight tin canisters holding one dozen each. They are of two qualities--hard and soft. For work where large pictures are required--necessitating the use of the mixed jet with both gases under heavy pressure--the hard limes must invariably be used. But where only a small sheet has to be covered, and one gas only is subjected to the unusual pressure, the soft limes will afford perhaps a better light than the harder ones. Occasionally the lime, be it hard or soft, will split. In such a case it ought to be immediately replaced by a fresh one, otherwise the flame may possibly be diverted towards the condensing lenses, and will fracture that nearest to the light. It is advisable always to keep a spare lime within the lantern, lying on the tray to which the jet is attached. By this means it gets warmed, and ready for use if required. Lime is most absorbent of moisture, and will, if kept where air can get to it, swell to double its former size, and finally crumble to powder. For this reason the tin canister containing the cylinders should have stretched over it, when once opened, a broad indiarubber band which will cover the junction between lid and box. If this precaution be neglected, the limes will swell with a force sufficient to break the tin-containing vessel asunder. A compressed lime cartridge, to which water is applied by artificial means, has lately been successfully introduced to supersede explosives hitherto used for mining purposes. This will show the immense power of expansion of which the substance is capable.

THE SCREEN OR SHEET.

And now a word about the best form of screen or sheet for showing lantern pictures upon. The best possible form of surface is a smooth whitewashed wall; but as this is not commonly found among the appointments of a sitting-room, where the lantern will be wanted, we must find some substitute which will most nearly resemble it. A sheet of cartoon paper, which can be bought of any length, and measuring more than four feet across, will do well if only a small disc is desired. The paper can be rolled up out of the way at a minute's notice. If a larger screen is wanted, it can be made of stout calico, faced with white paper, and can be made to roll up and down like a school map of large dimensions. A map-mounter, or even an upholsterer, would soon rig up such an arrangement.

There is a very effective way of showing small pictures and diagrams with an oil-lantern, which I have more than once adopted, where a room has been long in proportion to its breadth. This is to make a wooden frame just large enough to take the full width of a sheet of tracing-paper, and to put this screen between the lantern and the spectators. Tracing-_cloth_ should be avoided, as it is so transparent that the light streaming from the lens makes a blotch in each picture when seen through it.

If the lantern is brought into regular use--in a schoolroom, for instance--it might be thought worth while to have a canvas sheet whitewashed, and hung in the same manner that a stage drop-scene is fixed. In making such a screen, the canvas should be tacked on a frame, and should have a coating of thin glue, which should be allowed to dry before two or more coats of whitewash are applied. It will be understood that a really opaque screen, such as this represents, is the more effective, because the light, instead of being partly lost--as it must be in penetrating an ordinary calico sheet--is reflected and utilized.

But for public exhibitions on a large scale, the calico sheet is the screen commonly in vogue, for it is conveniently put up and taken down, and can be rolled into a bundle for easy transport. A sheet properly hung should be as flat as a board and perfectly free from wrinkles of any kind, and this can be accomplished without much difficulty by adopting the following method, which is applicable to

screens from twelve feet square upwards.

[Illustration: FIG. 5.

Showing method of hanging a sheet.]

The sheet should have at its top edge a strong cord sewn into its hem, which cord should terminate at each side with a loop. On its sides and bottom edges, the sheet should have brass curtain rings sewn on to it at intervals of two feet. Having chosen the position of the screen, a couple of screw-eyes are screwed into the roof, or cornice near the top of the hall, at such a distance apart that the sheet can easily go between them. Through each of these screw-eyes is passed a thin, strong line, having at its end a clip like that commonly attached to a dog's chain. This clip is to clutch the loop of rope on each side of the sheet. The sheet can now be pulled up into position: the free ends of the cord being fastened to screw-eyes in the floor. It now merely remains to lace with string the curtain rings on the side of the sheet to the adjacent cord, and the arrangement is complete. The annexed diagram shows the upper corner of such a sheet, with its attachments, as just explained. Where the hall is of such a height that this plan is not available, or where the stern custodians faint with horror at the thought of their walls or ceilings being pierced with a screw-hole, the same method can be carried out by fastening the screw-eye to a timber upright on each side, supported by light struts.

Some persons prefer a sheet stretched on a frame, and such a frame of a very portable character can be easily devised. The frame itself is best made of lengths of pine, about the size of broom-handles. These can be joined together so as to make a frame of any reasonable dimensions, by six-inch lengths of brass tubing. The same tubing, mitred into L-pieces, will serve for the four corners. The sheet is furnished with tapes to secure it to the frame, and the woodwork is kept in an upright position by strong cords fastened by screw-eyes to the floor. The appearance of such a screen is much enhanced if the plain woodwork be hidden by a little drapery in the shape of narrow curtains at each side, and festoons of the same material above.

PICTURES FOR THE LANTERN.

Before the advent of the art of photography, pictures or slides for the lantern were traced on glass and painted by hand; and this art was carried to very great perfection. But no handiwork can equal the productions of the photographic camera; so that when it was found possible to produce transparent positives on glass, that could be magnified on the sheet to any extent without deterioration, the occupation of the artist on glass was almost gone. Photographs are now almost exclusively used, and form, when properly executed, the finest pictures for lantern use. The manner of their production is fully described in my little book 'How to Photograph;' but as there may be many would-be lanternists who do not care to dabble in photography, I will here give a few plain directions by which lantern slides can be extemporised.

The standard size for lantern pictures is 3¼ × 3¼ inches. The glass chosen should be as thin as possible, and quite free from scratches, bubbles, or flaws of any kind whatever. Remember that a piece of the finest hair which may well be overlooked upon the slide itself, will appear on the screen as a huge snake. In like manner a tiny bubble in the glass is magnified into a blemish the size of a soup-plate. Glass presents a very difficult surface to draw or paint upon, particularly if water-colours are employed, but by coating it with a transparent medium in the first instance the difficulty is much reduced. A film of plain collodion will, when dry, give a surface that can be easily sketched upon with a fine pen and Indian ink. The sketch so made can afterwards be filled in with water-colour, tempered with prepared ox-gall, and taking care that the colours used are those which are naturally transparent. Prussian blue, indigo, lake, the madders, gamboge, burnt and raw Sienna, Vandyke brown, are all transparent pigments, and will answer every purpose. Mixed with one another in the manner detailed in any manual of water-colour painting, greens, purples, and all secondary and tertiary tints are readily obtainable.

Another method, and an easier one, for producing lantern slides was introduced some years ago by the Rev. W. H. Dallinger; and although the author of the method intended it for drawings of microscopic subjects only, and with that idea brought it before the notice of the Royal Microscopical Society, it will be readily seen that it is adapted to all manner of lantern pictures. This method is best described in its inventor's own words: 'On finely ground glass drawing with a black-lead pencil is as easy as drawing upon cardboard. I get squares of glass to suit the size of my lantern carefully ground on one side like the focusing-glass of a camera.' The author goes on to describe how, by sketching upon the finely ground surface with a well-pointed hard pencil--HH or HHH--and shading with a softer one, such as HB, capital effects can be obtained. 'If it be necessary to put in colour it may be done, cleanly and carefully over the shading; thus one layer of colour suffices. Now, of course, although we have a perfect drawing of the object, with all the detail accurately given, it is not a transparency. But we can easily make it one. Thin some good pale Canada balsam

with benzine to about the consistency of cream, and simply float it over the ground surface of your glass; pour off until the drop comes very sluggishly. Then reverse the glass so that the corner from which the balsam was flowing off be placed upwards. Let the return flow reach about the middle; then reverse it again, and move it in several directions to get the balsam level. This may be done with a very little practice, so that the surface shall be undistinguishable from glass. We have now a perfect transparency. All that is required is twenty-four hours for hardening (keeping the glass level), and then another square of glass fastened on to it by strips of paper at the edges, with small pieces of card at the corners to prevent contact, and it makes an admirable lantern transparency.'

A hint about giving a fine grain to glass will not be out of place. Upon a perfectly flat and firm table lay a piece of glass say six and a half inches square, for this size can afterwards be cut across into four lantern pictures. A sheet of wet blotting-paper under the glass will keep it steady. Now pour upon its surface a mixture of flour-emery and water. Place another piece of glass above, and work it round with a circular motion, constantly spooning up the mud formed by the emery and water, and which oozes out between the glasses, and replacing it between them. In a short time both glasses will be beautifully ground on the surfaces which have been rubbed together. A moment's consideration will show that the ground effect is produced by the surface being broken up into innumerable tiny pits, each one of which scatters the light. By Mr. Dallinger's method of filling up these pits with a glassy medium like Canada balsam, the glass is once more presented with a flat surface, and therefore becomes once more transparent.

By whatever means the picture is produced the operator should have a glass transparent easel to work upon placed at an angle of forty-five degrees, with a sheet of paper underneath it to throw the light up through the glass he is drawing upon. A good easel can be made of a small frame--that belonging to a twopenny slate will do--attached to a base-board, and supported on each side by struts. A ledge of wood screwed across the frame makes a convenient support for the picture. The annexed cut will sufficiently explain the arrangements described.

[Illustration: FIG. 6.

Glass easel.]

And now a word or two about mounting the picture. As Mr. Dallinger points out, a cover-glass should be provided, but it should be prevented from actually touching the painted surface. This is best brought about by using the masks cut out of black paper, and sold for the purpose. A mask is inserted between the glasses, after which the whole is fastened together by pasting a slip of paper round the edges of the double glass, and turning it over on either side. Gum arabic with twenty-five per cent. loaf-sugar added, is a good medium by which to attach paper to glass.

[Illustration: FIG. 7. Masks for lantern slides.]

ON THE COLOURING OF PHOTOGRAPHIC TRANSPARENCIES.

There are many amateur photographers nowadays who can produce fair transparencies for the lantern, but at the same time there are many possessors of a lantern who know nothing about the 'black art.' Luckily for these, first-class pictures can be bought cheaply, their average price ranging from eighteenpence to two shillings each. Any optician's catalogue will show what an immense variety of subjects there is to chose from; not only can we obtain landscapes of nearly every part of the world, but we can purchase figure studies, copies of various pictures from books, maps, diagrams of scientific matters--micro-photographs and statuary. These slides if coloured are double the price of plain ones, and if very well coloured their price is quadrupled.

It would therefore be serviceable to many if they could learn how to colour such pictures for their own use, and I give simple directions how this can be accomplished. At the same time it is only fair to state that the work is really difficult, and anyone to attain even slight proficiency in slide-painting must devote a great deal of time and patience to the subject.

The photographic slide as sold consists of two glasses, one of which bears the photograph. This is separated from the cover-glass by a paper mask, the whole being bound round by a fillet of gummed paper. After carefully cutting round this fillet the two glasses may be separated, and the one bearing the picture is placed, varnished side upwards, upon the glass easel, ready for colouring. Some colourists speak in favour of water-colours for glass-painting, others prefer oil-colours, while some, I understand, employ both on the same picture. I have tried each system, and most certainly recommend oil-colours as being both easier to work with, and doing more satisfactory work into the bargain than water-colours.

The materials required comprise ordinary oil-colours in tubes, of which the following are perhaps the most useful that can be employed for the purpose:

Italian Pink. Raw Sienna. Yellow Lake. Chinese Orange. Brown Pink. Prussian Blue. Indigo. Neutral Tint. McGilp. Brown Madder. Rose Madder. Purple Madder. Crimson Lake. Burnt Sienna. Ivory Black.

It is curious to observe that the suitability of these colours for the particular purpose of glass-painting varies with the method of manufacture. I find by experience that one maker's Prussian blue is better than another's, while for a suitable crimson lake I have to go to quite a different shop, and so on.

The brushes used must be of the best, the majority of them being camel-hair, a few fine sables being kept for special touches. It is also necessary to provide some good large bushy camel-hair brushes to be used as softeners.

A flat porcelain palette is better than one of any other material, for the strength of the tints is seen well, and the surface can easily be cleaned with a little turpentine. A flexible palette knife must also be provided.

Dabbers to soften down skies and other flat masses of colour can be made by wrapping a ball of cotton wool in fine wash-leather. The leather should be first thoroughly washed with soap and water, and it will be better if a little of the soap be left in it as it dries, for this renders it soft and pliant. Both dabbers and brushes should be kept in a dust-tight box, for dust is the greatest enemy of the slide-painter.

It will be noticed that the list of colours given includes those only which are transparent, many others used in ordinary oil-painting being omitted. It is obvious that opaque colours like Naples yellow or chrome yellow would simply appear black on the sheet. The tyro who is used to other methods of painting, and has some idea of the harmony of colours, will, of course, have an immense advantage over anyone without artistic knowledge or feeling; and when he has once mastered the technicalities of the new work, will soon be able to produce passable pictures. The list of colours given is necessarily limited for the reason already given, but their number can be increased indefinitely by judicious blending one with the other. Let me give a few instances.

There is no green in the list given, simply because I do not know of a good transparent one. But various tints of green suitable for foliage can be easily made up with the colours named. Prussian blue mixed with any of the yellows will at once give a crude green, but it will not be suitable for use without the help of some other tint, such as burnt Sienna, or one of the reds. Italian pink and indigo make a fine green. Italian pink, brown madder, and Prussian blue is also another useful combination. Brown pink, indigo, and Vandyke brown will be found admirable for the shadows in foliage; indeed, the combinations for this purpose are endless. Again, there is a difficulty generally found in obtaining any approach to scarlet. The best I know of is a mixture of Italian pink, crimson lake, and Chinese orange. For browns, Vandyke brown, Chinese orange, ivory black, and burnt Sienna, will give any range of tints, from the coldest to the warmest. The reader will soon find by experiment the right proportions for mixing these colours to produce the desired effect, and he will be much assisted in the work by studying any good manual of water-colour painting. I recommend a water-colour manual in preference to one dealing with oil-colours, because the first deals more with transparent tints, which depend for their effect upon the white ground upon which they are laid. In like manner a lantern picture depends much upon the white surface upon which the tints are subsequently exhibited.

Our first attempt at glass-painting shall be an open landscape with figures in front--and we will suppose that the scene is laid in Britain. This would seem to some an unimportant point, until they remember that the skies and atmospheric effects seen in some other lands would require an altogether different treatment. I once coloured an Egyptian scene for a friend, and he admired my work, with one exception. 'You have given me an English sky,' he said. The sky will be the first thing to see to, and we will endeavour to give it a flat tint of blue slightly darker at the zenith than it is at the horizon. We squeeze out from its tube a little Prussian blue upon the palette, and dipping a good-sized camel-hair brush into a small cup of turpentine, we take up a little of the colour and work it about on the palette until it seems of the right strength. Before applying it to the glass we add to it a very small quantity of McGilp medium. Having mixed this last addition with our brush-load of colour, we can apply it to the glass, painting it in broad bands from side to side until the sky is all striped with blue. If the subject comprises a range of distant hills, let them too partake of the blue tint. When this is done, lay aside the brush and let the coloured glass rest for a minute, so that some of the turpentine will dry off. Now proceed to dab it carefully with one of the leather dabbers. With a very light touch bring the dabber down over and over again, and avoid anything like a rubbing action. The movement must be vertical, and not in the least horizontal. By bearing a little more heavily on the dabber as the horizon is approached, the tint will be sensibly lightened.

When this sky-colour has been uniformly dabbed in we may proceed to put in, or rather wipe out, some cloud effects. A little piece of soft kid wrapped round a pointed pen-holder is a good tool to use for the purpose, but a leather stump will answer the same end. This part of the work requires a little judgment and artistic taste. In a picture full of detail and which only has a small portion of sky exposed, it is best coloured simply blue. But where there is not much detail in the landscape, as in the case for instance of a mill on a bleak moor, the sky can be worked up with great advantage to the general effect. The clouds are wiped out by a rubbing action combined with a dabbing movement, so that the edges of the clouds formed remain quite soft. If they appear too hard they can be corrected by a few gentle dabs with the top of the finger. Before the leather is laid aside, it may be employed for wiping off any portions of colour which have accidentally been placed where they should not be. But if there is water included in the subject, such as a lake or river, it will when the sky is reflected in it partake of the same colour, and should be dabbed in at the same time.

We must now consider how we are going to treat the rest of our picture. If there is some expanse of foreground it will make the best contrast with the sky if we use a warm sandy colour. Chinese orange, raw Sienna, and brown pink mixed in various proportions to suit the lights and shadows of the picture will give the tint required. At this stage, too, the middle tints of the composition lying between the sky and the foreground can also be laid in. These will mostly consist of subdued greys, made up of Prussian blue, burnt Sienna, purple madder, and crimson lake. When these tints are all dabbed in, and the whole picture has been carefully gone over with the leather point, so as to remove truant colour, the slide may be laid aside to dry. I find it a good plan to have a tin box containing grooves for this purpose. The slides when grounded in in the way just described are placed in the grooves, and the open box is turned towards a fire. In an hour or so the colours are dry enough for further treatment.

We can now once more view our work on the easel, and most probably we shall see much to amend. The trees in the middle distance are too yellow, or too blue. They are easily corrected by a touch of the tint in which they fail. But at this stage of the painting we must use a different medium for our colours. We have done with dabbing, and must now lay the colours on as smoothly as possible with the brush alone. Canada balsam in turpentine, of the consistence of very thin varnish, is perhaps the best medium to use. It should be mixed with every colour as it is taken upon the brush.

The beginner will find some difficulty at first, particularly if oil-colours are new to him, in keeping his brushes in order. He need not have a brush for every tint. Let one be kept for skies, but only two or three others are necessary. When I commence to paint a batch of pictures I put on my table, after carefully dusting it all over with a damp cloth, a sheet of newspaper. In the centre stands my easel. On the left hand my colour-box, and on the right my palette. Close to the palette is placed a double thickness of clean white tissue paper, and a small pot of turpentine. When I wish to clean my brush, it is simply dipped in turpentine, and drawn over the surface of the white paper until I see that it leaves no trail of colour. By this simple means one brush can be used for any number of tints, for the cleansing of it does not occupy more than ten seconds.

It is in the foreground of a picture that the artist must be lavish with his bright colours. If the figures in the subject will allow of bright colouring, so much the better; but it must be remembered that if these colours are not put in with some regard to contrast, their effect is much diminished, if not altogether lost. Let the painter remember that the principal colours have their complementary colours, and that wherever we can place one of these tints against its complementary, we are bound to have harmony. Thus the complementary of blue is orange; of red, green; and of yellow, purple. But for further particulars of this nature, the aforesaid 'Manual of Water-Colours' must be studied.

When the picture is apparently finished, it will, most likely, require some finishing-touches. And here a new tool comes into use, namely, the etching-needle. Take a pointed piece of wood, about the size of a penholder, and bind upon it, by means of waxed thread, a good strong sewing-needle, leaving not more than a quarter of an inch of the point exposed. A few judicious touches with this needle will make a vast difference in the effect of a picture, but anything like coarse scratching must be avoided. The beginner will do well to view his work in the lantern as it gradually progresses, for what may look very well on the easel, will look very different when all its imperfections are magnified on the screen. The art of slide-painting is one which requires constant care and practice before anything like proficiency is attained.

In case some of my readers should be well acquainted with the use of water-colours, and may be deterred from trying the art of glass-painting because oils only are recommended for the work, I will briefly describe how water-colours are utilized for slide-painting. At the same time, I hold to my previously expressed opinion, that oil-colours are the more suitable pigments to use.

The varnished surface of a glass picture does not take kindly to water-colour, and as the brush is applied to it there is a repellent action which would make the painter despair if some means were not at hand to obviate the difficulty. By mixing each colour with a

certain proportion of prepared ox-gall the difficulty vanishes, and it is a wise precaution to rub a little ox-gall and water over the surface of the picture by means of a tuft of cotton wool, before any colour is applied at all.

The same transparent colours as those recommended for oil-painting may be employed, besides a few more transparent tints which are commonly not ground up in oil. But the dabbers are of a different description. Procure two or three good thick camel-hair brushes, and cut the hair off straight with a pair of scissors, so as to leave the ends of the hairs like a flat stump. Now carefully turn the brush round and round in the flame of a spirit lamp, or candle, so as to just singe the point of each hair. When this is done, rub the ends of the hair on the finest glass-paper until every trace of singeing has disappeared. This treatment will leave the brush with a flat woolly head like a mop, which makes an excellent dabber.

When the sky-colour has been applied as evenly as possible, and has been allowed to dry, the surface may be worked over with the dabber. But, before doing this, gently breathe over the colour. The dabber will remove little particles of the pigment, and will reduce the general strength of the tint, so that this loss should be provided for when the colour is first applied. Clouds, etc., can be wiped out with the leather, after the breathing operation, and in many other respects the two modes of colouring agree.

When the general tints have been laid in, the colours may receive a coat of mastic varnish, and this again can be worked over with colour to strengthen those tints which may require it. The varnish also confers a transparency upon the tints that they do not possess without it.

SHOWING SOLID & OPAQUE OBJECTS ON THE LANTERN SCREEN.

Those who are familiar with the working of the microscope know that the objects which are employed in that instrument can be viewed in two different ways. Transparent preparations have the light thrown through them by means of the adjustable mirror beneath the stage. Opaque objects, on the other hand, must have light thrown upon them from above, and this is managed by means of a separate condensing lens. For the magic lantern, transparent pictures are almost wholly employed; but there is a means of utilizing paper prints, photographic _cartes de visite_, and a certain limited number of solid objects, so that they may be shown in an enlarged form on the sheet. The effect is not so bright as when transparencies are employed, for a large proportion of the available light is absorbed in the operation; but there are many who would sacrifice a good deal in the way of effect, for the undoubted advantage of being able to utilize the contents of their albums, etc.

[Illustration: FIG. 8. Ground-plan of Chadburn's Opaque Lantern.

_p_, Picture; _c_, Condenser; _l_, Light; _r_, Reflector; _o_, Objective.]

The first instrument which was constructed to accomplish this end is known as Chadburn's lantern; and, as will be seen from the annexed diagram, it differs very much from the ordinary form of magic lantern. From what has been already said concerning the loss of light, it will be evident that a powerful luminant is a matter of prime consideration. A good oil-lantern will do the work--but not so well as the lime-jet. The luminous face of the lime, instead of being turned towards the optical system, is opposite a concave reflector placed at the back of the lantern. From this the light is reflected towards the condenser, which condenser concentrates the light obliquely upon the object. The picture or object is contained in a kind of box joined to the main lantern, and which holds immediately opposite the illuminated picture the lens for projecting its image upon the screen. This pioneer form of opaque lantern has been superseded by the instrument called the Aphengescope. This can be purchased now of most opticians. Virtually it consists of the front chamber of Chadburn's lantern constructed to fit on to the front of any ordinary oil or lime-lit lantern.

The aphengescope can be used for showing woodcuts, paper photographs, printed and written matter of any kind, so long as the space covered is within the size of the instrument. Thus any caricatures from our comic publications could be pasted on card, and enlarged by its means. But it will be readily observed that this class of subjects, if photographed as transparent positives and used in the ordinary lantern, can be shown far better. The principal use of the aphengescope is to show solid objects which cannot by any possibility be shown enlarged without its help.

Let us suppose, for instance, that it is desired by some collector to show his friends a cabinet of coins and medals. Such objects are so bright in themselves that they are admirably adapted to this instrument. Their form, colour, and minute markings are faithfully reproduced; whilst the raised portions catch the reflected light in such a way as to make the images look as solid as the objects themselves. At the Polytechnic Institution, a lecture upon the invention of the watch, and its gradual development, was beautifully illustrated by the opaque lantern. First came the different parts of the watch, and then the varied movements. It was most curious

and instructive to see the wheels and springs all in movement upon the screen.

There are also many natural things which can be shown by the same means. A freshly opened oyster makes a very remarkable object. A still more curious effect is obtained by concentrating the light upon a freshly cut orange or lemon. When the fruit is squeezed, the pips and juice appear to fly upwards; for, of course, everything is shown upside down, as in the ordinary lantern. The opaque lantern was once introduced into a court of law in America, as a witness for the prosecution in a case of forgery. The following is a condensed account of the occurrence, taken from a New York paper:

'During the recent trial, it became necessary to show the differences between a genuine signature and an imitation or forgery of the same. For this purpose, there was brought into court a powerful reflecting magic lantern. The room was darkened, and images of the two signatures, enormously magnified, were thrown side by side upon a screen before the judge and jury. The false signature was at once revealed. The illumination of the writing was effected by means of two powerful lime-lights contained within the lantern. The peculiar arrangement of the lights and screen enables the examiner to discover the surface of the paper through the ink, so that patching, shading, or painting of letters becomes evident the instant it is brought under the focus of the lantern. An arrangement of screens, by which the light is cut off alternately from either side of the instrument, discovers any tampering with the surface of the paper, either by scratching or washing by chemicals. (In other words, by throwing the light alternately from either side, the relief caused by the grain of the paper is clearly shown; and any tampering with that relief, by scratching or otherwise, at once becomes apparent.) The instrument, in this case, was of sufficient capacity to view at once two bank-notes placed side by side, and the pictures were of such fineness that there was no difficulty in viewing their smallest details. I fear that the introduction of a magic lantern into an English court of law would be rather too sensational for the ordinary legal mind--particularly as the evidence of an expert, with the help of a microscope, would answer the same end.

Under the name of the Physioscope, an immense opaque lantern was exhibited some years back in London. The object magnified on the sheet was the human face, and a correcting lens was included in the apparatus, so that the face was seen right way up. It was always rather an unhappy face, for the individual who lent his countenance to the transaction had on either side of him, and within a few inches of his cheeks, a very powerful lime-light, the heat and glare from which were sufficient to render anyone uncomfortable who was not a salamander.

THE LANTERN MICROSCOPE.

Of late years it has become possible to take very beautiful photographs of microscopic objects, which, when used as lantern-slides, give a very fine effect. Numerous slides of this character may now be purchased, which cover a vast field of microscopic knowledge, and many will be content with what they can thus obtain. But there is another class of workers who, perhaps possessing a large number of microscopic slides, will be glad to utilize them for the lantern, so that they are no longer limited to the individual eye. For these the lantern microscope, which will screw in front of the lantern in place of the usual optical system, is a most useful instrument. Different makers advertise in their catalogues lantern microscopes which range in price from twenty-five shillings to as many guineas. And it recently came to my knowledge that a well-known London optician has undertaken the construction of a few of these instruments at the price of £150 each. The amateur lanternist will, therefore, have some difficulty in deciding what he ought to pay for such an instrument. And it is most difficult to advise him on that point. His best plan is, perhaps, to see for himself what the makers can offer him, and, if possible, to seek a trial of the instrument before he purchases it.

The lantern microscope is a modification of the old solar microscope--an instrument which could be screwed against a hole in the shutter of a darkened room--and which had a mirror outside which projected a beam of sunlight through it. The objective lenses were uncorrected, and small in aperture, so that the instrument was far from being a perfect one. But the intensity of the solar light covered many objectionable features, and it was possible to get some astonishing effects with the contrivance. But sunlight is such an uncertain commodity in our climate that, when the lime-light came into prominence, the old solar microscope was forgotten in favour of that which depended upon a more constant, if a far less intense, light source.

The great difficulty to overcome in the lantern microscope is to get the light sufficiently intense to well illuminate the objects. The aperture of a microscope objective, even of low power, is so small, that, when the pencil of light which it emits is spread over a screen, the light is so attenuated that the details of the object are difficult to make out. In the near future, when we are promised that electricity shall be laid on to our homes, as gas is now supplied to us, the difficulty will disappear, for the electric-arc light is many times more intense than the most powerful lime-jet.

Having obtained a lantern microscope, the next thing to consider is the class of objects which can best be shown with it. To help the reader in determining this point, I will now give a kind of sketch of a popular lecture to accompany an exhibition of the instrument.

Such a lecture might usefully commence with a brief description of the microscope: its history, and how, in its improved form, it has opened up a world of minute life, of which our forefathers could have had no conception. We might then put forward a few remarks as to the adaptation of the microscope to the oxyhydrogen lantern, and point out how by its aid a number of persons can at the same time see what, in an ordinary microscope, is visible to only one person. So much by way of introduction.

We might next enlarge upon the circumstance that the contents of the world have been classified into three general divisions--popularly known as the three kingdoms of Nature: the Mineral Kingdom, the Vegetable Kingdom, and the Animal Kingdom. Show how one is dependent upon the other, and the difficulty in many cases of drawing a line to separate the minute organisms of the Animal Kingdom from those of the Vegetable World. Numerous examples from the lower forms of life may be quoted to illustrate this. Now show and explain subjects from each of the three divisions, taking the minerals first. Define a mineral, and show how they crystallize in definite forms. Illustrate the process of crystallization by putting a drop of a saturated solution of sal-ammoniac on a slip of glass, and spreading it over with a brush. Such a glass placed in the microscope will, as it dries, become covered with branches of crystals, which seem to grow and strike out in various directions on the sheet in a truly marvellous manner. Sections of various minerals may next be shown, finishing with sections of coal. In pointing out the origin of coal from plants, we may easily drift into the next division of our subject--the Vegetable Kingdom.

Here we have indeed a wide field to illustrate. Commencing from the simple cell, as exhibited, for instance, in a bit of so-called green mould, and arriving gradually at sections of different stems of plants (which by the way form most beautiful objects on the screen), sections of different woods, parts of flowers, etc. From these it will be easy to step over the indistinct boundary-line which separates us from the Animal World. Here we can commence with the lowest organisms; next show the living inhabitants of our ponds and ditches. Arrive at the Insect World, and show the generally unfamiliar parts of familiar insects--bees, wasps, flies, etc. We can then go higher, and exhibit sections of bone, hair, etc.; finishing with the structure of the human body, so far as it can be indicated by means of the microscope. This is a brief sketch of the kind of entertainment the microscope is able to afford, which can be modified to suit the views of the exhibitor.

MECHANICAL OR MOVING-PICTURES.

The most common form of moveable slide is that known as a 'comic slip.' This mechanical contrivance for the amusement of youth is generally of the coarsest execution, and it speaks little for the originality of our slide-producers that the same old things should appear in catalogues year after year with no improvement. The 'comic slip' consists of a glass in a wooden frame, with another loose piece of glass which can work backwards and forwards in front of it. This movable glass generally serves as a mere screen to cover something painted underneath it, and it is rubbed over with black varnish so as to be opaque. Thus a gentleman is represented with a nose of the normal size, but as the screen is withdrawn it elongates to an awful extent. Or a woman's tongue may be graphically, if not elegantly, portrayed in the same manner.

In another class of slide a circular glass is kept in slow rotation in front of the slide proper by means of a rack-work attachment. A common design for this device is a landscape with a windmill in the centre. The sails of the mill are painted on the revolving glass, and can be kept in rotation as long as desired. The chromatrope effect is managed in the same way, only that in this case both glasses are caused to slowly revolve in reverse directions. There are many people who admire chromatropes, and many others who regard them as rather trying to the eyes. Rippling water, the rising or setting of the sun or moon, and astronomical slides illustrative of the movements of the heavenly bodies, are among the subjects which can be well illustrated by mechanical means.

Perhaps the cleverest piece of apparatus ever invented to give the effect of movement by means of a magic lantern is Beale's choreutoscope. This instrument depends upon the well-known phenomenon common to our eyes, called persistence of vision. The image of anything that we look at is cast upon the retina at the back of the eye by the agency of the crystalline lens, which is placed behind the pupil. So far, the human eye resembles a camera obscura. Persistence of vision means that an image so cast upon the retina remains impressed there for about the eighth part of a second. For this reason we wink continually without knowing it, for the light impression remains with us during the short time that the eye is closed in accomplishing that necessary action. A burnt stick with a red-hot end whirled round and round appears to us like an unbroken circle of fire. The separate drops of rain as they fall from the sky look like streaks of water, and so an artist will represent them in his picture. A quickly moving meteor looks like a long trail of fire for the same reason.

In the choreutoscope we have a very elegant adaptation of the same principle. It consists, in its commercial form, of a slide arrangement that can be placed in any lantern. This contains a narrow strip of glass, with, say, six figures painted upon it, each figure having a different position. A dancing man is a good representative of the rest. By a turn of a handle each figure is brought into view successively, but so rapidly as to give the effect of moving arms and legs. An interceptor or screen runs in front of each figure as the change occurs.

One of the best designs made for this instrument is a dancing skeleton (see annexed cut). In this case the figures are cut stencil-fashion out of very thin brass, and the openings thus cut transmit so much light that the effect is far more brilliant than if the design were executed on glass in the usual manner. The choreutoscope is not only a most amusing contrivance, but it illustrates in a very beautiful manner this optical law called 'persistence of vision.'

[Illustration: FIG. 9. Facsimile of a dancing skeleton for Beale's Choreutoscope.]

CONCLUDING REMARKS.

The best lantern and the best pictures will not interest an audience unless the entertainer or lecturer is up to his work, and the matter which he conveys is skilfully put together. I believe that lecturing would be far more popular among us had it not been for the numbers of utterly incompetent men who have in past years bored audiences to such an extent that the word 'lecture' is to them as a red rag is to a bull. When I say incompetent men, I do not mean uneducated ones; but I mean those who from natural want of voice, and utter ignorance of its management, are generally unfit for public speaking. It seems to be too often conceded that because a man has written a book--or done something else which has brought him before public notice--he is, without any previous knowledge or practice, fit to lecture on the particular subject with which his name is identified. Or his claims to recognition as a lecturer are based upon certain cabalistic letters after his name, which in many cases represent only so many guineas yearly subscribed to those who confer them. Lecturing is an art that can only be acquired successfully by those who have certain qualifications for the work, and among these the foremost is the power of imparting knowledge to others in a common-sense and interesting manner. Luckily for him, the amateur lecturer is likely to meet with a far more indulgent audience than those which professional men have occasionally to face; but this is no reason why he should be careless as to his method of delivery, or of the matter delivered. Perhaps the er--worst fault er--which a lecturer can er--fall into--is the one indicated er--in this sentence. 'To _err_ is human,' in a wider sense, unfortunately, than Pope, the writer of that well-known line, ever dreamt of. Unless a would-be lecturer can conquer this tiresome habit, or any other trick of speech which he may have cultivated, by all means let him confine himself to the management of the lantern while some one else acts as showman.

If two people are thus managing an exhibition between them, and if the room be large, so that they are widely separated, some signal from the lecturer to indicate that he wants the next picture thrown on the screen becomes necessary. A bell, or anything that makes a noise, is distracting both to lecturer and audience. Still worse are verbal instructions from one to the other. I myself use an electric single-stroke bell with the gong removed, the hammer of which gives a little click unmistakable to the operator, but quite unheard by the audience. Such a bell can be placed close to the lantern, while its push is far away on the lecturer's desk. Sometimes a string can be carried from lecturer to operator, a gentle pull of which will give the necessary signal. Some lecturers signal by uncovering a little pane of red glass in the back of their reading-lamp. But I think that any sight signal is inadmissible, because the operator has quite enough to do in attending to his duties without having his attention thus distracted. The signal, of whatever nature it be, should be given by the lecturer some seconds before he has finished with the picture in hand, otherwise there is an awkward pause while the operator makes the necessary change. Before the lecture begins, the reader should make himself not only thoroughly familiar with his subject, but should be also familiar with the different pictures which illustrate it. And this especially applies to the common case of those who have purchased or hired a set of slides and a published lantern reading--many of which are compiled by writers of repute, and are in every way excellent. Let him, then, carefully go through the reading beforehand, comparing each picture with the text, and making himself so familiar with its details that he is afterwards able, during performance, to point out anything to which attention may advantageously be directed. Particularly is this necessary in the case of an introductory map, where places of importance to the subject in hand must be pointed out. The most convenient form of pointer, by the way, is a Japanese fishing-rod, which telescopes into small compass when not in use.

For an evening's lantern entertainment to be successful, a great deal depends upon the operator. With a mineral-oil lamp in a small room, his duties are not very onerous, for the lamp when once established should require no further attention, except it be to turn down a wick which shows symptoms of smoking. But he should be careful to have in reserve a glass or two to replace the front

glass of the combustion-chamber, which may crack through some unexpected draught of air. His slides must all be numbered and in order. They may be each mounted in a wooden frame to fit the lantern stage, or else the lantern may be fitted with a permanent grooved slide in which the glass pictures are placed one after another, the last one pushing out the one before. Another plan, which is a good one to adopt where a single lantern only is being used, is to make use of what is called a panoramic slide. It is constructed like the one just described, only it is furnished with a travelling tape upon which each picture rests. The turn of a handle moves the tape, and the pictures travel forward panorama-fashion.

In the use of a double lantern furnished with lime-jets, there is plenty for two hands to do, for the operator has to keep his attention fixed not only upon the business of changing the pictures, but upon the condition of the lights. As the pressure of the oxygen gas varies as it is gradually consumed, so the supply of the two gases to the jets will want constant adjustment if the maximum quantity of light is expected. Extra weights, too, must be added as the pressure-boards gradually sink down. Beyond carefulness in this respect, the lantern operator must see to the occasional turning of his limes, taking care to do this when the lime wanting attention is not in actual use. He should also find time to wipe the glass of each picture with a leather before putting it in the lantern, for a film of moisture condenses on the surface, particularly in a room full of people.

The success of a lantern entertainment depends nearly as much on the competence of the assistant as it does on the powers of the lecturer. I am perhaps fastidious on this point, for my lecturing apprenticeship was served at the late Royal Polytechnic Institution, where operators were employed who had spent the best part of their lives in this particular work. It was seldom, indeed, that they made a mistake.

THE END.

BILLING AND SONS, PRINTERS, GUILDFORD.

Transcriber's Notes:

Italics are shown thus: _sloping_.

Variations in spelling and hyphenation are retained.

Perceived typographical errors have been changed.

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The slide rule

Charles N. Pickworth

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THE SLIDE RULE: A PRACTICAL MANUAL

BY

CHARLES N. PICKWORTH

WHITWORTH SCHOLAR; EDITOR OF “THE MECHANICAL WORLD”; AUTHOR OF “LOGARITHMS FOR BEGINNERS”; “THE INDICATOR: ITS CONSTRUCTION AND APPLICATION”; “THE INDICATOR DIAGRAM: ITS ANALYSIS AND CALCULATION,” ETC.

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PREFACE TO THE FIFTEENTH EDITION.

Several new slide rules for special calculations are described in this edition, and the contents further extended to include a section dealing with screw-cutting gear calculations by the slide rule—an application of the instrument to which attention has been given recently.

Mention should be made of the fact that some of the special slide rules described in previous editions are no longer obtainable. As, however, the descriptive notes may be of service to those possessing the instruments, and are, in some measure, of general interest, they have been allowed to remain in the present issue.

The author tenders his thanks to the many who have evinced their appreciation of his efforts to popularise the subject; also for the many kind hints and suggestions which he has received from time to time, and with a continuance of which he trusts to be favoured in the future.

C. N. P.

WITHINGTON, MANCHESTER, _November 1917_.

PREFACE TO THE SEVENTEENTH EDITION.

The sustained demand for this very successful work having resulted in the early call for a new edition, the opportunity has been taken to introduce descriptions of new slide rules and to effect some slight revisions.

C. N. P.

WITHINGTON, MANCHESTER, _December 1920_.

CONTENTS.

PAGE Introductory 5 The Mathematical Principle of the Slide Rule 6 Notation by Powers of 10 8 The Mechanical Principle of the Slide Rule 9 The Primitive Slide Rule 10 The Modern Slide Rule 12 The Notation of the Slide Rule 14 The Cursor or Runner 17 Multiplication 19 Division 24 The Use of the Upper Scales for Multiplication and Division 26 Reciprocals 27 Continued Multiplication and Division 28 Multiplication and Division with the Slide Inverted 30 Proportion 31 General Hints on the Elementary Uses of the Slide Rule 36 Squares and Square Roots 37 Cubes and Cube Roots 40 Miscellaneous Powers and Roots 45 Power and Roots by Logarithms 45 Other Methods of Obtaining Powers and Roots 47 Combined Operations 49 Hints on Evaluating Expressions 52 Gauge Points 53 Examples in Technical Calculations 56 Trigonometrical Application 74 Slide Rules with Log-log Scales 84 Special Types of Slide Rules 92 Long-Scale Slide Rules 96 Circular Calculators 101 Slide Rules for Special Calculations 109 Construction Improvements in Slide Rules 110 The Accuracy of Slide Rule Results 111 Appendix:— New Slide Rules 113 The Solution of Algebraic Equations 122 Screw-Cutting Gear Calculations 124 Gauge Points and Signs on Slide Rules 126 Tables and Data 128 Slide Rule Data Slips 133

THE SLIDE RULE.

INTRODUCTORY.

The slide rule may be defined as an instrument for mechanically effecting calculations by logarithms. Those familiar with logarithms and their use will recognise that the slide rule provides what is in effect a concisely arranged table of logarithms, together with a simple and convenient means for adding and subtracting any selected values. Those, however, who have no acquaintance with logarithms will find that only an elementary knowledge of the subject is necessary to enable them to make full use of the slide rule. It is true that for simple slide-rule operations, as multiplication and division, a knowledge of logarithms is unnecessary; indeed, many who have no conscious understanding of logarithms make good use of the instrument. But this involves a blind reliance upon rules without an appreciation of their origin or limitations, and this, in turn, engenders a want of confidence in the results of any but the simplest operations, and prevents the fullest use being made of the instrument. For this reason a brief, but probably sufficient _résumé_ of the principles of logarithmic calculation will be given. Those desiring a more detailed explanation are referred to the writer's "Logarithms for Beginners."

The slide rule enables various arithmetical, algebraical and trigonometrical processes to be performed with ease and rapidity, and with sufficient accuracy for most practical purposes. A grasp of the simple fundamental principles which underlie its operation, together with a little patient practice, are all that are necessary to acquire facility in using the instrument, and few who have become proficient in this system of calculating would willingly revert to the laborious arithmetical processes.

THE MATHEMATICAL PRINCIPLE OF THE SLIDE RULE.

Logarithms may be defined as a series of numbers in _arithmetical_ progression, as 0, 1, 2, 3, 4, etc., which bear a definite relationship to another series of numbers in _geometrical_ progression, as 1, 2, 4, 8, 16, etc. A more precise definition is:—The logarithm of a number to any base, is the _index of the power_ to which the base must be raised to equal the given number. In the logarithms in general use, known as _common logarithms_, and with which we are alone concerned, 10 is the base selected. The general definition may therefore be stated in the following modified form:—_The common logarithm of a number is the index of the power to which 10 must be raised to equal the given number._ Applying this rule to a simple case, as 100 = 10^2, we see that the base 10 must be squared (_i.e._, raised to the 2nd power) in order to equal 100, the number selected. Therefore, as 2 is the index of the power to which 10 must be raised to equal 100, it follows from our definition that 2 is the common logarithm of 100. Similarly the common logarithm of 1000 will be 3, while proceeding in the opposite direction the common log. of 10 must equal 1. Tabulating these results and extending, we have:—

Numbers 10,000 1000 100 10 1 Logarithms 4 3 2 1 0

It will now be evident that for numbers

between 1 and 10 the logs. will be between 0 and 1 „ 10 „ 100 „ „ 1 „ 2 „ 100 „ 1000 „ „ 2 „ 3 „ 1000 „ 10,000 „ „ 3 „ 4

In other words, the logarithms of numbers between 1 and 10 will be wholly fractional (_i.e._, decimal); the logs. of numbers between 10 and 100 will be 1 _followed by a decimal quantity_; the logs. of numbers between 100 and 1000 will be 2 followed by a decimal quantity, and so on. These decimal quantities for numbers from 1 to 10 (which are the logarithms of this particular series)

are as follows:—

Numbers 1 2 3 4 5 6 7 8 9 10 Logarithms 0 0·301 0·477 0·602 0·699 0·778 0·845 0·903 0·954 1·000

Combining the two tables, we can complete the logarithms. Thus for 3 multiplied successively by 10, we have:—

Numbers 3 30 300 3000 30,000 etc. Logarithms 0·477 1·477 2·477 3·477 4·477 „

We see from this that for numbers having the _same significant figure_ (or figures), 3 in this case, the decimal part or _mantissa_ of the logarithm is the same, but that the integral part or _characteristic_ is always _one less than the number of figures before the decimal point_.

For numbers less than 1 the same plan is followed. Thus extending our first table downwards, we have:—

Numbers 1 0·1 0·01 0·001 0·0001 etc. Logarithms 0 –1 –2 –3 –4 „

so that for 3 divided successively by 10, we have:—

Numbers 3 0·3 0·03 0·003 0·0003 etc. Logarithms 0·477 ■1·477 ■2·477 ■3·477 ■4·477 „

Here again we see that with the same significant figures in the numbers, the mantissa of the logarithm has always the same (_positive_) value, but the characteristic is _one more_ than the _number of 0's immediately following the decimal point_, and is _negative_, as indicated by the minus sign written over it. Only the decimal parts of the logarithms of numbers between 1 and 10 are given in the usual tables, for, as shown above, the logarithms of all tenfold multiples or submultiples of a number can be obtained at once by modifying the characteristic in accordance with the rules given.

An examination of the two rows of figures giving the logarithms of numbers from 1 to 10 will reveal some striking peculiarities, and at the same time serve to illustrate the principle of logarithmic calculation. First, it will be noticed that the addition of any two of the logarithms gives the logarithm of the _product_ of these two numbers. Thus, the addition of log. 2 and log. 4 = 0·301 + 0·602 = 0·903, and this is seen to be the logarithm of 8, that is, of 2 × 4. Conversely, the difference of the logarithms of two numbers gives the logarithm of the _quotient_ resulting from the division of these two numbers. Thus, log. 8 – log. 2 = 0·903 – 0·301 = 0·602, which is the log. of 4, or of 8 ÷ 2.

One other important point is to be noted. If the logarithm of any number is _multiplied_ by 2, 3, or any other quantity, whole or fractional, the result is the logarithm of the original number, raised to the 2nd, 3rd, or other power respectively. Thus, multiplying the log. of 3 by 2, we obtain 0·477 × 2 = 0·954, and this is seen to be the log. of 9, that is, of 3 raised to the 2nd power, or 3 _squared_. Again, log. 2 multiplied by 3 = 0·903—that is, the log. of 8, or of 2 raised to the 3rd power, or 2 _cubed_. Conversely, dividing the logarithm of any original number by any number _n_, we obtain the logarithm of the _n_th root of the original number. Thus, log. 8 ÷ 3 = 0·903 ÷ 3 = 0·301, and is therefore equal to log. 2 or to the log. of the _cube root_ of 8.

Only simple logs. have been taken in these examples, but the student will understand that the same reasoning applies, whatever the number. Thus for 20^3 we prefix the characteristic (1 in this case) to log. 2, giving 1·301. Multiplying by 3, we have 3·903 as the resulting logarithm, and as its characteristic is 3, we know that it corresponds to the number 8000. Hence 20^3 = 8000.

In this brief explanation is included all that need now be said with regard to the properties of logarithms. The main facts to be borne clearly in mind are:—(1.) That to find the _product_ of two numbers, the logarithms of the numbers are to be _added_ together, the result being the logarithm of the product required, the value of which can then be determined. (2.) That in finding the _quotient_ resulting from the division of one number by another, _the difference_ of the logarithms of the numbers gives the logarithm of the quotient, from which the value of the latter can be ascertained. (3.) That to find the result of _raising a number to the nth power_, we _multiply_ the logarithm of the number by _n_, thus obtaining the logarithm, and hence the value, of the desired result. And (4.) That to find the n_th root of a number_, we _divide_ the logarithm of the number by _n_, this giving the logarithm of the result, from which its value may be determined.

NOTATION BY POWERS OF 10.

A convenient method of representing an arithmetical quantity is to split it up into two factors, of which the first is the original number, with the decimal point moved so as to immediately follow the first significant figure, and the second, 10^{_n_} where _n_ is the

number of places the decimal point has been moved, this index being _positive_ for numbers greater than 1, and _negative_ for numbers less than 1.[1] In this system, therefore, we regard 3,610,000 as 3·61 × 1,000,000, and write it as 3·61 × 10^6. Similarly 361 = 3·61 x 10^2; 0·0361 (= (3·61)/(100)) = 3·61 × 10^{–2}; 0·0000361 = 3·61 × 10^{–5}, etc. To restore a number to its original form, we have only to move the decimal point through the number of places indicated by the index, moving to the right if the index is positive and to the left (prefixing 0's) if negative. This method, which should be cultivated for ordinary arithmetical work, is substantially that followed in calculating by the slide rule. Thus with the slide rule the multiplication of 63,200 by 0·0035 virtually resolves itself into 6·32 × 10^4 × 3·5 × 10^{–3} or 6·32 × 3·5 × 10^{4–3} = 22·12 x 10^1 = 221·2. It will be seen later, however, that the result can be arrived at by a more direct, if less systematic, method of working.

THE MECHANICAL PRINCIPLE OF THE SLIDE RULE.

[Illustration: FIG. 1.]

The mechanical principle involved in the slide rule is of a very simple character. In Fig. 1, A and B represent two rules divided into 10 equal parts, the division lines being numbered consecutively as shown. If the rule B is moved to the right until 0 on B is opposite 3 on A, it is seen that any number on A is equal to the coinciding number on B, plus 3. Thus opposite 4 on B is 7 on A. The reason is obvious. By moving B to the right, we add to a length 0·3, another length 0·4, the result read off on A being 7. Evidently, the same result would have been obtained if a length 0·4 had been added, by means of a pair of dividers, to the length 0·3 on the scale A. By means of the slide B, however, the addition is more readily effected, and, what is of much greater importance, the result of adding 3 to _any one of the numbers_ within range, on the lower scale, is _immediately_ seen by reading the adjacent number on A.

Of course, subtraction can be quite as readily performed. Thus, to subtract 4 from 7, we require to deduct from 0·7 on the A scale, a length 0·4 on B. We do this by placing 4 on B under 7 on A, when over 0 on B we find 3, on A. It is here evident that the _difference_ of any pair of coinciding numbers on the scales is constantly equal to 3.

[Illustration: FIG. 2.]

An important modification results if the slide-scale B is inverted as in Fig. 2. In this case, to find the sum of 4 and 3 we require to place the 4 of the A scale to 3 on the B scale, and the result is read on A over 0 on B. Here it will be noted, the _sum_ of any pair of coinciding numbers on the scales is constant and equal to 7. This case, therefore, resembles that of the immediately preceding one, except that the _sum_, instead of the _difference_, of any pair of coinciding numbers is constant.

To find the difference of two factors, the converse operation is necessary. Thus, to subtract 4 from 7, 0 on B is placed opposite 7 on A, and over 4 on B is found 3 on A.

From these examples it will be seen that with the slide _inverted_ the methods of operation are the reverse of those used when the slide is in its normal position.

It will be understood that although we have only considered the primary divisions of the scales, the remarks apply equally to any subdivisions into which the primary spaces of the scales might be divided. Further, we note that the length of scale taken to represent a unit is quite arbitrary.

THE PRIMITIVE SLIDE RULE.

The application of the foregoing principles to the slide rule can be shown most conveniently by describing the construction of a simple form of slide rule:—Take a strip of card about 11 in. long and 2 in. wide; draw a line down the centre of its width, and mark off two points, 10 in. apart. Draw cross lines at these points and figure them 1 and 10 on each side, as in Fig. 3. Next mark off lengths of 3·01, 4·77, 6·02, 6·99, 7·78, 8·45, 9·03 and 9·54 inches, from the line marked 1. Draw cross lines as before, and figure these lines, 2, 3, 4, 5, 6, 7, 8 and 9. To fill in the intermediate divisions of the scale, take the logs, of 1·1, 1·2, 1·3, etc. (from a table), multiply each by 10, and thus obtain the distances from 1, at which the several subdivisions are to be placed. Mark these 1·2, 1·3, 1·4, etc., and complete the scale, making the interpolated division marks shorter to facilitate reading, as with an ordinary measuring rule. Cutting the card cleanly down the centre line, we have the essentials of the slide rule.

[Illustration: FIG. 3.]

The fundamental principle of the slide rule is now evident:—Each scale is graduated in such a manner that the _distance of any number from 1 is proportional to the logarithm of that number_.

[Illustration: FIG. 4.]

"We know that to find the product of 2 × 3 by logarithms, we add 0·301, or log. 2, to 0·477, the log. of 3, obtaining 0·778, or log. 6. With our primitive slide rule we place 1 on the lower scale to 3·01 in. (which we have marked 2) on the upper scale (Fig. 4). Then over 4·77 in. on the lower scale (which we marked 3), we have 7·78 in. (which we marked 6) on the upper scale. Conversely, to divide 6 by 3, we place 3 on the lower scale in agreement with 6 on the upper, and over 1 on the lower scale read 2 on the upper scale. This method of adding and subtracting scale lengths will be seen to be identical with that used in the simple case shown in Fig. 1.

THE MODERN SLIDE RULE.

The modern form of slide rule, variously styled the Gravêt, the Tavernier-Gravêt, and the Mannheim rule, is frequently made of boxwood, but all the leading instrument makers now supply rules made of boxwood or mahogany, and faced with celluloid, the white surface of which brings out the graduations much more distinctly than lines engraved on a boxwood surface. The celluloid facings should not be polished, as a dull surface is much less fatiguing to the eyes. The most generally used, and on the whole the most convenient size of rule, is about 10½in. long, 1¼in. wide, and about ■in. thick; but 5 in., 8 in., 15 in., 20 in., 24 in. and 40 in. rules are also made. In the centre of the stock of the rule a movable slip is fitted, which constitutes the slide, and corresponds to the lower of the two rules of our rudimentary examples.

[Illustration: FIG. 5.]

From Fig. 5, which is a representation of the face of a Gravêt or Mannheim slide rule, it will be seen that four series of logarithmic graduations or scale-lines are employed, the upper and lower being engraved on the stock or body of the rule, while the other two are engraved upon the slide. The two upper sets of graduations are exactly alike in every particular, and the lower sets are also similar. It is usual to identify the two upper scale-lines by the letters A and B, and the two lower by the letters C and D, as indicated in the figure at the left-hand extremities of the scales.

Referring to the scales C and D, these will each be seen to be a development of the elementary scales of Fig. 3, but in this case each principal space is subdivided, more or less minutely. The principle, however, is exactly the same, so that by moving the slide (carrying scale C), multiplication and division can be mechanically performed in the manner described.

The upper scale-line A consists of two exactly similar scales, placed end to end, the first lying between IL and IC, and the second between IC and IR. The first of these scales will be designated the _left-hand A scale_, and the second the _right-hand A scale_. Similarly the coinciding scales on the slide are the _left-hand B scale_ and the _right-hand B scale_. Each of these four scales is divided (as finely as convenient) as in the case of the C and D scales, but, of course, they are exactly one half the length of the latter.

The two end graduations of both the C and D scales are known as the _left-_ and _right-hand indices_ of these scales. Sometimes they are figured 1 and 10 respectively; sometimes both are marked 1. Similarly IL and IR are the left- and right-hand indices of the A and B lines, while IC is the centre index of these scales. Other division lines usually found on the face of the rule are one on the left-hand A and B scales, indicating the ratio of the circumference of a circle to its diameter, $\pi = 3{\cdot}1416$; and a line on the right-hand B scale marking the position of $(\pi)/(4) = 0{\cdot}7854$, used in calculating the areas of circles. Reference will be made hereafter to the scales on the under-side of the slide, and we need now only add that one of the edges of the rule, usually bevelled, is generally graduated in millimetres, while the other edge has engraved on it a scale of inches divided into eighths or tenths. On the bottom face inside the groove of the rule either one or the other of these scales is continued in such a manner that by drawing the slide out to the right and using the scale inside the rule, in conjunction with the corresponding scale on the edge, it is possible to measure 20 inches in the one case, or nearly 500 millimetres in the other. On the back of the rule there is usually a collection of data, for which the slips given at the end of this work may often be substituted with advantage.

THE NOTATION OF THE SLIDE RULE.

Hitherto our attention has been confined to a consideration of the primary divisions of the scales. The same principle of graduation is, however, used throughout; and after what has been said, this part of the subject need not be further enlarged upon. Some explanation of the method of reading the scales is necessary, as facility in using the instrument depends in a very great measure upon the dexterity of the operator in assigning the correct value to each division on the rule. By reference to Fig. 5, it will be seen that each of the primary spacings in the several scales is invariably subdivided into ten; but since the lengths of the successive primary divisions rapidly diminish, it is impossible to subdivide each main space into the same number of parts that the space 1–2 can be subdivided. This variable spacing of the scales is at first confusing to the student, but with a little practice the difficulty is soon overcome.

With the C or D scale, it will be noticed that the length of the interval 1–2 is sufficient to allow each of the 10 subdivisions to be again divided into 10 parts, so that the whole interval 1–2 is divided into 100. The shorter main space 2–3, and the still shorter one 3–4, only allow of the 10 subdivisions of each being divided into five parts. Each of these main spaces is therefore divided into 50 parts. For the remainder of the scale each of the 10 subdivisions of each main space is divided into two parts only; so that from the main division 4 to the end of the scale the primary spaces are divided into 20 parts only.

In the upper scales A or B, it will be found that—as the space 1–2 is of only half the length of the corresponding space on C or D—the 10 subdivisions of this interval are divided into five parts only. Similarly each of the 10 subdivisions of the intervals 2–3, 3–4, and 4–5 are further divided into two parts only, while for the remainder of the scale only the 10 subdivisions are possible, owing to the rapidly diminishing lengths of the primary spacings.

The values actually given on the rule run from 1 to 10 on the lower scales and from 1 to 100 on the upper scales, and, as explained on page 9, all factors are brought within these ranges of values by multiplying or dividing them by powers of 10. By following this plan, we virtually regard each factor as merely a series of significant figures, and make the necessary modification due to the "powers of 10" when fixing the position of the decimal point in the answer.

Many, however, find it convenient in practice to regard the values on the rule as multiplied or divided by such powers of 10 as may be necessary to suit the factors entering into the calculation. If this plan is adopted, the values given to each graduation of the scales will depend on that given to the left index figure (1) of the lower scales, this being any multiple or submultiple of 10. Thus IL on the D scale may be regarded as 1, 10, 100, 1000, etc., or as 0·1, 0·01, 0·001, 0·0001, etc.; but once the initial value is assigned to the index, the ratio of value must be maintained throughout the whole scale. For example, if 1 on C is taken to represent 10, the main divisions 2, 3, 4, etc., will be read as 20, 30, 40, etc. On the other hand, if the fourth main division is read as 0·004, then the left index figure of the scale will be read as 0·001. The figured subdivisions of the main space 1–2 are to be read as 11, 12, 13, 14, 15, 16, 17, 18 and 19—if the index represents 10,—and as corresponding multiples for any other value of the index.

Independently considered, these remarks apply equally to the A or B scale, but in this case the notation is continued through the second half of the scale, the figures of which are to be read as tenfold values of the corresponding figures in the first half of the scale.

The reading of the intermediate divisions will, of course, be determined by the values assigned to the main divisions. Thus, if IL on D is read as 1, then each of the smallest subdivisions of the space 1–2 will be read as 0·01, and each of the smallest subdivisions of the spaces 2–3 or 3–4 as 0·02, while for the remainder of the scale the smallest subdivisions are read as 0·05. In the A or B scale the subdivisions of the space 1–2 of the first half of the scale are (if IL = 1) read as 0·02, 0·04, etc.; for the divisions 2–3, 3–4, and 4–5, the smallest intervals are read as 0·05 of the primary spaces, and from 5 to the centre index of the scale the divisions represent 0·1 of each main interval. Passing the centre index, which is, now read as 10, the smallest subdivisions immediately following are read 10·2, 10·4, etc., until 20·0 is reached; then we read 20·5, 21·0, 21·5 22·0, etc., until the figured main division 5 is reached. The remainder of the scale is read 51, 52, 53, etc., up to 100, the right-hand index.

Further subdivision of any of the spaces of the rule can be effected by the eye, and after a little practice the operator will become quite expert in estimating any intermediate value. It affords good practice to set 1 on C to 1·04, 1·09, etc. on D, and to read the values on D, under 4, 6, 8, etc. on C. As the exact results are easily calculated mentally, the student, by this means, will receive better instruction in estimating intermediate results than can be given by any diagram.

Some rules will be found figured as shown in Fig. 5; in others, the right-hand upper scales are marked 10, 20, 30, etc. Again, others are marked decimally, the lower scales and the left-hand upper scales being figured 1, 1·1, 1·2, 1·3 ... 2·5, etc. The latter form has advantages from the point of view of the beginner.

The method of reading the A and B scales, just given, applies only when these scales are regarded as altogether independent of the lower pair of scales C and D. Some operators prefer to use the A and B scales, and some the C and D scales, for the ordinary operations of proportion, multiplication, and division. Each method has its advantages, as will be shown, but in the more complex calculations, as involution and evolution, etc., the relation of the upper scales to the lower scales becomes a very important factor.

The distance 1–10 on the upper scales is one-half of the distance 1–10 on the lower scales. Hence any distance from 1, taken on the upper scales, represents _twice the logarithm_ which the same distance represents on the lower scales. In other words, the length which represents log. N on D, would represent 2 log. N on A; and, conversely, the length which represents log. N on A, would represent (log. N)/(2) on D.

Now we have seen (page 8) that multiplying the log. of a number by 2 gives the log. of the square of the number. Hence, above any number on D we find its _square_ on A, or, conversely, below any number on A, we find its _square root_ on D. Thus, above 2 we find 4; under 49, we find 7 and so on. Obviously the same relation exists between the B and C scales.

THE CURSOR OR RUNNER.

All modern slide rules are now fitted with a _cursor_ or _runner_, which usually consists of a light metal frame moving under spring control in grooves in the edges of the stock of the rule. This frame carries a piece of glass, mica or transparent celluloid, about 1 in. square, across the centre of which a fine reference line is drawn exactly at right angles to the line of scales. To "set the cursor" to any value on the scales of the rule, the frame is taken between the thumb and forefinger and adjusted in position until the line falls exactly upon the graduation, or upon an estimated value, between a pair of graduations, as the case may be. Having fixed one number in this way, another value on either of the scales on the slide may be similarly adjusted in reference to the cursor line. The cursor will be found very convenient in making such settings, especially when either or both of the numbers are located by eye estimation. It also finds a very important use in referring the readings of the upper scale to those of the lower, or _vice versa_, while as an aid in continued multiplication and division and complex calculations generally, its value is inestimable.

Multiple Line Cursors.—Cursors can be obtained with _two_ lines, the distance between them being that between 7·854 and 10 on the A scale. The use of this cursor is explained on page 57. Another multiple line cursor has short lines engraved on it, corresponding to the main graduations from 95 to 105 on the respective scales. This is useful for adding or deducting small percentages.

The Broken Line Cursor.—To facilitate setting, broken line cursors are made, in which the hair-line is not continued across the scales, but has two gaps, as shown in Fig. 6.

The Pointed Cursor has an index or pointer, extending over the bevelled edge of the rule, on which is a scale of inches. It is useful for summing the lengths of the ordinates of indicator diagrams, and also for plotting lengths representing the logarithms of numbers, sometimes required in graphic calculations.

The Goulding Cursor.—It has been pointed out that in order to obtain the third or fourth figure of a reading on the 10 in. slide rule, it is frequently necessary to depend upon the operator's ability to mentally subdivide the space within which the reading falls. This subdivision can be mechanically effected by the aid of the Goulding Cursor (Fig. 7), which consists of a frame fitting into the usual grooves in the rule, and carrying a metal plate faced with celluloid, upon which is engraved a triangular scale A B C. The portion carrying the chisel edges E is not fixed to the cursor proper, but slides on the latter, so that the index marks on the projecting prongs can be moved slightly along the scales of the rule, this movement being effected by the short end of the bent lever F working in the slot as shown. D is a pointer which can be moved along F under spring control. As illustrating the method of use, we will assume that 1 on C is placed to 155 on D, and that we require to read the value on D under 27 on C. This is seen to lie between 4150 and 4200, so setting the pointer D to the line B C—always the first operation—we move the whole along the rule until the index line on the lower prong agrees with 4200. We then move F across the scale until the index line agrees with 4100, set the pointer D to the line A C, and move the lever back until the index line agrees with 27 on the slide. It will then be found that the pointer D gives 85 on A B as the value of the supplementary figures, and hence the complete reading is 4185.

[Illustration: FIG. 6.]

[Illustration: FIG. 8.]

[Illustration: FIG. 7.]

[Illustration: FIG. 9.]

Magnifying Cursors are of assistance in reading the scales, and in a good and direct light are very helpful. In one form an ordinary lens is carried by two light arms hinged to the upper and lower edges of the cursor, so that it can be folded down to the face of the rule when not in use. A more compact form, shown in Fig. 8, consists of a strip of plano-convex glass, on the under-side of which is the hair-line. In a cursor made by Nestler of Lahr, the plano-convex strip is fixed on the ordinary cursor. The magnifying power is about 2, so that a 5 in. rule, having the same number of graduations as a 10 in. rule, can be read with equal facility, by the aid of this cursor.

The Digit-registering Cursor, supplied by Mr. A. W. Faber, London, and shown in Fig. 9, has a semicircular scale running from 0 at the centre upward to –6 and downward to +6. A small finger enables the operator to register the number of digits to be added or subtracted at the end of a lengthy operation, as explained at page 28.

MULTIPLICATION.

In the preliminary notes it was shown that by mechanically adding two lengths representing the logarithms of two numbers, we can obtain the _product_ of these numbers; while by subtracting one log. length from another, the number represented by the latter is divided by the number represented by the former. Hence, using the C and D scales, we have the

RULE FOR MULTIPLICATION.—_Set the index of the C scale to one of the factors on D, and under the other factor on C, find the product on D._

[Illustration: FIG. 10.]

Thus, to find the product of 2 × 4, the slide is moved to the right until the left index (1) of C is brought over 2 on D, when under the other factor (4) on C, is found the required product (8) on D. Following along the slide, to the right, we find that beyond 5 on C (giving 10 on D), we have no scale below the projecting slide (Fig. 10). If we imagine the D scale prolonged to the right, we should have a repetition of the earlier portion, but, as with the two parts of the A scales, the repeated portion would be of tenfold value, and 10 on C would agree with 20 on the prolonged D scale. We turn this fact to account by moving the slide to the left until 10 on C agrees with 2 on D, and we can then read off such results as 2 × 6 = 12; 2 × 8 = 16, etc., remembering that as the scale is now of tenfold value, there will be two figures in the result. Hence, for those who prefer rules, we have the

RULE FOR THE NUMBER OF DIGITS IN A PRODUCT.—_If the product is read with the slide projecting to the_ LEFT, ADD THE NUMBER OF THE DIGITS IN THE TWO FACTORS; _if read with the slide to the_ RIGHT, _deduct 1 from this sum_.

EX.—25 × 70 = 1750.

The product is found with the slide projecting to the _left_, so the number of digits in the product = 2 + 2 = 4.

EX.—3·6 × 25 = 90.

The slide projects to the _right_, and the number of digits in the product is therefore 1 + 2 – 1 = 2.

EX.—0·025 × 0·7 = 0·0175.

The product is obtained with the slide projecting to the _left_, and the number of digits is therefore –1 + 0 = –1.

EX.—0·000184 × 0·005 = 0·00000092.

The sum of the number of digits in the two factors = –3 + (–2) = –5, but as the slide projects to the _right_, the number of digits will be –5 – 1 = –6.

From the last two examples it will be seen that when the first significant figure of a decimal factor does not immediately follow the decimal point, the minus sign is to be prefixed to the number of digits, counting as many digits _minus_ as there are 0's following the decimal point. Thus, 0·03 has –1 digit, 0·0035 has –2 digits, and so on. Some little care is necessary to ensure these minus values being correctly taken into account in determining the number of digits in the answer. For this reason many prefer to treat

decimal factors as whole numbers, and to locate the decimal point according to the usual rules for the multiplication of decimals. Thus, in the last example we take 184 × 5 = 920, but as by the usual rule the product must contain 6 + 3 = 9 decimal places, we prefix six cyphers, obtaining 0·00000092. When both factors consist of integers as well as decimals, the number of digits in the product, and therefore the position of the decimal point, will be determined by the usual rule for whole numbers.

Another method of determining the number of digits in a product deserves mention, which, not being dependent upon the position of the slide, is applicable to all calculating instruments.

GENERAL RULE FOR NUMBER OF DIGITS IN A PRODUCT.—_When the first significant figure in the product is smaller than in_ EITHER _of the factors, the number of digits in the product is equal to the_ SUM _of the digits in the two factors. When the contrary is the case, the number of digits is 1_ LESS _than the sum of the digits in the two factors. When the first figures are the same, those following must be compared._

Estimation of the Figures in a Product.—We have given rules for those who prefer to decide the number of figures by this means, but experience will show that to make the best use of the instrument, the result, as read on the rule, should be regarded merely as the _significant figures of the answer_, the position of the decimal point, if not obvious, being decided by a very rough mental calculation. In very many instances, the magnitude of the result will be evident from the conditions of the problem—_e.g._, whether the answer should be 0·3 in., 3 in., or 30 in.; or 10 tons, 0·1 ton, 100 tons, etc. In those cases where the magnitude of the answer cannot be estimated, and the factors contain many figures, or have a number of 0's following the decimal point, the use of notation by powers of 10 (page 8) is of considerable assistance; but more usually it will be found, that a very rough calculation will settle the point with comparatively little trouble. Considerable practice is needed to work rapidly and with certainty, when using rules. Moreover, the experience thus acquired is confined to slide-rule work. The same time spent in practising the "rough approximation" method will enable reliable results to be obtained rapidly, with the advantage that the method is applicable to calculations generally. However, the choice of methods is a matter of personal preference. Both methods will be given, but whichever plan is followed, the student is strongly advised to cultivate the habit of forming an idea of the magnitude of the result.

EX.—33·6 × 236 = 7930.

Setting 1 on C to 33·6 on D, we read under 236 on D and find 793 on D, as the significant figures of the answer. A rough calculation, as 30 × 200 = 6000, indicates that the result will consist of 4 figures, and is therefore to be read as 7930.

EX.—17,300 × 3780 = 65,400,000.

By factorising with powers of 10

1·73 × 10^4 × 3·78 × 10^3 = 1·73 × 3·78 × 10^7.

Setting 1 on C to 1·73 on D, we read, under 3·78 on C, the result of the simple multiplication, as 6·54. Multiplying by 10^7 moves the decimal point 7 places to the right, and the answer is 65,400,000.

If it is required to find a series of products of which one of the factors is _constant_, set 1 on C to the constant factor on D and read the several products on D, under the respective variable factors.

If the factors are required which will give a constant _product_ (really a case of division), set the cursor to the constant product on D. Then obviously, as the slide is moved along, any pair of factors found simultaneously under the cursor line on C, and on D under index of C, will give the product. A better method of working will be explained when we deal with the inversion of the slide.

It is sometimes useful to remember that although we usually set the slide to the rule, we can obtain the result equally well by setting the rule to the slide. Thus, bringing 1 (or 10) on D to 2 on C, we find on C, _over_ any other factor, _n_ on D, the product of 2 × _n_. But note that the slide and rule have now changed places, and if we use rules for the number of digits in the result, we must now deduct 1 from the sum of the digits in the factors, when the _rule projects_ to the _right of the slide_.

With the ordinary 10 in. rule it will be found in general that the extent to which the C and D scales are subdivided is such as to enable not more than three figures in either factor being dealt with. For the same reason it is impossible to directly read more than the first three figures of any product, although it is often possible—by mentally dividing the smallest space involved in the reading—to correctly determine the fourth figure of a product. Necessarily this method is only reliable when used in the earlier parts of the C and D scales. However, the last numeral of a three-figure, and in some cases the last of a four-figure, product can be

readily ascertained by an inspection of the factors.

EX.—19 × 27 = 513. Placing the L.H. index of C to 19 on D, we find opposite 27 on C, the product, which lies between 510 and 515. A glance at the factors, however, is sufficient to decide that the third figure must be 3, since the product of 9 and 7 is 63, and the last figure of this product must be the last figure in the answer.

EX.—79 × 91 = 7189.

In this case the division line 91 on C indicates on D that the answer lies between 7180 and 7190. As the last figure must be 9, it is at once inferred that the last two figures are 89.

When there are more than three figures in either or both of the factors, the fourth and following figures to the right must be neglected. It is well to note, however, that if the first neglected figure is 5, or greater than 5, it will generally be advisable to increase by 1 the third figure of the factor employed. Generally it will suffice to make this increase in one of the two factors only, but it is obvious that in some cases greater accuracy will be obtained by increasing both factors in this way.

CONTINUED MULTIPLICATION.—To find the product of more than two factors, we make use of the cursor to mark the position of successive products (the value of which does not concern us) as the several factors are taken into the calculation. Setting the index of C to the 1st factor on D, we bring the line of the cursor to the 2nd factor on C, then the index of C to the cursor, the cursor to the 3rd factor, index of C to cursor, and so on, reading the final product on D under the last factor on C. (Note that the 1st factor and the result are read on D; all intermediate readings are taken on C.)

If the rule for the number of digits in a product is used, it is necessary to note the number of times multiplication is effected with the slide projecting to the right. This number, deducted from the sum of the digits of the several factors, gives the number of digits in the product. Ingenious devices have been adopted to record the number of times the slide projects to the right, but some of these are very inconvenient. The author's method is to record each time the slide so projects, by a minus mark, thus –. These can be noted down in any convenient manner, and the sum of the marks so obtained deducted from the sum of the digits in the several factors, gives the number of digits in the product as before explained.

EX.—42 × 71 × 1·5 × 0·32 × 121 = 173,200.

The product given, which is that read on the rule, is obtained as follows:—Set R.H. index of C to 42 on D, and bring the cursor to 71 on C. Next bring the L.H. index of C to the cursor, and the latter to 1·5 on C. This multiplication is effected with the slide to the right, and a memorandum of this fact is kept by making a mark –. Bring the R.H. index of C to the cursor and the latter to 0·32 on C. Then set the L.H. index of C to the cursor and read the result, 1732, on D under 121 on C, while as a slide again projects to the right, a second – memo-mark is recorded. There are 2 + 2 + 1 + 0 + 3 = 8 digits in the factors, and as there were 2 – marks recorded during the operation, there will be 8 – 2 = 6 digits in the product, which will therefore read 173,200 (173,194·56).

For a very rough evaluation of the result, we note that 1·5 × 0·3 is about 0·5; hence, as a clue to the number of figures we have

40 × 70 × 60 = 3000 × 60 = 180,000.

DIVISION.

The instructions for multiplication having been given in some detail, a full discussion of the inverse process of division will be unnecessary.

RULE FOR DIVISION.—_Place the divisor on C, opposite the dividend on D, and read the quotient on D under the index of C._

EX.—225 ÷ 18 = 12·5.

Bringing 18 on C to 225 on D, we find 12·5 under the L.H. index of C.

As in multiplication, the factors are treated as whole numbers, and the position of the decimal point afterwards decided according to the following rule, which, as will be seen, is the reverse of that for multiplication:—

RULE FOR THE NUMBER OF DIGITS IN A QUOTIENT.—_If the quotient is read with the slide projecting to the_ LEFT, _subtract the number of digits in the divisor from those in the dividend; but if read with the slide to the_ RIGHT, ADD _1 to this difference_.[2]

In the above example the quotient is read off with the slide to the right, so the number of digits in the answer = 3 – 2 + 1 = 2.

EX.—0·000221 ÷ 0·017 = 0·013.

Here the number of digits in the dividend is –3, and in the divisor –1. The difference is –2; but as the result is obtained with the slide to the right, this result must be increased by 1, so that the number of digits in the quotient is –2 + 1 = –1, giving the answer as 0·013.

If preferred, the result can be obtained in the manner referred to when considering the multiplication of decimals. Thus, treating the above as whole numbers, we find that the result of dividing 221 by 17 = 13, since the difference in the number of digits in the factors, which is 1, is, owing to the position of the slide, increased by 1, giving 2 as the number of digits in the answer. Then by the rules for the division of decimals we know that the number of decimal places in the quotient is equal to 6 – 3 = 3, showing that a cypher is to be prefixed to the result read on the rule.

As in multiplication, so in division, we have a

GENERAL RULE FOR NUMBER OF DIGITS IN A QUOTIENT.—_When the first significant figure in the_ DIVISOR _is greater than that in the_ DIVIDEND_, the number of digits in the quotient is found by subtracting the digits in the divisor from those in the dividend. When the contrary is the case, 1_ IS TO BE ADDED _to this difference. When the first figures are the same, those following must be compared._

ESTIMATION OF THE FIGURES IN A QUOTIENT.—The method of roughly estimating the number of figures in a quotient needs little explanation.

EX.—3·95 ÷ 5340 = 0·00074.

Setting 534 on C to 3·95 on D we read under the (R.H.) index of C, the significant figures on D, which are 74. Then 3·9 ÷ 5 is about 0·8 and 0·8 ÷ 1000 gives 0·0008 as a rough estimate.

EX.—0·00000285 ÷ 0·000197 = 0·01446.

Regarding this as 2·85 × 10^{–6} ÷ 1·97 × 10^{–4} we divide 2·85 by 1·97 and obtain 1·446. Dividing the powers of 10 we have 10^{–6} ÷ 10^{–4} = 10^{–2}, so the decimal point is to be moved two places to the left and the answer is read as 0·01446.

Another method of dividing deserves mention as of special service when dividing a number of quantities by a _constant divisor_:—Set the index of C to the divisor on D and over any dividend on D, read the quotient on C.

For the division of a _constant dividend_ by a variable divisor, set the cursor to the dividend on D and bring the divisor on C successively to the cursor, reading the corresponding quotients on D under the index of C. Another method which avoids moving the slide is explained in the section on “Multiplication and Division with the Slide Inverted.”

CONTINUED DIVISION, if we can so call such an expression as

(3·14)/(785 × 0·00021 × 4·3 × 64·4) = 0·0688,

may be worked by repeating as follows:—Set 7·85 on C to 3·14 on D, bring cursor to index of C, 2·1 on C to cursor, cursor to index, 4·3 to cursor, cursor to index, 6·44 to cursor, and under index of C read 688 on D as the significant figures of the answer.

For the number of figures in the result, we deduct the sum of the number of digits in the several factors and add 1 for each time the slide projects to the right, which in this case occurs once. There are 3 + (–3) + 1 + 2 = 3 denominator digits, 1 numerator digit, and 1 is to be added to the difference. Therefore there are 1 – 3 + 1 = –1 digits in the answer, which is therefore 0·0688. The foregoing method of working may confuse the beginner, who is apt to fall into the process of continued multiplication. For this reason, until familiarity with combined methods has been acquired, the product of the several denominators should be first found by the continued multiplication process, and the figures in this product determined. Then divide the numerator by this product to obtain the result.

As the denominator product will be read on D, we may avoid resetting the slide by bringing the numerator on C to this product and reading the result on C _over_ the index of D. The slide and rule have here changed places; hence if rules are followed for the

number of figures in the result, 1 must be added to the difference of digits, when the _rule projects_ to the _right of the slide_.

The author's method of recording the number of times division is performed with the slide to the right is by vertical memorandum marks, thus |. The full significance of these memo-marks will appear in the following section.

For a rough calculation to fix the decimal point, in this example we move the decimal points in the factors, obtaining

(3)/(0·8 × 2 × 4 × 6) = (3)/(40) = 0·075.

THE USE OF THE UPPER SCALES FOR MULTIPLICATION AND DIVISION.

Many prefer to use the upper scales A and B, in preference to C and D. The disadvantage is that as the scales are only one-half the length of C or D, the graduation does not permit of the same degree of accuracy being obtained as when working with the lower scales. But the result can always be read directly from the rule without ever having to change the position of the slide after it has been initially set. Hence, it obviates the uncertainty as to the direction in which the slide is to be moved in making a setting.

When the A and B scales are employed, it is understood that the left-hand pair of scales are to be used in the same manner as C and D, and so far the rules relating to the latter are entirely applicable. But in this case the slide is always moved to the right, so that in multiplication the product is found either upon the left or right scales of A. If it is found on the left A scale, the rule for the number of digits in the product is found as for the C and D scales, and is equal to the _sum of the digits in the two factors, minus 1_; but if found on the right-hand A scale, the number of digits in the product is equal to the sum of the digits in the two factors.

In division, similar modifications are necessary. If when moving the slide to the right the division can be completely effected by using the L.H. scale of A, the quotient (read on A above the L.H. of index B) has a number of digits equal to the number in the dividend, less the number in the divisor, _plus 1_. But if the division necessitates the use of both the A scales, the number of digits in the quotient equals the number in the dividend, less the number in the divisor.

RECIPROCALS.

A special case of division to be considered is the determination of the _reciprocal_ of a number _n_, or (1)/(_n_). Following the ordinary rule for division, it is evident that setting _n_ on C to 1 on D, gives (1)/(_n_) on D under 1 on C. It is more important to observe that by inverting the operation—setting 1 (or 10) on C to _n_ on D—we can read (1)/(_n_) on C over 1 (or 10) on D. Hence whenever a result is read on D under an index of C, we can also read its reciprocal on C over whichever index of D is available.

The Number of Digits in a Reciprocal is obvious when _n_ = 10, 100, or any power (_p_) of 10. Thus (1)/(10) = 0·1; (1)/(100) = 0·01; (1)/(10^{_p_}) = 1 preceded by _p_ – 1 cyphers. For all other cases we have the rule:—_Subtract from 1 the number of digits in the number._

EX.—(1)/(339) = 0·00295.

There are 3 digits in the number; hence, there are 1 – 3 = –2 digits in the answer.

EX.—(1)/(0·0000156) = 64,100.

There are –4 digits in the number; hence, there are 1 – (–4) = 5 digits in the result.

CONTINUED MULTIPLICATION AND DIVISION.

By combining the rules for multiplication and division, we can readily evaluate expressions of the form (_a_)/(_b_) × (_c_)/(_d_) × (_e_)/(_f_) × (_g_)/(_h_) = _x_. The simplest case, (_a_ × _c_)/(_b_) can be solved by one setting of the slide.[3] Take as an example, (14·45 × 60)/(8·5) = 102. Setting 8·5 on C to 14·45 on D, we can, if desired, read 1·7 on D under 1 on C, as the quotient. However, we are not concerned with this, but require its multiplication by 60, and the slide being already set for this operation, we at once read under 60 on C the result, 102, on D. The figures in the answer are obvious.

When there are more factors to take into account, we place the cursor over 102 on D, bring the next divisor on C to the cursor, move the cursor to the next multiplier on C, bring the next divisor on C to the cursor, and so on, until all the factors have been dealt with. Note that only the first factor and the result are read on D; also _that the cursor is moved for multiplying and the slide for

dividing_.

Number of Digits in Result in Combined Multiplication and Division.—For those who use rules the author's method of determining the decimal point in combined multiplication and division may be used. Each time _multiplication_ is performed with the slide projecting to the _right_, make a – mark; each time _division_ is effected with the slide to the right, make a | mark; _but allow the_ | _marks to cancel the_ – _marks as far as they will_. Subtract the sum of the digits in the denominator from the sum of digits in the numerator, and to this difference _add_ any uncancelled memo-marks, if of | character, or _subtract_ them if of – character.

EX.—(43·5 × 29·4 × 51 × 32)/(27 × 3·83 × 10·5 × 1·31) = 1468.

[Sidenote: ■ ■ ■ ■]

Set 27 on C to 43·5 on D, and as with this _division_ the slide is to the right, make the first ■ mark. Bring cursor to 29·4 on C, and as in this _multiplication_ the slide is to the right, make the first – mark, cancelling as shown. Setting 3·83 on C to the cursor, requires the second ■ mark, which, however, is cancelled in turn by the multiplication by 51. The division by 10·5 requires the third ■ mark, and after multiplying by 32 (requiring no mark) the final division by 1·31 requires the fourth ■ mark. Then, as there are 8 numerator digits, 6 denominator, and 2 uncancelled memo-marks (which, being 1, are additive) we have

Number of digits in result = 8 – 6 + 2 = 4.

Had the uncancelled marks been – in character, the number of digits would have been 8 – 6 – 2 = 0.

For quantities less than 0·1 the digit place numbers will be _negative_. The troublesome addition of these may be avoided by transferring them to the opposite side and treating them as positive.

_2_ _4_ 0·00356 × 27·1 × 0·08375 Thus:— ■■■■■■■■■■■■■■■■■■■■■■■■■■ = 288 0·1426 × 9·85 × 0·00002 _2_ _1_ _1_

The first numerator, 0·00356, has –2 digits. Note this by placing 2 _below the lower line_ as shown. 27·1 has 2 digits; place 2 over it. 0·08375 has –1 digit; hence place 1 _below the lower line_. The first denominator has no digits; the second, 9·85, has 1 digit; hence place 1 under it. 0·00002 has –4 digits; place 4 _above the upper line_. The sum of the top series is 2 + 4 = 6; of the bottom series 2 + 1 + 1 = 4. Subtracting the bottom from the top, we have 6 – 4 = 2 digits, to which 1 has to be added for an uncancelled memo-mark, and the result is read as 288.

Moving the decimal point often facilitates matters. Thus, (32·4 × 0·98 × 432 × 0·0217)/(4·71 × 0·175 × 0·00000621 × 412000) is much more conveniently dealt with when re-arranged as (32·4 × 9·8 × 432 × 2·17)/(4·71 × 17·5 × 6·21 × 4·12) = 141.

To determine the number of figures in the result by rough cancelling and mental calculation, we note that 4·71 enters 432 about 100 times; 9·8 enters 17·5 about 2; 6·21 into 32·4 about 5; and 2·17 into 4·12 about 2. This gives (500)/(4) = 125, showing that the result contains 3 digits. From the slide rule we read 141, which is therefore the result sought.

The occasional traversing of the slide through the rule, to interchange the indices—a contingency which the use of the C and D scales always involves—may often be avoided by a very simple expedient. Such an example as (6·19 × 31·2 × 422)/(1120 × 8·86 × 2.09) = 3·93 is sometimes cited as a particularly difficult case. Working through the expression as given, two traversings of the slide are necessary; but by taking the factors in the slightly different order, (6·19 × 31·2 × 422)/(8·86 × 2·09 × 1120), _so that the significant figures of each pair are more nearly alike_, we not only avoid any traversing the slide, but we also reduce the extent to which the slide is moved to effect the several divisions.

Such cases as (_a_ × _b_)/(_c_ × _d_ × _e_ × _f_ × _g_) or (_a_ × _b_ × _c_ × _d_ × _e_)/(_f_ × _g_) really resolve themselves into (_a_ × _b_ × 1 × 1 × 1)/(_c_ × _d_ × _e_ × _f_ × _g_) and (_a_ × _b_ × _c_ × _d_ × _e_)/(_f_ × _g_ × 1 × 1 × 1), but, of course, if rules are used to locate the decimal point, the 1's so (mentally) introduced are not to be counted as additional figures in the factors.

MULTIPLICATION AND DIVISION WITH THE SLIDE INVERTED.

If the slide be inverted in the rule but with the same face uppermost, so that the ■ scale lies adjacent to the A scale, and the right and left indices of the slide and rule are placed in coincidence, we find the product of any number on D by the coincident number on

■ (readily referred to each other by the cursor) is always 10. Hence, by reading the numbers on ■ as decimals, we have over any unit number on D, its _reciprocal_ on ■. Thus 2 on D is found opposite 0·5 on ■; 3 on D opposite to 0·333; while opposite 8 on ■ is 0·125 on D, etc. The reason of this is that the sum of the lengths of the slide and rule corresponding to the factors, is always equal to the length corresponding to the product—in this case, 10.

It will be seen that if we attempt to apply the ordinary rule for multiplication, with the slide inverted, we shall actually be multiplying the one factor taken on D by the _reciprocal_ of the other taken on ■. But multiplying by the _reciprocal of a number_ is equivalent to _dividing_ by that number, and _dividing_ a factor by the _reciprocal_ of a number is equivalent to _multiplying_ by that number. It follows that with the slide inverted the operations of multiplication and division are reversed, as are also the rules for the number of digits in the product and the position of the decimal point. Hence, in multiplying with the slide inverted, we place (by the aid of the cursor) one factor on ■ opposite the other factor on D, and read the result on D under either index of ■. It follows that with the slide thus set, any pair of coinciding factors on ■ and D will give the same constant product found on D under the index of ■. One useful application of this fact is found in selecting the scantlings of rectangular sections of given areas or in deciding upon the dimensions of rectangular sheets, plates, cisterns, etc. Thus by placing the index of ■ to 72 on D, it is readily seen that a plate having an area of 72 sq. ft. may have sides 8 by 9 ft., 6 by 12, 5 by 14·4, 4 by 18, 3 by 24, 2 by 36, with innumerable intermediate values. Many other useful applications of a similar character will suggest themselves.

PROPORTION.

With the slide in the ordinary position and with the indices of the C and D scales in exact agreement, the _ratio_ of the corresponding divisions of these scales is 1. If the slide is moved so that 1 on C agrees with 2 on D, we know that under any number _n_ on C is _n_ × 2 on D, so that if we read numerators on C and denominators on D we have

C 1 1·5 2 3 4 ■■■

read off. It must be remembered that if the slide is moved in the direction of notation (to the _right_), the values read thereon have a tenfold _greater_ value; if the slide is moved to the _left_, the readings thereon are _decreased_ in a tenfold degree. Although preferred by many, in the form given, the case is obviously one of multiplication, and is so treated in the Data Slips at the end of the book.

TABLE OF CONVERSION FACTORS.

■■■

■28·23 „ „ ■Imperial gallons ■6·235 „ „ ■U.S. gallons ■7·48 Litre of water ■Cubic inches ■61·025 Gallons of water ■Weight in kilos ■4·54 Pounds of fresh water ■Pounds of sea water ■1·026 Grains per gallon ■Grammes per litre ■0·01426 Pounds per gallon ■Kilos. per litre ■0·0998 „ per U.S. gal. ■„ „ ■0·115

■■■

We have seen that the relation which the upper scales bear to the lower set is such that over any number on D is its square on A, and, conversely, under any number on A is its square root on D, the same remarks applying to the C and B scales on the slide. Taking the values engraved on the rule, we have on D, numbers lying between 1 and 10, and on A the corresponding squares extending from 1 to 100. Hence the squares of numbers between 1 and 10, or the roots of numbers between 1 and 100, can be read off on the rule by the aid of the cursor. All other cases are brought within these ranges of values by factorising with powers of 10, as before explained.

The more practical rule is the following:—

To Find the Square of a Number, set the cursor to the number on D and read the required square on A under the cursor. The rule for

The Number of Digits in a Square is easily deducible from the rule for multiplication. If the square is read on the _left_ scale of A, it will contain _twice_ the number of digits in the original number _less_ 1; if it is read on the _right_ scale of A, it will contain _twice_ the number of digits in the original number.

EX.—Find the square of 114.

Placing the cursor to 114 on D, it is seen that the coinciding number on A is 13. As the result is read off on the _left_ scale of A, the number of digits will be $(3 \times 2) - 1 = 5$, and the answer is read as 13,000. The true result is 12,996.

EX.—Find the square of 0·0093.

The cursor being placed to 93 on D, the number on A is found to be 865. The result is read on the _right_ scale of A, so the number of digits = $-2 \times 2 = -4$, and the answer is read as 0·0000865 [0·00008649].

Square Root.—The foregoing rules suggest the method of procedure in the inverse operation of extracting the square root of a given number, which will be found on the D scale opposite the number on the A scale. It is necessary to observe, however, that if the number consists of an _odd_ number of digits, it is to be taken on the _left-hand_ portion of the A scale, and the number of digits in the root = $(N + 1)/(2)$, N being the number of digits in the original number. When there is an even number of digits in the number, it is to be taken on the _right-hand_ portion of the A scale, and the root contains _one-half_ the number of digits in the original number.

EX.—Find the square root of 36,500.

As there is an _odd_ number of digits, placing the cursor to 365 on the L.H. A scale gives 191 on D. By the rule there are $(N + 1)/(2) = (5 + 1)/(2) = 3$ digits in the required root, which is therefore read as 191 [191·05].

EX.—Find $\sqrt{}$(0·0098.)

Placing the cursor to 98 on the right-hand scale of A (since –2 is an _even_ number of digits), it is seen that the coinciding number on D is 99. As the number of digits in the number is –2, the number of digits in the root will be $(-2)/(2) = -1$. It will therefore be read as 0·099 [0·09899+].

EX.—Find $\sqrt{}$(0·098).

The number of digits is –1, so under 98 on the left scale of A, we find 313 on D. By the rule the number in the root will be $(-1 + 1)/(2) = 0$, and the root is therefore read as 0·313 [0·313049+].

EX.—Find $\sqrt{}$(0·149.)

As the number of digits (0) is _even_, the cursor is set to 149 on the right-hand scale of A, giving 386 on D. By the rule, the number of digits in the root will be $(0)/(2) = 0$, and the root will be read as 0·386 [0·38605+].

Another method of extracting the square root, by which more accurate readings may generally be obtained, is by using the C and D scales only, with the slide inverted. If there is an _odd_ number of digits in the number, the _right_ index, or if an even number of digits the _left_ index, of the inverted scale ■ is placed so as to coincide with the number on D of which the root is sought. Then with the cursor, the number is found on D which coincides with the same number on ■, which number is the root sought.

EX.—Find √(22·2.)

Placing the left index of ■ to 222 on D, the two equal coinciding numbers on ■ and D are found to be 4·71.

Note that under the cursor line we have the original number, 22·2, on A, and from this the number of digits in the root is determined as before.

The plan of finding the square of a number by ordinary multiplication is often very convenient. The inverse process of finding a square root by trial division is not to be recommended.

To obtain a close value of a root or to verify one found in the usual way, the author has, on occasion, adopted the following plan:—Set 1 (or 10) on B to the number on the A scale (L.H. or R.H. as the case may require), and bring the cursor to the number on D. If the root found is correct, the readings on C under the cursor and on D under the index of C, will be in exact agreement.

If 1 on B is placed to a number _n_ on the L.H. A scale, the student will note that while root _n_ is read on D under 1 on C, the root of 10 _n_ is read on D under 10 on B. Hence, if preferred, the number can be taken always on the first scale of A and the root read under 1 or 10 on B, according to whether there is an odd or even number of digits in the number. Obviously the second root is the first multiplied by √(10).

CUBES AND CUBE ROOTS.

In raising a number to the third power, a combination of the preceding method and ordinary multiplication is employed.

TO FIND THE CUBE OF A NUMBER.—_Set the_ L.H. _or_ R.H. _index of C to the number on D, and opposite the number_ ON THE LEFT-HAND _scale of B read the cube on the_ L.H. _or_ R.H. _scale of A_.

By this rule four scales are brought into requisition. Of these, the D scale and the L.H. B scale are _always_ employed, and are to be read as of equal denomination. The values assigned to the L.H. and R.H. scales of A will be apparent from the following considerations.

Commencing with the indices of C and D coinciding, and moving the slide to the right, it will be seen that, working in accordance with the above rule, the cubes of numbers from 1 to 2·154 (= ■(10)) will be found on the first or L.H. scale of A. Moving the slide still farther to the right, we obtain _on the_ R.H. _A scale_ cubes of numbers from 2·154 to 4·641 (or ■(10) to ■(100)). Had we a _third_ repetition of the L.H. A scale, the L.H. index of C could be still further traversed to the right, and the cubes of numbers from 4·641 to 10 read off on this prolongation of A. But the same end can be attained by making use of the R.H. index of C, when, traversing the slide to the right as before, the cubes of numbers from 4·641 to 10 on D can be read off _on the_ L.H. _A scale_ over the corresponding numbers on the L.H. B scale. Hence, using the L.H. index of C, the readings on the L.H. A scale may be regarded comparatively as units, those on the R.H. A scale as tens; while for the hundreds we again make use of the L.H. A scale in conjunction with the _right-hand_ index of C.

By keeping these points in view, the number of digits in the cube (N) of a given number (_n_) are readily deduced. Thus, if the units scale is used, N = 3_n_ – 2; if the tens scale, N = 3_n_ – 1; while if the hundreds scale be used, N = 3_n_. Placed in the form of rules:—

N = 3_n_ – 2 when the product is read on the L.H. scale of A with the slide to the _right_ (units scale).

N = 3_n_ – 1 when the product is read on the R.H. scale of A; slide to the _right_ (tens scale).

N = 3_n_ when the product is read on the L.H. scale of A with the slide to the _left_ (hundreds scale).

With decimals the same rule applies, but, as before, the number of digits must be read as –1, –2, etc., when one, two, etc., cyphers follow immediately after the decimal point.

EX.—Find the value of 1·4^3.

Placing the L.H. index of C to 1·4 on D, the reading on A opposite 1·4 on the L.H. scale of B is found to be about 2·745 [2·744].

EX.—Find the value of 26·4^3.

Placing the L.H. index of C to 26·4 on D, the reading on A opposite 26·4 on the L.H. scale of B is found to be about 18,400 [18,399·744].

EX.—Find the value of 7·3^3.

In this case it becomes necessary to use the R.H. index of C, which is set to 7·3 on D, when opposite 7·3 on the L.H. scale of B is read 389 [389·017] on A.

EX.—Find the value of 0·073^3.

From the setting as before it is seen that the number of digits in the number must be multiplied by 3. Hence, as there is –1 digit in 0·073, there will be –3 in the cube, which is therefore read 0·000389.

The last two examples serve to illustrate the principle of factorising with powers of 10. Thus

$0{\cdot}073 = 7{\cdot}3 \times 10^{-2}$; $0{\cdot}073^3 = 7{\cdot}3^3 \times (10^{-2})^3 = 389 \times 10^{-6} = 0{\cdot}000389$.

Cube Root (_Direct Method_).—One method of extracting the cube root of a number is by an inversion of the foregoing operation. Using the same scales, _the slide is moved either to the right or left until under the given number on A is found a number on the_ L.H. _B scale, identical with the number simultaneously found on D under the right or left index of C_. This number is the required cube root.

From what has already been said regarding the combined use of these scales in cubing, it will be evident that in extracting the cube root of a number, it is necessary, in order to decide which scales are to be used, to know the number of figures to be dealt with. We therefore (as in the arithmetical method of extraction) point off the given number into sections of three figures each, commencing at the decimal point, and proceeding to the left for numbers greater than unity, and to the right for numbers less than unity. Then if the first section of figures on the left consists of—

1 figure, the number will evidently require to be taken on what we have called the "units" scale—_i.e._, on the L.H. scale of A, using the L.H. index of C.

If of 2 figures, the number will be taken on the "tens" scale—_i.e._, on the R.H. scale of A, using the L.H. index of C.

If of 3 figures, the number will be taken on the "hundreds" scale—_i.e._, on the L.H. scale of A, using the R.H. index of C.

To determine the number of digits in cube roots it is only necessary to note that when the number is pointed off into sections as directed, there will be one figure in the root for every section into which the number is so divided, whether the _first_ section consists of 1, 2, or 3 digits.

Of numbers wholly decimal, the cube roots will be decimal, and for every group of _three_ 0s immediately following the decimal point, _one_ 0 will follow the decimal point in the root. If necessary, 0s must be added so as to make up complete multiples of 3 figures before proceeding to extract the root. Thus 0·8 is to be regarded as 0·800, and 0·00008 as 0·000080 in extracting cube roots.

EX.—Find ■(14,000.)

Pointing the number off in the manner described, it is seen that there are _two_ figures in the first section—viz., 14. Setting the cursor to 14 on the R.H. scale of A, the slide is moved to the right until it is seen that 241 on the L.H. scale of B falls under the cursor, when 241 on D is under the L.H. index of C. Pointing 14,000 off into sections we have 14 000—that is, _two_ sections. Therefore, there are two digits in the root, which in consequence will be read 24·1 [24·1014+].

EX.—Find ■(0·162.)

As the divisional section consists of _three_ figures, we use the "hundreds" scale. Setting the cursor to 0·162 on the L.H. A scale, and using the R.H. index of C, we move the slide to the left until under the cursor 0·545 is found on the L.H. B scale, while the R.H. index of C points to 0·545 on D, which is therefore the cube root of 0·162.

EX.—Find ■(0·0002.)

To make even multiples of 3 figures requires the addition of 00; we have then 200, the cube root of which is found to be about 5·85. Then, since the first divisional group consists of 0s, one 0 will follow the decimal point, giving ■(0·0002) = 0·0585 [0·05848].

Cube Root (Inverted Slide Method).—Another method of extracting the cube root involves the use of the inverted slide. Several methods are used, but the following is to be preferred:—_Set the_ L.H. _or_ R.H. _index of the slide to the number on A, and the number on ■ (i.e., B inverted), which coincides with the same number on D, is the required root._

Setting the slide as directed, and using first the L.H. index of the slide and then the R.H. index, it is always possible to find _three_ pairs of coincident values. To determine which of the three is the required result is best shown by an example.

EX.—Find ■(5,) ■(50,) and ■(500.)

Setting the R.H. index of the slide to 5 on A, it is seen that 1·71 on D coincides with 1·71 on ■. Then setting the L.H. index to 5 on A, further coincidences are found at 3·68 and at 7·93, the three values thus found being the required roots. Note that the first root was found on that portion of the D scale lying under 1 to 5 on A; the second root on that portion lying under 5 to 50 on A; and the third root on that portion of D lying under 50 to 100 on A. In this connection, therefore, scale A may always be considered to be divided into three sections—viz., 1 to _n_, _n_ to 10_n_, and 10_n_ to 100. For all numbers consisting of 1, 1 + 3, 1 + 6, 1 + 9—_i.e._, of 1, 4, 7, 10, or –2, –5, etc., figures—the coincidence under the first section is the one required. If the number has 2, 5, 8, or –1, –4, –7, etc., figures, the coincidence under the second section is correct, while if the number has 3, 6, 9, or 0, –3, etc., figures, the coincidence under the last section is that required. The number of digits in the root is determined by marking off the number into sections, as already explained.

Cube Root (Pickworth's Method).—One of the principal objections to the two methods described is the difficulty of recollecting which scales are to be employed and with which index of the slide they are to be used. With the direct method another objection is that the readings to be compared are often some distance apart, the maximum distance intervening being _two-thirds_ of the length of the rule. To carry the eye from one to another is troublesome and time-taking. With the inverted scale method the reading of a scale reversed in direction and with the figures inverted is also objectionable.

With the author's method these objections are entirely obviated. The _same scales and index are always used_, and are read in their normal position. The three roots of _n_, 10_n_ and 100_n_ (_n_ being less than 10 and not less than 1) are given with one setting and appear in their natural sequence, no traversing of the slide being needed. The readings to be compared are always close together, the maximum distance between them being _one-sixth_ of the length of the rule. The setting is always made in the earlier part of the scales where closer readings can be obtained, and finally, if desired, the result may be readily verified on the lower scales by successive multiplication.

For this method two gauge points are required on C. To conveniently locate these, set 53 on C to 246 on D; join 1 on D to 1 on A with a straight-edge and with a needle point draw a short fine line on C. Set 246 on C to 53 on D, and repeat the process at the other end of the rule. The gauge points thus obtained (dividing C into three equal parts) will be at 2·154 and 4·641, and should be marked ■(10) and ■(100) respectively.[6]

EX.—Find ■(2·86,) ■(28·6) and ■(286).

Set cursor to 2·86 on A and drawing the slide to the right find 1·42 under 1 on C, when 1·42 on B is under the cursor. Then reading under 1, ■(10) and ■(100,) we have

■(2·86) = 1·42; ■(28·6) = 3·06 and ■(286) = 6·59.

It will be seen that factorising with powers of 10, we multiply the initial root by ■(10) and ■(100). Obviously the three roots will always be found on D, in their natural order and at intervals of one-third the length of the rule. The number of digits in the roots of numbers which do not lie between 1 and 1000, is found as before explained.

In any method of extracting cube roots in which the slide has to be adjusted to give equal readings on B and D, the author has found it of advantage to adopt the following plan:—The cursor being set to, say, 4·8 on A, bring a near _main_ division line on B, as 1·7, to the cursor; then 1 on C is at 1·68 on D. The difference in the readings is two small divisions on D, and moving the slide forward by _one-third the space representing this difference_, we obtain 1·687 as the root required. With a little practice it is possible to obtain more accurate results by this method than by comparing the reading on D with that on the less finely-graded B

scale.

MISCELLANEOUS POWERS AND ROOTS.

In addition to squares and cubes, certain other powers and roots may be readily obtained with the slide rule.

Two-thirds Power.—The value of N^■ is found on A over ■■N on D. The number of digits is decided by the rule for squares, working from the number of digits in the cube root. It will often be found preferable to treat N^■ as N ÷ ■■N, as in this way the magnitude of the result is much more readily appreciated.

Three-two Power.—N^{⅔■} can be obtained by cubing the square root, deciding the number of digits in each process. For the reason just given, it is preferable to regard N^{⅔■} as N × √■N.

Fourth Power.—For N^4 set the index of C to N on D and over N on C read N^4 on A; or find the square of the square of N, deciding the number of digits at each step.

Fourth Root.—Similarly for ■■N, take the square root of the square root.

Four-third Power.—N^{■/■} = N^{1·33} (useful in gas-engine diagram calculations) is best treated as N × ■■N.

Other powers can be found by repeated multiplication. Thus setting 1 on B to N on A, we have on A, N^2 over N; N^3 over N^2; N^4 over N^3; N^5 over N^4, etc. In the same way, setting N on B to N on D, we can read such values as N^¾, N^■, etc.

POWERS AND ROOTS BY LOGARITHMS.

For powers or roots other than those of the simple forms already discussed, it is necessary to employ the usual logarithmic process. Thus to find _a^n_ = _x_, we multiply the logarithm of _a_ by _n_, and find the number _x_ corresponding to the logarithm so obtained. Similarly, to find _■√■a_ = _x_ we divide the logarithm of _a_ by _n_, and find the number _x_ corresponding to the resulting logarithm.

The Scale of Logarithms.—Upon the back of the slide of the Gravêt and similar slide rules there will be found three scales. One of these—usually the centre one—is divided equally throughout its entire length, and figured from right to left. It is sometimes marked L, indicating that it is a scale giving logarithms. The whole scale is divided primarily into ten equal parts, and each of these subdivided into 50 equal parts. In the recess or notch in the right-hand end of the rule is a reference mark, to which any of the divisions of this evenly-divided scale can be set.

As this decimally-divided scale is equal in length to the logarithmic scale D, and is figured in the reverse direction, it results that when the slide is drawn to the right so that the L.H. index of C coincides with any number on D, the reading on the equally-divided scale will give the decimal part of the logarithm of the number taken on D. Thus if the L.H. index of C is placed to agree with 2 on D, the reading of the back scale, taken at the reference mark, will be found to be 0·301, the logarithm of 2. It must be distinctly borne in mind that the number so obtained is the _decimal part_ or _mantissa_ of the logarithm of the number, and that to this the characteristic must be prefixed in accordance with the usual rule—viz., _The integral part, or characteristic of a logarithm is equal to the number of digits in the number, minus 1. If the number is wholly decimal, the characteristic is equal to the number of cyphers following the decimal point, plus 1._ In the latter case the characteristic is negative, and is so indicated by having the minus sign written _over_ it.

To obtain any given power or root of a number, the operation is as follows:—Set the L.H. index of C to the given number on D, and turning the rule over, read opposite the mark in the notch at the right-hand end of the rule, the decimal part of the logarithm of the number. Add the characteristic according to the above rule, and multiply by the exponent of the power, or divide by the exponent of the root. Place the _decimal part_ of the resultant reading, taken on the scale of equal parts, opposite the mark in the aperture of the rule, and read the answer on D under the L.H. index of C, pointing off the number of digits in the answer in accordance with the number of the characteristic of the resultant.

EX.—Evaluate 36^{1·414}.

Set 1 on C to 36 on D and read the decimal part of log. 36 on the scale of logarithms on the back of the slide. This value is found to be 0·556. As there are two digits in the number, the characteristic will be 1; hence log. 36 = 1·556. Multiply by 1·414, using the C

and D scales, and obtain 2·2 as the log. of the result. Set the decimal part, 0·2, on the log. scale to the mark in the notch at the end of the rule and read 1585 on D under 1 on C. Since the log. of the result has a characteristic 2, there will be 3 digits in the result, which is therefore read as 158·5.

This example will suffice to show the method of obtaining the nth power or the _n_th root of _any_ number.

OTHER METHODS OF OBTAINING POWERS AND ROOTS.

A simple method of obtaining powers and roots, which may serve on occasion, is by scaling off proportional lengths on the D scale (or the A scale) of the ordinary rule. Thus, to determine the value of 1·25^{1·67} we take the actual length 1–1·25 on D scale, and increase it by any convenient means in the proportion of 1 ■ 1·67. Then with a pair of dividers we set off this new length from 1, and obtain 1·44 as the result. One convenient method of obtaining the desired ratio is by a pair of proportional compasses. Thus to obtain 1·52^{1■/■■}, the compasses would be set in the ratio of 16 to 17, and the smaller end opened out to include 1–1·52 on the D scale; the opening in the large end of the compasses will then be such that setting it off from 1 we obtain 1·56 on D as the result sought.

[Illustration: FIG. 11.]

The converse procedure for obtaining the _n_th root of a number N will obviously resolve itself into obtaining (1)/(_n_)th of the scale length 1-N, and need not be further considered.

Simple geometrical constructions are also used for obtaining scale lengths in the required ratio. A series of parallel lines ruled on transparent celluloid or stout tracing paper may be placed in an inclined position on the face of the rule and adjusted so as to divide the scale as desired. When much work is to be done which requires values to be raised to some constant but comparatively low power, _n_, the author has found the following device of assistance:—On a piece of thin transparent celluloid a line OC is drawn (Fig. 11) and in this a point B is taken such that (OC)/(OB) is the desired ratio. It is convenient to make OB = 1–10 on the A scale, so that assuming we require a series of values of _v_^{1·35}, OB would be 12·5 cm. and OC, 16·875 cm. On these lines semi-circles are drawn as shown, both passing through the point O.

Applying this cursor to the upper scales so that the point O is on 1 and the semi-circle O M B passes through _v_ on A, the larger semi-circle will give on A the value of _v^n_. Thus for _p_ _v^n_ = 39·5 × 4·9^{1·35}, set 1 on B to 39·5 on A (Fig. 12) and apply the cursor to the working edge of B, so that O agrees with 1 and O M B passes through 4·9 on B. The larger semi-circle then cuts the edge of the slide on a point, giving 337 on A as the result required.

Of course any number of semi-circles may be drawn, giving different ratios. If a number of evenly-spaced divisions are used as bases, the device affords a simple means of obtaining a succession of small powers or roots, while it also finds a use in determining a number of geometric means between two values as is required in arranging the speed gears of machine tools, etc. The converse operation of finding roots will be evident as will also many other uses for which the device is of service.

[Illustration: FIG. 12.]

The lines should be drawn in Indian ink with a very sharp pen and on the _under_ side of the celluloid so that the lines lie in close contact with the face of the rule.

The Radial Cursor, another device for the same purpose, is always used in conjunction with the upper scales. As will be seen from Fig. 13, the body of the cursor P carries a graduated bar S which can be removed in a direction transverse to the rule, and adjusted to any desired position. Pivoted to the lower end of S is a radial arm R of transparent celluloid on which a centre line is engraved.

A reference to the illustration will show that the principle involved is that of similar triangles, the width of the slide being used as one of the elements. Thus, to take a simple case, if 2 on S is set to the index on P, and 1 on B is brought to N on A, then by swinging the radial arm until its centre line agrees with 1 on C, we can read N^2 on A. Evidently, since in the two similar triangles A O N^2 and N _t_ N^2 the length of A O is twice that of N _t_, it results that A N^2 = 2 A N. In general, then, to find the _n_th power of a number, we set the cursor to 1 or 10 on A, bring _n_ on the cross bar S to the index on the cursor, and 1 on B to N on A. Then to 1 on C we set the line on the radial arm, and under the latter read N^{_n_} on A. The inverse proceeding for finding the _n_th root will be obvious.

[Illustration: FIG. 13.]

An advantage offered by this and analogous methods of obtaining powers and roots is that the result is obtained on the ordinary scale of the rule, and hence it can be taken directly into any further calculation which may be necessary.

COMBINED OPERATIONS.

Thus far the various operations have been separately considered, and we now pass on to a consideration of the methods of working for solving the various formulæ met with in technical calculations. We propose to explain the methods of dealing with a few of the more generally used expressions, as this will suffice to suggest the procedure in dealing with other and more intricate calculations. In solving the following problems, both the upper and lower scales are used, and the relative value of the several scales must be observed throughout. Thus, in solving such an expression as √((74·5)/(15·8)) = 6·86, the division is first effected by setting 15·8 on B to 745 on A. From the relation of the two parts of the upper scales (page 37) we know that such values as 7·45, 745, etc., will be taken on the _left-hand_ A and B scales, while values as 15·8, 1580, etc., will be taken on the _right-hand_ A and B scales. Hence, 15·8 on the R.H. B scale is set to 745 on the L.H. A scale, and the result read on D under the index of C. Had both values been taken on the L.H. A and B scales, or both on the R.H. A and B scales, the results would have corresponded to _x_ = √((7·45)/(1·58)) = 2·17, or to _x_ =√((74·5)/(15·8)) = 2·17, _i.e._, to (6·86)/(√(10)). Hence if a wrong choice of scales has been made, we can correct the result by multiplying or dividing by √(10) as the case may require. If the result is read on D, set to it the centre index (10) of B and read the corrected result under the index of C.

To solve _a_ × _b_^2 = _x_. Set the index of C to _b_ on D, and over _a_ on B read _x_ on A.

To solve (_a_^2)/(_b_) = _x_. Set _b_ on B to _a_ on D by using the cursor, and over index of B read _x_ on A.

To solve (_b_)/(_a_^2) = _x_. Set _a_ on C to _b_ on A, and over 1 on B read _x_ on A.

To solve (_a_ × _b_^2)/(_c_) = _x_. Set _c_ on B to _b_ on D, and over _a_ on B read _x_ on A.

To solve (_a_ × _b_)^2 = _x_. Set 1 on C to _a_ on D, and over _b_ on C read _x_ on A.

To solve ((_a_)/(_b_))^2 = _x_. Set _b_ on C to _a_ on D, and over 1 on C read _x_ on A.

To solve √(_a_ × _b_) = _x_. Set 1 on B to _a_ on A, and under _b_ on B read _x_ on D.

To solve √((_a_)/(_b_)) = _x_. Set _b_ on B to _a_ on A, and under 1 on C read _x_ on D.

To solve _a_ (_b_)/(_c_^2) = _x_. Set _b_ on C to _c_ on D and over _a_ on B read _x_ on A.

To solve _c_√((_a_)/(_b_)) = _x_. Set _b_ on B to _a_ on A, and under _c_ on C read _x_ on D.

To solve (√_■a_)/(_b_) = _x_. Set _b_ on C to _a_ on A, and under 1 on C read _x_ on D.

To solve (_a_)/(√_■b_) = _x_. Set _b_ on B to _a_ on D, and under 1 on C read _x_ on D.

To solve _b_√_■a_ = _x_. Set 1 on C to _b_ on D, and under _a_ on B read _x_ on D.

To solve √(_a_^3) = _x_. Treat as _a_√_■a_.

To solve _a_√(_b_^3) = _x_. Treat as _a_√_■b_ × _b_.

To solve (√_■a_^3)/(_b_) = _x_. Treat as (√_■a_ × _a_)/(_b_).

To solve √((_a_^3)/(_b_)) = _x_. Treat as (√_■a_ × _a_)/(√_■b_) = √((_a_)/(_b_)) × _a_.

To solve √((_a_ × _b_)/(_c_)) = _x_. Set _c_ on B to _a_ on A, and under _b_ on B read _x_ on D.

To solve (_a_ × _b_)/(√_■c_) = _x_. Set _c_ on B to _b_ an D, and under _a_ on C read _x_ on D.

To solve √((_a_^2 × _b_)/(_c_)) = _x_. Set _c_ on B to _a_ on D, and under _b_ on B read _x_ on D.

To solve (_a_^2 × _b_^2)/(_c_) = _x_. Set _c_ on B to _a_ on D, and over _b_ on C read _x_ on A.

To solve (_a_√_■b_)/(_c_) = _x_. Set _c_ on C to _b_ on A, and under _a_ on C read _x_ on D.

To solve ((_a_ × √_■b_)/(_c_))^2 = _x_. Set _c_ on C to _a_ on D, and over _b_ on B read _x_ on A.

HINTS ON EVALUATING EXPRESSIONS.

As a general rule, the use of cubes and higher powers should be avoided whenever possible. Thus, in the foregoing section, we recommend treating an expression of the form _a_√(_b_^3) as _a_ × _b_ × √_■b_; the magnitudes of the values thus met with are more easily appreciated by the beginner, and mistakes in estimating the large numbers involved in cubing are avoided.

EX.—7·3 × √(57^3) = 3140.

Set 1 on C to 57 on D; bring cursor to 57 on B (R.H., since 57 has an _even_ number of digits); bring 1 on C to cursor, and under 7·3 on C read 3140 on D. As a rough estimate we have √(57), about 8; 8 × 57, about 400; 400 × 7, gives 2800, showing the result consists of 4 figures.

An expression of the form _a_■(_b_^2), or _a_ _b_^■, is better dealt with by rearranging as _a_ × (_b_)/(■_b_).

EX.—3·64■(4·32^2) = 9·65.

Set cursor to 4·32 on A, and move the slide until 1·63 is found simultaneously under the cursor on B and on D under 1 on C; bring cursor to 1 on C; 4·32 on C to cursor, and _over_ 3·64 on D read 9·65 on C. (Note that in this case it is convenient to read the answer on the _slide_; see page 22). From the slide rule we know ■(4·32) = about 1·6; this into 4·32 is roughly 3; 3·64 × 3 is about 10, showing the answer to be 9·65.

Similarly products of the form _a_ × _b_^{■/■} are best dealt with as _a_ × _b_ × ■_b_.

Factorising expressions sometimes simplifies matters, as, for instance, in _x_^4 – _y_^4 = (_x_^2 + _y_^2)(_x_^2 – _y_^2). Here, working with the fourth powers involves large numbers and the troublesome determination of the number of digits in each factor; but squares are read on the rule at once, the number of digits is obvious, and, in general, the method should give a more accurate result. Take the expression, D_{1} = ■((D^4 – _d_^4)/(D)) giving the diameter D_{1} of a solid shaft equal in torsional strength to a hollow shaft whose external and internal diameters are D and _d_ respectively. Rearranging as D_{1} = ■(((D^2 + _d_^2)(D^2 – _d_^2))/(D)) and taking, as an example, D = 15 in. and _d_ = 7 in., we have D^2 + _d_^2 = 274 and D^2 – _d_^2 = 176; hence D_1 = ■((274 × 176)/(15)) = ■(3210) = 14·75 in.

Reversed Scale Notation.—With expressions of the form 1 – _x_, or 100 – _x_, it is often convenient to regard the scales as having their notation reversed, _i.e._, to read the scale backwards. When this is done the D scale is read as shown on the lower line—

Direct Notation 1 2 3 4 5 6 7 8 9 10 D Scale Reversed Notation 9 8 7 6 5 4 3 2 1 0

The new reading can be found by subtracting the ordinary reading from 1, 10, 100, etc., according to the value assigned to the R.H. index, but actually it is unnecessary to make this calculation, as with a little practice it is quite an easy matter to read both the main and subdivisions in the reversed order. Applications are found in plotting curves, trigonometrical formulæ, etc.

EX.—Find the per cent. of slip of a screw propeller from

100 – S = (10133V)/(PR)

taking the speed, V, as 15 knots, the pitch of the propeller, P, as 27 ft. 6 in., and the revolutions per minute, R, as 60.

Set 27·5 on B to 10133 on A (N.B.—Take the setting near the _centre_ index of A); bring the cursor to 15 on B and 60 on B to cursor. Reading the L.H. A scale backwards, the slip, S, = 8 per cent. is found on A over 10 on B.

Percentage Calculations.—To increase a quantity by _x_ per cent. we multiply by 100 + _x_; to diminish a quantity by _x_ per cent. we multiply by 100 – _x_. Hence, to add _x_ per cent., set 100 + _x_ on C to 1 on D and read new values on D under original values on C. To deduct _x_ per cent. read the D scale backwards from 10 and set R.H. index of C to _x_ per cent. so read. Then read as before.

GAUGE POINTS.

Special graduations, marking the position of constant factors which frequently enter into engineering calculations, are found on most slide rules. Usually the values of $\pi = 3{\cdot}1416$ and $(\pi)/(4) = 0{\cdot}7854$—the "gauge points" for calculating the circumference and area of a circle—are marked on the upper scales. The first should be given on the lower scales also. Marks _c_ and _c_^1 are sometimes found on the lower scales at $1{\cdot}128 = \sqrt{((4)/(\pi))}$ and at $3{\cdot}568 = \sqrt{((40)/(\pi))}$. These are useful in calculating the contents of cylinders and are thus derived:—Cubic contents of cylinder of diameter _d_ and length _l_ = $(\pi)/(4)$_d_^2_l_; substituting for $(\pi)/(4)$ its reciprocal $(4)/(\pi)$, the formula becomes (_d_^2)/(1·273 × _l_), and by taking the square root of the fractional part we have (_d_)/(1·128)^2 × _l_. This is now in a very convenient form, since by setting the gauge point _c_ on C to _d_ on D, we can read over _l_ on B the cubic contents on A. This example indicates the principle to be followed in arranging gauge points. Successive multiplication is avoided by substituting the reciprocal of the constant, thus bringing the expression into the form (_a_ × _b_)/(_c_), which, as we know, can be resolved by one setting of the slide. The advantage of dividing _d_ before squaring is also evident. The mark _c_^1 = _c_ × $\sqrt{(10)}$ is used if it is necessary to draw the slide more than one-half its length to the right.

A gauge point, M, at $31{\cdot}83 = (100)/(\pi)$ is found on the upper scales of some rules. Setting this point on B to the diameter of a cylinder on A, the circumference is read over 1 or 100 on B or the area of the curved surface over the length on B.

As another example of establishing a gauge point, we will take the formula for the theoretical delivery of pumps. If _d_ is the diameter of the plunger in inches, _l_ the length of stroke in feet, and Q the delivery in gallons, we have

Q = _d_^2 × $(\pi)/(4)$ × _l_ × (12)/(277). (N.B.—277 cubic inches = 1 gallon.)

Multiplying out the constant quantities and taking its reciprocal, we readily transform the statement into Q = (_d_^2_l_)/(29·4) or ((_d_)/(5·42))^2 × _l_. Hence set gauge point 5·42 on C to _d_ on D and over length of stroke in feet on B, read delivery in gallons per stroke on A; or over piston speed in feet per minute on B, read theoretical delivery in gallons per minute on A.

Several examples of gauge points will be found in the section on calculating the weights of metal (see pages 59 and 60). In most cases their derivation will be evident from what has been said above. In the case of the weight of spheres, we have Vol. = 0·5236_d_^3, and this multiplied by the weight of 1 cubic inch of the material will give the weight W in lb. Hence for cast-iron, W = 0·5236 × _d_^3 × 0·26, which is conveniently transformed into W = (_d_ × _d_^2)/(7·35) as in the example on page 60.

With these examples no difficulty should be experienced in establishing gauge points for any calculation in which constant factors recur.

Marking Gauge Points.—The practice of marking gauge points by lines extending to the working edge of the scale is not to be recommended, as it confuses the ordinary reading of the scales. Generally speaking, gauge points are only required occasionally, and if they are placed clear of the scale to which they pertain, but near enough to show the connection, they can be brought readily into a calculation by means of the cursor. Usually there is sufficient margin above the A scale and below the D scale for various gauge points to be marked. Another plan consists in cutting two nicks in the upper and lower edges of the cursor near the centre and about ■ in. apart. These centre pieces, when bent out, form a tongue, which are in line with the cursor line and run nearly in contact with the square and bevelled edges of the rule respectively. A fine line in the tongue can then be set to gauge points marked on these two edge strips, the ordinary measuring graduations being removed, if desired, by a piece of fine sand-paper.

For gauge points marked on the face of the rule, the author prefers two fine lines drawn at 45°—thus, ✕—and crossing in the exact point which it is required to indicate. With the "cross" gauge point the meeting lines facilitate the placing of the cursor, and an exact setting is readily made.[7] All lines should be drawn in Indian ink with a very sharp drawing pen. For a more permanent marking the Indian ink may be rubbed up in glacial acetic acid or the special ink for celluloid may be used. If any difficulty is found in writing the distinguishing signs against the gauge point, the inscription may be formed by a succession of small dots made with a sharp pricker.

EXAMPLES IN TECHNICAL CALCULATIONS.

In order to illustrate the practical value of the slide rule, we now give a number of examples which will doubtless be sufficient to suggest the methods of working with other formulæ. A few of the rules give results which are approximate only, but in all cases the degree of accuracy obtained is well within the possible reading of the scales. In many cases the rules given may be modified, if desired, by varying the constants. In most of the examples the particular formula employed will be evident from the solution, but in a

few of the more complicated cases a separate statement has been given.

Given the chord _c_ of a circular arc, and the vertical height _h_, to find the diameter _d_ of the circle.

Set the height _h_ on B to half the chord on D, and over 1 on B read _x_ on A. Then _x_ + _h_ = _d_.

EX.—_c_ = 6; _h_ = 2; find _d_. Set 2 on B to 3 on D, and over 1 on B read 4·5 on A. Then 4·5 + 2 = 6·5 = _d_.

Given the radius of a circle _r_, and the number of degrees _n_ in an arc, to find the length _l_ of the arc.

Set _r_ on C to 57·3 on D, and over any number of degrees _n_ on D read the (approximate) length of the arc on C.

EX.—_r_ = 24; _n_ = 30; find _l_.

Set 24 on C to 57·3 on D, and over 30 on D read 12·56 = _l_ on C.

Given the diameter _d_ of a circle in _inches_, to find the circumference _c_ in _feet_.

Set 191 on C to 50 on D, and under any diameter in inches on C read circumference _c_, in feet on D.

EX.—Find the circumference in feet of a pulley 17 in. in diameter. Set 191 on C to 50 on D, and under 17 on C read 4·45 ft. on D.

Given the diameter of a circle, to find its area.

Set 0·7854 on B to 10 (centre index) on A and over any diameter on D read area on B.

When the rule has a special graduation line = 0·7854, on the right-hand scale of B, set this line to the R.H. index of A and read off as above. If only π is marked, set this special graduation on B to 4 on A.

On the C and D scales of some rules a gauge point marked _c_ will be found indicating $\sqrt{((4)/(\pi))} = 1{\cdot}1286$. In this case, therefore, set 1 on C to gauge point _c_ on D, and read area on A as above. If the gauge point _c_′ is used, divide the result by 10. Or set _c_ on C, to diameter on D, and over index of B read area on A. Cursors are supplied, having _two_ lines ruled on the glass, the interval between them being equal to $(4)/(\pi) = 1{\cdot}273$ on the A scale. In this case, if the right hand of the two cursor lines be set to the diameter on D, the _area_ will be read on A under the _left_-hand cursor line. For diameters less than 1·11 it is necessary to set the middle index of B to the L.H. index of A, reading the areas on the L.H. B scale. The confusion which in general work is sometimes caused by the use of two cursor lines might be obviated by making the left-hand line in two short lengths, each only just covering the scales.

Given diameter of circle _d_ in _inches_, to find area _a_ in square _feet_.

Set 6 on B to 11 on A, and over diameter in inches on D read area in square feet on B.

To find the surface in square feet of boiler flues, condenser tubes, heating pipes, etc., having given the diameter in inches and length in feet.

Find the circumference in feet as above and multiply by the length in feet.

EX.—Find the heating surface afforded by 160 locomotive boiler tubes 1¾in. in diameter and 12 ft. long.

Set 191 on C to 50 on D; bring cursor 1·75 on C, L.H. index of C to cursor; cursor to 12 on C; 1 on C to cursor; and under 160 on C read 880 sq. ft. of heating surface on D.

If the dimensions are in the same denomination and the rule has a gauge point M at 31·83 (= $(100)/(\pi)$), set this mark on B to diameter of cylinder on A, and read cylindrical surface on A over length on B.

To find the side _s_ of a square, equal in area to a given rectangle of length _l_ and breadth _b_.

Set R.H. or L.H. index of B to _l_ on A, and under _b_ on B read _s_ on D.

EX.—Find the side of a square equal in area to a rectangle in which _l_ = 31 ft. and _b_ = 5 ft.

Set the (R.H.) index of B to 31 on A, and under 5 on B read 12·45 ft. on D.

To find various lengths _l_ and breadths _b_ of a rectangle, to give a constant area _a_.

Invert the slide and set the index of ■ to the given area on D. Then opposite any length _l_ on ■ find the corresponding breadth _b_ on D.

EX.—Find the corresponding breadths of rectangular sheets, 16, 18, 24, 36, and 60 ft. long, to give a constant area of 72 sq. ft.

Set the R.H. index of ■ to 72 on D, and opposite 16, 18, 24, 36, and 60 on ■ read 4·5, 4, 3, 2, and 1·2 ft., the corresponding breadths on D.

To find the contents in cubic feet of a cylinder of diameter _d_ in inches and length _l_ in feet.

Find area in feet as before, and multiply by the length.

If dimensions are all in inches or feet, set the mark _c_ (= 1·128) on C to diameter on D and over length on B, read cubic contents on A.

To find the area of an ellipse.

Set 205 on C to 161 on D; bring cursor to length of major axis on C, 1 on C to cursor, and under length of minor axis on C read area on D.

EX.—Find the area of an ellipse the major and minor axes of which are 16 in. and 12 in. in length respectively.

Set 205 on C to 161 on D; bring cursor to 16 on C, 1 on C to cursor, and under 12 on C read 150·8 in. on D.

To find the surface of spheres.

Set 3·1416 on B to R.H. or L.H. index of A, and over diameter on D read by the aid of the cursor, the convex surface on B.

To find the cubic contents of spheres.

Set 1·91 on B to diameter on A, and over diameter on C read cubic contents on A.

WEIGHTS OF METALS.

To find the weight in lb. per lineal foot of square bars of metal.

Set index of B to weight of 12 cubic inches of the metal (_i.e._, one lineal foot, 1 square inch in section) on A, and over the side of the square in inches on C read weight in lb. on A.

EX.—Find the weight per foot length of 4½in. square wrought-iron bars.

Set middle index of B to 3·33 on A, and over 4½ on C read 67·5 lb. on A.

(N.B.—For other metals use the corresponding constant in column (2), below).

To find the weight in lb. per lineal foot of round bars.

Set R.H. or L.H. index of B to weight of 12 cylindrical inches of the metal on A (column (4), below), and opposite the diameter of the bar in inches on C, read weight in lb. per lineal foot on A.

EX.—Find the weight of 1 lineal foot of 2 in. round cast steel.

Set L.H. index of B to 2·68 on A, and over 2 on C read 10·7 lb. on A.

To find the weight of flat bars in lb. per lineal foot.

Set the breadth in inches on C to (1)/(weight of 12 cub. in.) of the metal (column (3), below) on D, and above the thickness on D read weight in lb. per lineal foot on C.

EX.—Find the weight per lineal foot of bar steel, 4½in. wide and ■in. thick.

Set 4·5 on C to 0·294 on D, and over 0·625 on D read 9·56 lb. per lineal foot on C.

To find the weight per square foot of sheet metal, set the weight per cubic foot of the metal (col. 1) on C to 12 on D, and

■■■

To find velocity in feet per second of a falling body, given the time of fall in seconds.

Set index on C to time of fall on D, and under 32·2 on C read velocity in feet per second on D.

To find velocity in feet per second, given distance fallen through in feet.

Set 1 on C to distance fallen through on A, and under 64·4 on B read velocity in feet per second on D.

EX.—Find velocity acquired by falling through 14 ft.

Set (R.H.) index of C to 14 on A, and under 64·4 on B read 30 ft. per second on D.

To find distance fallen through in feet in a given time.

Set index of C to time in seconds on D, and over 16·1 on B read distance fallen through in feet on A.

CENTRIFUGAL FORCE.

To find the centrifugal force of a revolving mass in lb.

Set 2940 on B to revolutions per minute on D; bring cursor to weight in lb. on B; index of B to cursor, and over radius in feet on B read centrifugal force in lb. on A.

To find the centrifugal stress in lb. per square inch, in rims of revolving wheels of cast iron.

Set 61·3 on C to the mean diameter of the wheel in feet on D, and over revolutions per minute on C read stress per square inch on A.

EX.—Find the stress per square inch in a cast-iron fly-wheel rim 8 ft. in diameter and running at 120 revolutions per minute.

Set 61·3 on C to 8 on D, and over 120 on C read 245 lb. per square inch on A.

THE STEAM ENGINE.

Given the stroke and number of revolutions per minute, to find the piston speed.

Set stroke in inches on C to 6 on D, and over number of revolutions on D read piston speed in feet per minute on C.

To find cubic feet of steam in a cylinder at cut-off, given diameter of cylinder and period of admission in inches.

Set 2200 on B to cylinder diameter on D, and over period of admission on B read cubic feet of steam on A.

EX.—Cylinder diameter 26 in., stroke 40 in., cut-off at ■ of stroke. Find cubic feet of steam used (theoretically) per stroke.

Set 2200 on B to 26 on D, and over 40 × ■ or 25 in. on B, read 7·68 cub. ft. on A, as the number of cubic feet of steam used per stroke.

Given the diameter of a cylinder in inches, and the pressure in lb. per square inch, to find the load on the piston in tons.

Set pressure in lb. per square inch on B to 2852 on A, and over cylinder diameter in inches on D read load on piston in tons on B.

EX.—Steam pressure 180 lb. per square inch; cylinder diameter, 42 in. Find load in tons on piston.

Set 180 on B to 2852 on A, and over 42 on D read 111 tons, the gross load, on B.

Given admission period and absolute initial pressure of steam in a cylinder, to find the pressure at various points in the expansion period (isothermal expansion).

Invert the slide and set the admission period, in inches, on ■ to the initial pressure on D; then under any point in the expansion stroke on ■ find the corresponding pressure on D.

EX.—Admission period 12 in., stroke 42 in., initial pressure 80 lb. per square inch. Find pressure at successive fifths of the expansion period.

Set 12 on ■ to 80 on D, and opposite 18, 24, 30, 36 and 42 in. of the whole stroke on ■ find the corresponding pressures on D:—53·3, 40, 32, 26·6 and 22·8 lb. per square inch.

To find the mean pressure constant for isothermally expanding steam, given the cut-off as a fraction of the stroke.

Find the logarithm of the ratio of the expansion _r_, by the method previously explained (page 46). Prefix the characteristic and to the number thus obtained, on D, set 1 on C. Then under 2·302 on C read _x_ on D. To _x_ + 1 on D set _r_ on C, and under index of C read mean pressure constant on D. The latter, multiplied by the initial pressure, gives the mean forward pressure throughout the stroke. (N.B.—Common log. × 2·302 = hyperbolic log.)

EX.—Find the mean pressure constant for a cut-off of ¼th, or a ratio of expansion of 4.

Set (L.H.) index of C to 4 on D, and on the reverse side of the slide read 0·602 on the logarithmic scale. The characteristic = 0; hence to 0·602 on D set (R.H.) index of C, and under 2·302 on C read 1·384 on D. Add 1, and to 2·384 thus obtained on D set _r_ (= 4) on C, and under 1 on C read 0·596, the mean pressure constant required.

Mean pressure constants for the most usual degrees of cut-off are given below:—

Cut-off in fractions of stroke Mean pressure constant ¾ 0·968 ■/■■ 0·952 ■ 0·934 ■ 0·919 ■ 0·913 ½ 0·846 ■ 0·766 ■ 0·750 ■ 0·699 ⅜■■ 0·664 ¼ 0·596 ■ 0·522 ■ 0·465 ■ 0·421 ■ 0·385 ■ 0·355 ■ 0·330 ⅛■■ 0·309 ⅛■■ 0·290 ⅛■■ 0·274 ⅛■■ 0·260 ⅛■■ 0·247 ⅛■■ 0·236

To find mean pressure:—Set 1 on C to constant on D, and under initial pressure on C read mean pressure on D.

Given the absolute initial pressure, length of stroke, and admission period, to find the absolute pressure at any point in the expansion period, it being assumed that the steam expands adiabatically. (P_{2} = (P_{1})/(R^{1■/■}) in which P_{1} = initial pressure and P_{2} the pressure corresponding to a ratio of expansion R.)

Set L.H. index of C to ratio of expansion on D, and read on the back of the slide the decimal of the logarithm. Add the characteristic, and to the number thus obtained on D set 9 on C, and read off the value found on D under the index of C. Set this number on the logarithmic scale to the index mark, in the opening on the back of the rule, and under L.H. index of C read the value of R^{1■/■} on D. The initial pressure divided by this value gives the corresponding pressure due to the expansion.

EX.—Absolute initial pressure 120 lb. per square inch; stroke, 4 ft.; cut-off ¼. Find the respective pressures when ½ and ¾ths of the stroke have been completed.

In the first case R = 2. Therefore setting the L.H. index of C to 2 on D, we find the decimal of the logarithm on the back of the slide to be 0·301. The characteristic is 0, so placing 9 on C to 0·301 on D, we read 0·334 as the value under the R.H. index of C. (N.B.—In locating the decimal point it is to be observed that the log. of R has been multiplied by 10, in accordance with the terms of the above expression.) Setting this number on the logarithmic scale to the back index, the value of R^{1■/■} is found on D, under the L.H. index of C, to be 2·16. Setting 120 on C to this value, it is found that the pressure at ½ stroke, read on C over the R.H. index of D, is 55·5 lb. per square inch. In a similar manner, the pressure when ¾ths of the stroke is completed is found to be 35·4 lb. per square inch.

For other conditions of expanding steam, or for gas or air, the method of procedure is similar to the above.

To find the horse-power of an engine, having given the mean _effective_ pressure, the cylinder diameter, stroke, and number of revolutions per minute.

To cylinder diameter on D set 145 on C; bring cursor to stroke in feet on B, 1 on B to cursor, cursor to number of revolutions on B, 1 on B to cursor, and over mean effective pressure on B find horse-power on A.

(N.B.—If stroke is in inches, use 502 in place of 145 given above.)

EX.—Find the indicated horse-power, given cylinder diameter 27 in., mean effective pressure 38 lb. per square inch, stroke 32 in., revolutions 57 per minute.

Set 502 on C to 27 on D, bring cursor to 32 on B, 1 on B to cursor, cursor to 57 on B, 1 on B to cursor, and over 38 on B read 200 I.H.P. on A.

To determine the horse-power of a compound engine, invert the slide and set the diameter of the _high_-pressure cylinder on ■ to the cut-off in that cylinder on A. Use the number then found on A over the diameter of the _low_-pressure cylinder on ■ as the cut-off in that cylinder, working with the same pressure and piston speed, and calculate the horse-power as for a single cylinder.

To find the cylinder ratio in compound engines, invert the slide and set index of ■ to diameter of the low-pressure cylinder on D. Then over the diameter of the high-pressure cylinder on C, read cylinder ratio on A.

EX.—Diameter of high-pressure cylinder 7¾in., low-pressure 15 in. Find cylinder ratio.

Set index on ■ to 15 on D, and over 7·75 on ■ read 3·75, the required ratio, on A.

The cylinder ratios of triple or quadruple-expansion engines may be similarly determined.

EX.—In a quadruple-expansion engine, the cylinders are 18, 26, 37, and 54 inches in diameter. Find the respective ratios of the high, first intermediate, and second intermediate cylinders to the low-pressure.

Set (R.H.) index of ■ to 54 on D, and over 18, 26, and 37 on ■ read 9, 4·31, and 2·13, the required ratios, on A.

Given the mean effective pressures in lb. per square inch in each of the three cylinders of a triple-expansion engine, the I.H.P. to be developed in each cylinder, and the piston speed, to find the respective cylinder diameters.

Set 42,000 on B to piston speed on A; bring cursor to mean effective pressure in low-pressure cylinder on B, index of B to cursor, and under I.H.P. on A read low-pressure cylinder diameter on C. To find the diameters of the high-pressure and intermediate-pressure cylinders, invert the slide and place the mean pressure in the low-pressure cylinder on ■ to the diameter of that cylinder on D. Then under the respective mean pressures on ■ read corresponding cylinder diameters on D.

EX.—The mean effective pressures in the cylinders of a triple-expansion engine are:—L.P., 10·32; I.M.P., 27·5; and H.P., 77·5 lb. per square inch. The piston speed is 650 ft. per minute, and the I.H.P. developed in each cylinder, 750. Find the cylinder diameters.

Set 42,000 on B to 650 on A, and bring cursor to 10·32 on B. Bring index of B to cursor, and under 750 on A read 68·5 in. on C, the L.P. cylinder diameter. Invert the slide, and placing 10·32 on ■ to 68·5 on D, read, under 27·5 on ■, the I.M.P. cylinder diameter = 42 in., on D; also under 77·5 on ■ read the H.P. cylinder diameter = 25 in., on D.

To compute brake or dynamometrical horse-power.

Set 525 on C to the total weight in lb. acting at the end of the lever (or pull of spring balance in lb.) on D; set cursor to length of lever in feet on C, bring 1 on C to cursor, and under number of revolutions per minute on C find brake horse-power on D.

Given cylinder diameter and piston speed in feet per minute, to find diameter of steam pipe, assuming the maximum velocity of the steam to be 6000 ft. per minute.

Set 6000 on B to cylinder diameter on D, and under piston speed on B read steam pipe diameter on D.

Given the number of revolutions per minute of a Watt governor, to find the vertical height in inches, from the plane of revolution of the balls to the point of suspension.

Set revolutions per minute on C to 35,200 on A, and over index of B read height on A.

Given the weight in lb. of the rim of a cast-iron fly-wheel, to find the sectional area of the rim in square inches.

Set the mean diameter of the wheel in feet on C to 0·102 on D, and under weight of rim on C find area on D.

Given the consumption of coal in tons per week of 56 hours, and the I.H.P., to find the coal consumed per I.H.P. per hour.

Set I.H.P. on C to 40 on D, and under weekly consumption on C read lb. of coal per I.H.P., per hour on D.

EX.—Find coal used per I.H.P. per hour, when 24 tons is the weekly consumption for 300 I.H.P.

Set 300 on C to 40 on D, and under 24 on C read 3·2 lb. per I.H.P. per hour on D.

(N.B.—For any other number of working hours per week divide 2240 by the number of working hours, and use the quotient in place of 40 as above.)

To find the tractive force of a locomotive.

Set diameter of driving wheel in inches on B to diameter of cylinder in inches on D, and over the stroke in inches on B read on A, tractive force in lb. for each lb. of effective pressure on the piston.

STEAM BOILERS.

To find the bursting pressure of a cylindrical boiler shell, having given the diameter of shell and the thickness and ultimate strength of the material.

Set the diameter of the shell in inches on C to twice the thickness of the plate on D, and under strength of material per square inch on C read bursting pressure in lb. per square inch on D.

EX.—Find the bursting pressure of a cylindrical boiler shell 7 ft. 6 in. in diameter, with plates ½in. thick, assuming an ultimate strength of 50,000 lb. per square inch.

Set 90 on C to 1·0 on D, and under 50,000 on C find 555 lb. on D.

To find working pressure for Fox's corrugated furnaces by Board of Trade rule.

Set the least outside diameter in inches on C to 14,000 on D, and under thickness in inches on C read working pressure on D in lb. per square inch.

To find diameter _d_ in inches, of round steel for safety valve springs by Board of Trade rule.

Set 8000 on C to load on spring in lb. on D, and under the mean diameter of the spring in inches on C read _d_^3 on D. Then extract the cube root as per rule.

SPEED RATIOS OF PULLEYS, ETC.

Given the diameter of a pulley and its number of revolutions per minute, to find the circumferential velocity of the pulley or the speed of ropes, belts, etc., driven thereby.

Set diameter of pulley in inches on C to 3·82 on D, and over revolutions per minute on D read speed in feet per minute on C.

EX.—Find the speed of a belt driven by a pulley 53 in. in diameter and running at 180 revolutions per minute.

Set 53 on C to 3·82 on D, and over 180 on D read 2500 ft. per minute on C.

EX.—Find the speed of the pitch line of a spur wheel 3 ft. 6 in. in diameter running at 60 revolutions per minute.

Set 42 in. on C to 3·82 on D, and over 60 on D read 660 ft. per minute on C.

Given diameter and number of revolutions per minute of a driving pulley, and the diameter of the driven pulley, to find the number of revolutions of the latter.

Invert the slide and set diameter of driving pulley on ■ to given number of its revolutions on D; then opposite diameter of any driven pulley on ■ read its number of revolutions on D.

EX.—Diameter of driving pulley 10 ft.; revolutions per minute 55; diameter of driven pulley 2 ft. 9 in. Find number of revolutions per minute of latter.

Set 10 on ■ to 55 on D, and opposite 2·75 on ■ read 200 revolutions on D.

BELTS AND ROPES.

To find the ratio of tensions in the two sides of a belt, given the coefficient of friction between belt and pulley μ and the number of degrees θ in the arc of contact (log. $R = (\mu\theta)/(132)$).

Set 132 on C to the coefficient of friction on D, and read off the value found on D under the number of degrees in the arc of contact on C. Place this value on the scale of equal parts on the back of the slide, to the index mark in the aperture, and read the required ratio on D under the L.H. index of C.

EX.—Find the tension ratio in a belt, assuming a coefficient of friction of 0·3 and an arc of contact of 120 degrees.

Set 132 on C to 0·3 on D, and under 120 on C read 0·273. Place this on the scale to the index on the back of the rule, and under the L.H. index C read 1·875 on D, the required ratio.

Given belt velocity and horse-power to be transmitted, to find the requisite width of belt, taking the effective tension at 50 lb. per inch of width.

Set 660 on C to velocity in feet per minute on D, and opposite horse-power on D find width of belt in inches on C.

Given velocity and width of belt, to find horse-power transmitted.

Set 660 on C to velocity on D, and under width on C find horse-power transmitted on D.

(N.B.—For any other effective tension, instead of 660 use as a gauge point:—33,000 ÷ tension.)

Given speed and diameter of a cotton driving rope, to find power transmitted, disregarding centrifugal action, and assuming an effective working tension of 200 lb. per square inch of rope.

Set 210 on B to 1·75 on D, and over speed in feet per minute on B read horse-power on A.

EX.—Find the power transmitted by a 1¾in. rope running at 4000 ft. per minute.

Set 210 on B to 1·75 on D, and over 4000 on B read 58·3 horse-power on A.

Find the "centrifugal tension" in the previous example, taking the weight per foot of the rope as = 0·27_d_^2.

Set 655 on C to the diameter, 1·75 in., on D, and over the speed, 4000 ft. on C, read centrifugal tension = 114 lb. on A.

SPUR WHEELS.

Given diameter and pitch of a spur wheel, to find number of teeth.

Set pitch on C to π (3·1416) on D, and under any diameter on C read number of teeth on D.

Given diameter and number of teeth in a spur wheel, to find the pitch.

Set diameter on C to number of teeth on D, and read pitch on C opposite 3·1416 on D.

Given the distance between the centres of a pair of spur wheels and the number of revolutions of each, to determine their diameters.

To twice the distance between the centres on D, set the sum of the number of revolutions on C, and under the revolutions of each wheel on C find the respective wheel diameters on D.

EX.—The distance between the centres of two spur wheels is 37·5 in., and they are required to make 21 and 24 revolutions in the same time. Find their respective diameters.

Set 21 + 24 = 45 on C to 75 (or 37·5 × 2) on D, and under 21 and 24 on C find 35 and 40 in. on D as the respective diameters.

To find the power transmitted by toothed wheels, given the pitch diameter _d_ in inches, the number of revolutions per minute _n_, and the pitch _p_ in inches, by the rule, H.P. = (_n_ _d_ _p_^2)/(400).

Set 400 on B to pitch in inches on D; set cursor to d on B, 1 on B to cursor, and over any number of revolutions n on B read power transmitted on A.

EX.—Find the horse-power capable of being transmitted by a spur wheel 7 ft. in diameter, 3 in. pitch, and running at 90 revolutions per minute.

Set 400 on B to 3 on D; bring cursor to 84 in. on B, 1 on B to cursor, and over 90 revolutions on B read 170, the horse-power transmitted, on A.

SCREW-CUTTING.

Given the number of threads per inch in the guide screw, to find the wheels to cut a screw of given pitch.

Set threads per inch in guide screw on C, to the number of threads per inch to be cut on D. Then opposite any number of teeth in the wheel on the mandrel on C, is the number of teeth in the wheel to be placed on the guide screw on D.

STRENGTH OF SHAFTING.

Given the diameter _d_ of a steel shaft, and the number of revolutions per minute _n_, to find the horse-power from:—

H.P. = _d_^3 × _n_ × 0·02.

Set 1 on C to _d_ on D, and bring cursor to _d_ on B. Bring 50 on B to cursor, and over number of revolutions on B read H.P. on A.

EX.—Find horse-power transmitted by a 3 in. steel shaft at 110 revolutions per minute.

Set 1 on C to 3 on D, and bring cursor to 3 on B. Bring 50 on B to cursor, and over 110 on B read 59·4 horse-power on A.

Given the horse-power to be transmitted and the number of revolutions of a steel shaft, to find the diameter.

Set revolutions on B to horse-power on A, and bring cursor to 50 on B. Then move the slide until the same number is found on B under the cursor that is simultaneously found on D under the index of C. This number is the diameter required.

To find the deflection _k_ in inches, of a round steel shaft of diameter _d_, under a uniformly distributed load in lb. _w_, and supported by bearings, the centres of which are _l_ feet apart (_k_ = (_w_ _l_^3)/(78,000_d_^4)).

Modifying the form of this expression slightly, we proceed as follows:—Set _d_ on C to _l_ on D, and bring the cursor to the same number on B that is found on D under the index of C. Bring _d_ on B to cursor, cursor to _w_ on B, 78,800 on B to cursor, and read deflection on A over index of B.

EX.—Find the deflection in inches of a round steel shaft 3½in. diameter, carrying a uniformly distributed load of 3200 lb., the distance apart of the centres of support being 9 ft.

Set 3·5 on C to 9 on D, and read 2·57 on D, under the L.H. index of C. Set cursor to 2·57 on B, and bring 3·5 on B to cursor, cursor to 3200 on B, 78,000 on B to cursor, and over L.H. index of B read 0·199 in., the required deflection on A.

To find the diameter of a shaft subject to twisting only, given the twisting moment in inch-lb. and the allowable stress in lb. per square inch.

Set the stress in lb. per square inch on B to the twisting moment in inch-lb. on A, and bring cursor to 5·1 on B. Then move the slide until the same number is found on B under the cursor that is simultaneously found on D under the index of C.

EX.—A steel shaft is subjected to a twisting moment of 2,700,000 inch-lb. Determine the diameter if the allowable stress is taken at 9000 lb. per square inch.

Set 9000 on B to 2,700,000 on A, and bring the cursor to 5·1 on B. Moving the slide to the left, it is found that when 11·51 on the R.H. scale of B is under the cursor, the L.H. index of C is opposite 11·51 on D. This, then, is the required diameter of the shaft.

(N.B.—The rules for the scales to be used in finding the cube root (page 42) must be carefully observed in working these examples.)

MOMENTS OF INERTIA.

To find the moment of inertia of a square section about an axis formed by one of its diagonals ($I = (s^4)/(12)$).

Set index of C to the length of the side of square _s_ on D; bring cursor to _s_ on C, 12 on B to cursor, and over index of B read moment of inertia on A.

To find the moment of inertia of a rectangular section about an axis parallel to one side and perpendicular to the plane of bending.

Set index of C to the height or depth _h_ of the section, and bring cursor to _h_ on B. Set 12 on B to cursor, and over breadth _b_ of the section on B read moment of inertia on A.

EX.—Find the moment of inertia of a rectangular section of which _h_ = 14 in. and _b_ = 7 in.

Set index of C to 14 on D, and cursor to 14 on B. Bring 12 on B to cursor, and over 7 on B read 1600 on A.

DISCHARGE FROM PUMPS, PIPES, ETC.

To find the theoretical delivery of pumps, in gallons per stroke.

Set 29·4 on B to the diameter of the plunger in inches on D, and over length of stroke in feet on B read theoretical delivery in gallons per stroke on A.

(N.B.—A deduction of from 20 to 40 per cent. should be made to allow for slip.)

To find loss of head of water in feet due to friction in pipes (Prony's rule).

Set diameter of pipe in feet on B to velocity of water in feet per second on D and bring cursor to 2·25 on B; bring 1 on B to cursor, and over length of pipe in miles on B, read loss of head of water in feet, on A.

To find velocity in feet per second, of water in pipes (Blackwell's rule).

Set 2·3 on B to diameter of pipe in feet on A, and under inclination of pipe in feet per mile on B read velocity in feet per second on D.

To find the discharge over weirs in cubic feet per minute and per foot of width. (Discharge = $214\sqrt{(h^3)}$)

Set 0·00467 on C to the head in feet _h_ on D, and under _h_ on B read discharge on D.

To find the theoretical velocity of water flowing under a given head in feet.

Set index of B to head in feet on A, and under 64·4 on B read theoretical velocity in feet per second on D.

HORSE-POWER OF WATER WHEELS.

To find the effective horse-power of a Poncelet water wheel.

Set 880 on C to cubic feet of flow of water per minute on D, and under height of fall in feet on C, read effective horse-power on D.

For breast water wheels use 960, and for overshot wheels 775, in place of 880 as above.

ELECTRICAL ENGINEERING.

To find the resistance per mile, in ohms, of copper wire of high conductivity, at 60° F. the diameter being given in mils. (1 mil. = 0·001 in.).

Set diameter of wire in mils. on C to 54,900 on A, and over R.H. or L.H. index of B read resistance in ohms on A.

EX.—Find the resistance per mile of a copper wire 64 mils. in diameter.

Set 64 on C to 54,900 on A, and over R.H. index of B read 13·4 ohms on A.

To find the weight of copper wire in lb. per mile.

Set 7·91 on C to diameter of wire in mils. on D, and over index of B read weight per mile on A.

Given electromotive force and current, to find electrical horse-power.

Set 746 on C to electromotive force in volts on D, and under current in ampères on C read electrical horse-power on D.

Given the resistance of a circuit in ohms and current in ampères, to find the energy absorbed in horse-power.

Set 746 on B to current on D, and over resistance on B read energy absorbed in H.P. on A.

EX.—Find the H.P. expended in sending a current of 15 ampères through a circuit of 220 ohms resistance.

Set 746 on B to 15 on D, and over 220 on B read 66·3 H.P. on A.

COMMERCIAL.

To add on percentages.

Set 100 on C to 100 + given percentage on D, and under original number on C read result on D.

To deduct percentages.

Set R.H. index of C to 100 – the given percentage on D, and under original number on C read result on D.

EX.—From £16 deduct 7½ per cent.

Set 10 on C to 92·5 on D and under 16 on C, read 14·8 = £14, 16s. on D.

To calculate simple interest.

Set 1 on C to rate per cent. on D; bring cursor to period on C and 1 on C to cursor. Then opposite any sum on C find simple interest on D.

For interest per annum.

Set R.H. index on C to rate on D, and opposite principal on C read interest on D.

EX.—Find the amount with simple interest of £250 at 8 per cent., and for a period of 1 year and 9 months.

Set 1 on C to 8 on D; bring cursor to 1·75 on C, and 1 on C to cursor; then opposite 250 on C read £35, the interest, on D. Then 250 + 35 = £285 = the amount.

To calculate compound interest.

Set the L.H. index of C to the amount of £1 at the given rate of interest on D, and find the logarithm of this by reading on the reverse side of the rule, as explained on page 46. Multiply the logarithm, so found, by the period, and set the result, on the scale of equal parts, to the index on the under-side of the rule; then opposite any sum on C read the amount (including compound interest) on D.

EX.—Find the amount of £500 at 5 per cent. for 6 years, with compound interest.

Set L.H. index of C to £1·05 on D, and read at the index on the scale of equal parts on the under-side of rule, 0·0212. Multiply by 6, we obtain 0·1272, which, on the scale of equal parts, is placed to the index in the notch at the end of the rule. Then opposite 500 on C read £670 on D, the amount required, including compound interest.

MISCELLANEOUS CALCULATIONS.

To calculate percentages of compositions.

Set weight (or volume) of sample on C, to weight (or volume) of substance considered, on D; then under index of C read required percentage on D.

EX.—A sample of coal weighing 1·25 grms. contains 0·04425 grm. of ash. Find the percentage of ash.

Set 1·25 on C to 0·04425 on D, and under index on C read 3·54, the required percentage of ash on D.

Given the steam pressure P and the diameter _d_ in millimetres, of the throat of an injector, to find the weight W, of water delivered in lb. per hour from W = (_d_^2√■P)/(0·505).

Set 0·505 on C to P on A; bring cursor to _d_ on C and index of C to cursor. Then under _d_ on C read delivery of water on D.

To find the pressure of wind per square foot, due to a given velocity in miles per hour.

Set 1 on B to 2 on A, and over the velocity in miles per hour on D read pressure in lb. per square foot on B.

To find the kinetic energy of a moving body.

Set 64·4 on B to velocity in feet per second on D, and over weight of body in lb. on B read kinetic energy or accumulated work in foot-lb. on A.

TRIGONOMETRICAL APPLICATIONS

Scales.—Not the least important feature of the modern slide rule is the provision of the special scales on the under-side of the slide, and by the use of which, in conjunction with the ordinary scales on the rule, a large variety of trigonometrical computations may be readily performed.

Three scales will be found on the reverse or under-side of the slide of the ordinary Gravêt or Mannheim rule. One of these is the evenly-divided scale or scale of equal parts referred to in previous sections, and by which, as explained, the decimal parts or mantissæ of logarithms of numbers may be obtained. Usually this scale is the centre one of the three, but in some rules it will be found occupying the lowest position, in which case some little modification of the following instructions will be necessary. The requisite transpositions will, however, be evident when the purposes of the scales are understood. The upper of the three scales, usually distinguished by the letter S, is a scale giving the logarithms of the sines of angles, and is used to determine the natural sines of angles of from 35 minutes to 90 degrees. The notation of this scale will be evident on inspection. The main divisions 1, 2, 3, etc., represent the degrees of angles; but the values of the subdivisions differ according to their position on the scale. Thus, if any primary space is subdivided into 12 parts, each of the latter will be read as 5 minutes (5′), since 1° = 60′.

Sines of Angles.—To find the sine of an angle the slide is placed in the groove, with the under-side uppermost, and the end division lines or indices on the slide, coinciding with the right and left indices of the A scale. Then over the given angle on S is read the value of the sine of the angle on A. If the result is found on the left scale of A (1 to 10), the logarithmic characteristic is –2; if it is found on the right-hand side (10 to 100), it is –1. In other words, results on the right-hand scale are prefixed by the decimal point only, while those on the left-hand scale are to be preceded by a cypher also. Thus:—

Sine 2° 40′ = 0·0465; sine 15° 40′ = 0·270.

Multiplication and division of the sines of angles are performed in the same manner as ordinary calculations, excepting that the slide has its under-face placed uppermost, as just explained. Thus to multiply sine 15° 40′ by 15, the R.H. index of S is brought to 15 on A, and opposite 15° 40′ on S is found 4·05 on A. Again, to divide 142 by sine 16° 30′, we place 16° 30′ on S to 142 on A, and over R.H. index of S read 500 on A.

The rules for the number of integers in the results are thus determined: Let N be the number of integers in the multiplier M or in the dividend D. Then the number of integers P, in the product or Q, in the quotient are as follows:—

When the result is found to the right of M or D, ■P = N – 2■Q = N and in the same scale ■ ■ When the result is found to the right of M or D, ■P = N – 1■Q = N + 1 and in the other scale ■ ■ When the result is found to the left of M or D, and■P = N – 1■Q = N + 1 in the other scale ■ ■ When the result is found to the left of M or D, and■P = N ■Q = N + 2 in the same scale ■ ■

If the division is of the form (20° 30′)/(50), the result cannot be read off directly on the face of the rule. Thus, if in the above example 20° 30′ on S, is placed to agree with 50 on the right-hand scale of A, the result found on S under the R.H. index of A is 44° 30′. The required numerical value can then be found: (1) By placing the slide with all indices coincident when opposite 44° 30′ on S will be found 0·007 on A; or (2) In the ordinary form of rule, by reading off on the scale B opposite the index mark in the opening on the under-side of the rule. The above rules for the number of integers in the quotient do not apply in this case.

If it is required to find the sine of an angle simply, this may be done with the slide in its ordinary position, with scale B under A. The given angle on scale S is then set to the index on the under-side of the rule, and the value of the sine is read off on B under the right index of A.

Owing to the rapidly diminishing differences of the values of the sines as the upper end of the scale is approached, the sines of angles between 60° and 90° cannot be accurately determined in the foregoing manner. It is therefore advisable to calculate the value of the sine by means of the formula:

Sine θ = 1 – 2 sin^2 (90 – θ)/(2).

To determine the value of sin^2 (90 – θ)/(2). With the slide in the normal position, set the value of (90 – θ)/(2). on S to the index on the under-side of the rule, and read off the value _x_ on B under the R.H. index of A. Without moving the slide find _x_ on A, and read under it on B the value required.

EX.—Find value of sine 79° 40′.

Sine 79° 40′ = 1 – 2sin^2 5° 10′.

But sine 5° 10′ = 0·0900, and under this value on A is 0·0081 on B. Therefore sine 79° 40′ = 1 – 0·0162 = 0·9838.

The sines of very small angles, being very nearly proportional to the angles themselves, are found by direct reading. To facilitate this, some rules are provided with two marks, one of which, a single accent (′), corresponds to the logarithm of (1)/(sine 1′) and is found at the number 3438. The other mark—a double accent (″)—corresponds to the logarithm of (1)/(sine 1″) and is found at the number 206,265. In some rules these marks are found on either the A or the B scales; sometimes they are on both. In either case the angle on the one scale is placed so as to coincide with the significant mark on the other, and the result read off on the first-named scale opposite the index of the second.

In sines of angles under 3″, the number of integers in the result is –5; while it is –4 for angles from 3″ to 21″; –3 from 21″ to 3′ 27″; and –2 from 3′ 27″ to 34′ 23″.

EX.—Find sine 6′.

Placing the significant mark for minutes coincident with 6, the value opposite the index is found to be 175, and by the rule above this is to be read 0·00175. For angles in seconds the other significant mark is used; while angles expressed in minutes and seconds are to be first reduced to seconds. Thus, 3′ 10″ = 190″.

Tangents of Angles.—There remains to be considered the third scale found on the back of the slide, and usually distinguished from the others by being lettered T. In most of the more recent forms of rule this scale is placed near the lower edge of the slide, but in some arrangements it is found to be the centre scale of the three. Again, in some rules this scale is figured in the same direction as the scale of sines—viz., from left to right,—while in others the T scale is reversed. In both cases there is now usually an aperture formed in the back of the left extremity of the rule, with an index mark similar to that already referred to in connection with the scale of sines. Considering what has been referred to as the more general arrangement, the method of determining the tangents of angles may be thus explained:—

The tangent scale will be found to commence, in some rules, at about 34′, or, precisely, at the angle whose tangent is 0·01. More usually, however, the scale will be found to commence at about 5° 43′, or at the angle whose tangent is 0·1. The other extremity of the scale corresponds in all cases to 45°, or the angle whose tangent is 1. This explanation will suggest the method of using the scale, however it may be arranged. If the graduations commence with 34′, the T scale is to be used in conjunction with the right and left scales of A; while if they commence with 5° 43′ it is to be used in conjunction with the D scale.

In the former case the slide is to be placed in the rule so that the T scale is adjacent to the A scales, and, with the right and left indices coinciding, when opposite any angle on T will be found its tangent on A. From what has been said above, it follows that the tangents read on the L.H. scale of A have values extending from 0·01 to 0·1; while those read on the R.H. scale of A have values from 0·1 to 1·0. Otherwise expressed, to the values of any tangent read on the L.H. scale of A a cypher is to be prefixed; while if found on the R.H. scale, it is read directly as a decimal.

EX.—Find tan. 3° 50′.

Placing the slide as directed, the reading on A opposite 3° 50′ on T is found to be 67. As this is found on the L.H. scale of A, it is to be read as 0·067.

EX.—Find tan. 17° 45′.

Here the reading on A opposite 17° 45′ on T is 32, and as it is found on the R.H. scale of A it is read as 0·32.

As in the case of the scale of sines, the tangents may be found without reversing the slide, when a fixed index is provided in the back of the rule for the T scale.

We revert now to a consideration of those rules in which a single tangent scale is provided. It will be understood that in this case the slide is placed so that the scale T is adjacent to the D scale, and that when the indices of both are placed in agreement, the value of the tangent of any angle on T (from 5° 43′ to 45°) may be read off on D, the result so found being read as wholly decimal. Thus tan. 13° 20′ is read 0·237.

If a back index is provided, the slide is used in its normal position, when, setting the angle on the tangent scale to this index, the result can be read on C over the L.H. index of D.

The tangents of angles above 45° are obtained by the formula: Tan. $\theta = (1)/(\tan.\ (90 - \theta))$. For all angles from 45° to (90° – 5° 43′) we proceed as follows:—Place $(90 - \theta)$ on T to the R.H. index of D, and read tan. θ on D under the L.H. index of T. The first figure in the value thus obtained is to be read as an integer. Thus, to find tan. 71° 20′ we place 90° – 71° 20′ = 18° 40′ on T, to the R.H. index of D, and under the L.H. index of T read 2·96, the required tangent.

The tangents of angles less than 40′ are sensibly proportional to the angles themselves, and as they may therefore be considered as sines, their value is determined by the aid of the single and double accent marks on the sine scale, as previously explained. The rules for the number of integers are the same as for the sines.

Multiplication and division of tangents may be quite readily effected.

EX.—Tan. 21° 50′ × 15 = 6.

Set L.H. index of T to 15 on D, and under 21° 50′ on T read 6 on D.

EX.—Tan. 72° 40′ × 117 = 375.

Set (90° – 72° 40′) = 17° 20′ on T to 117 on D, and under R.H. index of T read 375 on D.

Cosines of Angles.—The cosines of angles may be determined by placing the scale S with its indices coinciding with those of A, and when opposite $(90 - \theta)$ on S is read cos. θ on A. If the result is read on the L.H. scale of A, a cypher is to be prefixed to the value read; while if it is read on the R.H. scale of A, the value is read directly as a decimal. Thus, to determine cos. 86° 30′ we find opposite (90° – 86° 30′) = 3° 30′ on S, 61° on A, and as this is on the L.H. scale the result is read 0·061. Again, to find cos. 59° 20′ we read opposite (90° – 59° 20′) or 30° 40′ on S, 51 on A, and as this is found on the R.H. scale of A, it is read 0·51.

In finding the cosines of small angles it will be seen that direct reading on the rule becomes impossible for angles of less than 20°. It is advisable in such cases to adopt the method described for determining the _sines_ of the _large_ angles of which the complements are sought.

Cotangents of Angles.—From the methods of finding the tangents of angles previously described, it will be apparent that the cotangents of angles may also be obtained with equal facility. For angles between 5° 45′ and 45°, the procedure is the same as that for finding tangents of angles greater than 45°. Thus, the angle on scale T is brought to the R.H. index of D, and the cotangent read

off on D under the L.H. index of T. The first figure of the result so found is to be read as an integer.

If the angle (θ) lies between 45° and 84° 15′, the slide is placed so that the indices of T coincide with those of D, and the result is then read off on D opposite ($90 - \theta$) on T. In this case the value is wholly decimal.

Secants of Angles.—The secants of angles are readily found by bringing ($90 - \theta$) on S to the R.H. index of A and reading the result on A over the L.H. index of S. If the value is found on the L.H. scale of A, the first figure is to be read as an integer; while if the result is read on the R.H. scale of A, the first _two_ figures are to be regarded as integers.

Cosecants of Angles.—The cosecants of angles are found by placing the angle on S to the R.H. index of A, and reading the value found on A over the L.H. index of S. If the result is read on the L.H. scale of A, the first figure is to be read as an integer; while if the result is found on the R.H. scale of A, the first _two_ figures are to be read as integers.

It will be noted that some of the rules here given for determining the several trigonometrical functions of angles apply only to those forms of rules in which a single scale of tangents T is used, reading from left to right. For the other arrangements of the scale, previously referred to, some slight modification of the method of procedure in finding the tangents and cotangents of angles will be necessary; but as in each case the nature and extent of this modification is evident, no further directions are required.

THE SOLUTION OF RIGHT-ANGLED TRIANGLES.

From the foregoing explanation of the manner of determining the trigonometrical functions of angles, the methods of solving right-angled triangles will be readily perceived, and only a few examples need therefore be given.

Let _a_ and _b_ represent the sides and _c_ the hypothenuse of a right-angled triangle, and _a_° and _b_° the angles opposite to the sides. Then of the possible cases we will take

(1.) Given _c_ and _a_°, to find _a_, _b_, and _b_°.

The angle _b_° = 90 – _a_°, while _a_ = _c_ sin _a_° and _b_ = _c_ sin _b_°. To find _a_, therefore, the index of S is set to _c_ on A, and the value of _a_ read on A opposite _a_° on S. In the same manner the value of _b_ is obtained.

EX.—Given in a right-angled triangle _c_ = 9 ft. and _a_° = 30°. Find _a_, _b_, and _b_°.

The angle _b_° = 90 – 30 = 60°. To find _a_, set R.H. index of S to 9 on A, and over 30° on S read _a_ = 4·5 ft. on A. Also, with the slide in the same position, read _b_ = 7·8 ft. [7·794] on A over 60° on S.

(2.) Given _a_ and _c_, to determine _a_°, _b_°, and _b_.

In this case advantage is taken of the fact that in every triangle the sides are proportional to the sines of the opposite angles. Therefore, as in this case the hypothenuse c subtends a right angle, of which the sine = 1, the R.H. index (or 90°) on S is set to the length of _c_ on A, when under _a_ on A is found _a_° on S. Hence _b_° and _b_ may be determined.

(3.) Given _a_ and _a_°, to find _b_, _c_, and _b_°.

Here _b_° = (90 – _a_°), and the solution is similar to the foregoing.

(4.) Given _a_ and _b_, to find _a_°, _b_°, and _c_.

To find _a_°, we have tan. _a_° = _a_/_b_, which in the above example will be (4·5)/(7·8) = 0·577. Therefore, placing the slide so that the indices of T coincide with those of D, we read opposite 0·577 on D the value of _a_° = 30°. The hypothenuse _c_ is readily obtained from _c_ = _a_/(sin _a_°).

THE SOLUTION OF OBLIQUE-ANGLED TRIANGLES.

Using the same letters as before to designate the three sides and the subtending angles of oblique-angled triangles, we have the following cases:—

(1.) Given one side and two angles, as _a_, _a_°, and _b_°, to find _b_, _c_, and _c_°.

In the first place, _c_° = 180° – (_a_° + _b_°); also we note that, as the sides are proportional to the sines of the opposite angles, _b_ = (_a_ sine _b_°)/(sine _a_°) and _c_ = (_a_ sine _c_°)/(sine _a_°).

Taking as an example, _a_ = 45, _a_° = 57°, and _b_° = 63°, we have _c_° = 180 – (57 + 63) = 60°. To find _b_ and _c_, set _a_° on S to _a_ on A, and read off on A above 63° and 60° the values of _b_ (= 47·8) and _c_ (= 46·4) respectively.

(2.) Given _a_, _b_, and _a_°, to find _b_°, _c_°, and _c_.

In this case the angle _a_° on S is placed under the length of side _a_ on A and under _b_ on A is found the angle _b_° on S. The angle _c_° = 180 – (_a_° + _b_°), whence the length _c_ can be read off on A over _c_° on S.

(3.) Given the sides and the included angle, to find the other side and the remaining angles.

If, for example, there are given _a_ = 65, _b_ = 42, and the included angle _c_° = 55°, we have (_a_ + _b_) ■ (_a_ – _b_) = tan. (_a_° + _b_°)/(2) ■ tan. (_a_° – _b_°)/(2). Then, since _a_° + _b_° = 180° – 55° = 125°, it follows that (_a_° + _b_°)/(2) = (125°)/(2) = 62° 30′.

By the rule for tangents of angles greater than 45°, we find tan. 62° 30′ = 1·92. Inserting in the above proportion the values thus found, we have 107 ■ 23 = 1·92 ■ tan. (_a_° – _b_°)/(2). From this it is found that the value of the tangent is 0·412, and placing the slide with all indices coinciding, it is seen that this value on D corresponds to an angle of 22° 25′. Therefore, since (_a_° + _b_°)/(2) = 62° 30′, and (_a_° – _b_°)/(2) = 22° 25′, it follows that _a_° = 84° 55′, and _b_° = 40° 5′. Finally, to determine the side _c_, we have _c_ = (_a_ sin _c_°)/(sin _a_°) as before.

PRACTICAL TRIGONOMETRICAL APPLICATIONS.

A few examples illustrative of the application of the methods of determining the functions of angles, etc., described in the preceding section, will now be given.

To find the chord of an arc, having given the included angle and the radius.

With the slide placed in the rule with the C and D scales outward, bring one-half of the given angle on S to the index mark in the back of the rule, and read the chord on B under twice the radius on A.

EX.—Required the chord of an arc of 15°, the radius being 23 in.

Set 7° 30′ on S to the index mark in the back of the rule, and under 46 on A read 6 in., the required length of chord on B.

To find the area of a triangle, given two sides and the included angle.

Set the angle on S to the index mark on the back of the rule, and bring cursor to 2 on B. Then bring the length of one side on B to cursor, cursor to 1 on B, the length of the other side on B to cursor, and read area on B under index of A.

EX.—The sides of a triangle are 5 and 6 ft. in length respectively, and they include an angle of 20°. Find the area.

Set 20 on S to index mark, bring cursor to 2 on B, 5 on B to cursor, cursor to 1 on B, 6 on B to cursor, and under 1 on A read the area = 5·13 sq. ft. on B.

To find the number of degrees in a gradient, given the rise per cent.

Place the slide with the indices of T coincident with those of D, and over the rate per cent. on D read number of degrees in the slope on T.

As the arrangement of rule we have chiefly considered has only a single T scale, it will be seen that only solutions of the above problem involving slopes between 10 and 100 per cent. can be directly read off. For smaller angles, one of the formulæ for the determination of the tangents of submultiple angles must be used.

In rules having a double T scale (which is used with the A scale) the value in degrees of any slope from 1 to 100 per cent. can be directly read off on A.

To find the number of degrees, when the gradient is expressed as 1 in _x_.

Place the index of T to _x_ on D, and over index of D read the required angle in degrees on T.

EX.—Find the number of degrees in a gradient of 1 in 3·8.

Set 1 on T to 3·8 on D, and over R.H. index of D read 14° 45′ on T.

Given the lap, the lead and the travel of an engine slide valve, to find the angle of advance.

Set (lap + lead) on B to half the travel of the valve on A, and read the angle of advance on S at the index mark on the back of the rule.

EX.—Valve travel 4½in., lap 1 in., lead ■/■■in. Find angle of advance.

Set 1■/■■ = 1·312 on B to 2·25 on A, and read 35° 40′ on S opposite the index on the back of the rule.

Given the angular advance θ, the lap and the travel of a slide valve, to find the cut-off in percentage of the stroke.

Place the lap on B to half the travel of valve on A, and read on S the angle (the supplement of the _angle of the eccentric_) found opposite the index in the back of the rule. To this angle, add the angle of advance and deduct the sum from 180°, thus obtaining the _angle of the crank_ at the point of cut-off. To the cosine of the supplement of this angle, add 1 and multiply the result by 50, obtaining the percentage of stroke completed when cut-off occurs.

EX.—Given the angular advance = 35° 40′, the valve travel = 4½in., and the lap = 1 in., find the angle of the crank at cut-off and the admission period expressed as a percentage of the stroke.

Set 1 on B to 2·25 on A, and read off on S opposite the index, the supplement of the angle of the eccentric = 26° 20′. Then 180° – (35° 40′ + 26° 20′) = 118° = the crank angle at the point of cut-off. Further, cos. 118° = cos. 62° = sin (90° – 62°) = sin 28°, and placing 28° on S to the back index, the cosine, read on B under R.H. index of A, is found to be 0·469. Adding 1 and placing the L.H. index of C to the result, 1·469, on D, we read off under 50 on C, the required period of admission = 73·4 per cent. on D.

The trigonometrical scales are useful for evaluating certain formulæ. Thus in the following expressions, if we find the angle _a_ such that sin. _a_ = _k_, we can write:—

(_k_)/(√1 – _k^2_) = tan. _a_; (√1 – _k^2_)/(_k_) = cot. _a_; √(1 – _k^2_) = cos. _a_; etc.

In the first expression, take _k_ = 0·298. Place the slide with the sine scale outward and with its indices agreeing with the indices of the rule. Set the cursor to 0·298 on the (R.H.) scale of A, and read 17° 20′ on the sine scale as the angle required. Then under 17° 20′ on the tangent scale, read 0·312 on D as the result.

SLIDE RULES WITH LOG.-LOG. SCALES.

For occasional requirements, the method described on page 45 of determining powers and roots other than the square and cube, is quite satisfactory. When, however, a number of such calculations are to be made, the process may be simplified considerably by the use of what are known as _log.-log._, _logo-log._, or _logometric_ scales, in conjunction with the ordinary scales of the rule. The principle involved will be understood from a consideration of those rules for logarithmic computation (page 8) which refer to powers and roots. From these it is seen that while for the multiplication and division of numbers we _add_ their logarithms, for involution and evolution we require to _multiply_ or _divide_ the logarithms of the numbers by the exponent of the power or root as the case may be. Thus to find 3^{2.3}, we have (log. 3) × 2·3 = log. _x_, and by the ordinary method described on page 45 we should determine log. 3 by the aid of the scale L on the back of the slide, multiply this by 2·3 by using the C and D scales in the usual manner, transfer the result to scale L, and read the value of _x_ on D under 1 on C. By the simpler method, first proposed by Dr. P. M. Roget,[8] the multiplication of log. 3 by 2·3 is effected in the same way as with any two ordinary factors—_i.e._, by adding their logarithms and finding the number corresponding to the resulting logarithm. In this case we have log. (log. 3) + log. 2·3 = log. (log. _x_). The first of the three terms is obviously the _logarithm of the logarithm_ of 3, the second is the simple logarithm of 2·3, and the third the _logarithm of the logarithm of_ the answer. Hence, if we have a scale so graduated that the distances from the point of origin represent the logarithms of the logarithms (the log.-logs.) of the numbers engraved upon it, then by using this in conjunction with the ordinary scale of logarithms, we can effect the required multiplication in a manner which is both expeditious

and convenient. Slightly varying arrangements of the log.-log. scale, sometimes referred to as the "P line," have been introduced from time to time, but latterly the increasing use of exponential formulæ in thermodynamic, electrical, and physical calculations has led to a revival of interest in Dr. Roget's invention, and various arrangements of rules with log.-log. scales are now available.

The Davis Log.-Log. Rule.—In the rule introduced by Messrs. John Davis & Son Limited, Derby, the log.-log. scales are placed upon a separate slide—a plan which has the advantage of leaving the rule intact for all ordinary purposes, while providing a length of 40 in. for the log.-log. scales.

In the 10 in. Davis rule one face of the slide, marked E, has two log.-log. scales for numbers greater than unity, the lower extending from 1·07 to 2, and the upper continuing the graduations from 2 to 1000. On the reverse face of the slide, marked -E, are two log.-log. scales for numbers less than unity, the upper extending from 0·001 to 0·5, and the lower continuing the graduations from 0·5 to 0·933. Both sets of scales are used in conjunction _with the lower or D scale of the rule_, which is to be primarily regarded as running from 1 to 10, and constitutes a scale of exponents. In the 20 in. rule the log.-log. scales are more extensive, and are used in conjunction with the upper or A scale of the rule (1 to 100); in what follows, however, the 10 in. rule is more particularly referred to.

It has been explained that on the log.-log. scale the distance of any numbered graduation from the point of origin represents the log.-log. of the number. The point of origin will obviously be that graduation whose log.-log. = 0. This is seen to be 10, since log. (log. 10) = log. 1 = 0. Hence, confining attention to the E scale, to locate the graduation 20, we have log. (log. 20) = log. 1·301 = 0·11397, so that if the scale D is 25 cm. long, the distance between 10 and 20 on the corresponding log.-log. scale would be 113·97 ÷ 4 = 28·49 mm. For numbers less than 10 the resulting log.-logs. will be negative, and the distances will be spaced off from the point of origin in a negative direction—_i.e._, from right to left. Thus, to locate the graduation 5, we have

log. (log. 5) = log. 0·699 = ■1·844; _i.e._, –1 + 0·844 or –0·156;

so that the graduation marked 5 would be placed 156 ÷ 4 = 39 mm. distant from 10 in a _negative_ direction, and proceeding in a similar manner, the scale may be extended in either direction. In the -E scale, the notation runs in the reverse direction to that of the E scale, but in all other respects it is precisely analogous, the distance from the point of origin (0·1 in this case) to any graduation _x_ representing log. [-log. _x_.]. It follows that of the similarly situated graduations on the two scales, those on the -E scale are the _reciprocals_ of those on the E scale. This may be readily verified by setting, say, 10 on E to (R.H.) 1 on D, when turning to the back of the rule we find 0·1 on -E agreeing with the index mark in the aperture at the right-hand extremity of the rule.

In using the log.-log. scales it is important to observe (1) that the values engraved on the scale are definite and unalterable (_e.g._, 1·2 can only be read as 1·2 and not as 120, 0·0012, etc., as with the ordinary scales); (2) that the upper portion of each scale should be regarded as forming a prolongation to the right of the lower portion; and (3) that immediately above any value on the lower portion of the scale is found the 10th power of that value on the upper portion of the scale. Keeping these points in view, if we set 1·1 on E to 1 on D we find over 2 on D the value of 1·1^2 = 1·21 on E. Similarly, over 3 we find 1·1^3 = 1·331, and so on. Then, reading across the slide, we have, over 2, the value of 1·1^{2 × 10} = 1·1^{20} = 6·73, and over 3 we have 1·1^{3 × 10} = 1·1^{30} = 17·4. Hence the rule:—_To find the value of x^n, set x on E to 1 on D, and over n on D read x^n on E._

With the slide set as above, the 8th, 9th, etc., powers of 1·1 cannot be read off; but it is seen that, according to (2) in the foregoing, the missing portion of the E scale is that part of the upper scale (2 to about 2·6) which is outside the rule to the left. Hence placing 1·1 to 10 on D, the 8th, 9th, etc., powers of 1·1 will be read off _on the upper part_ of the E scale. In general, then,

If _x_ on the _lower_ line is set to 1 on D, then _x^n_ is read directly on that line and _x_^{10_n_} on the upper line.

If _x_ on the _upper_ line is set to 1 on D, then _x^n_ is read directly on that line and _x_^{_■/■■_} on the lower line.

If _x_ on the _lower_ line is set to 10 on D, then _x_^{_■/■■_} is read directly on that line and _x^n_ on the upper line.

If _x_ on the _upper_ line is set to 10 on D, then _x_^{_■/■■_} is read directly on that line and _x_^{_■/■■■_} on the lower line.

These rules are conveniently exhibited in the accompanying diagram (Fig. 14). They are equally applicable to both the E and -E scales of the 10 in. rule, and include practically all the instruction required for determining the _n_th power or the _n_th root of a number. They do not apply directly to the 20 in. rule, however, for here the relation of the lower and upper scales will be _x^n_ and _x_^{100_n_}.

EX.—Find 1·167^{2·56}.

Set 1·167 on E to 1 on D, and over 2·56 on D read 1·485 on E.

EX.—Find 4·6^{1·61}.

Set 4·6 on upper E scale to 1 on D, and over 1·61 on D read 11·7 (11·67) on E.

EX.—Find 1·4^{0·27} and 1·4^{2·7}.

Set 1·4 on E to 10 on D, and over 2·7 on D read 1·095 = 1·4^{0·27} on lower E scale and 2·48 = 1·4^{2·7} on upper E scale.

[Illustration: FIG. 14.]

EX.—Find 46^{0·0184} and 46^{0·184}.

Set 46 on upper E scale to 10 on D, and over 1·84 on D read 1·073 on lower E scale and 2·022 (2·0228) on upper E scale.

EX.—Find 0·074^{1·15}.

Using the -E scale, set 0·074 to 1 on D, and over 1·15 on D read 0·05 on -E.

The method of determining the root of a number will be obvious from the preceding examples.

EX.—Find ^{1.4}√(17) and ^{14}√(17).

Set 17 on E to 1·4 on D, and over 1 on D read 7·56 on upper E scale and 1·224 on lower E scale.

EX.—Find ^{0·031}√(0·914).

Set 0·914 on -E to 3·1 on D, and over 10 on D read 0·055 on upper -E scale.

When the exponent _n_ is fractional, it is often possible to obtain the result directly with one setting of the slide. Thus to determine 1·135^{1■■■} by the first method we find 1■■■ = 1·0625, and placing 1·135 on E to 1 on D, read 1·144 on E over 1·0625 on D. By the direct method we place 1·135 on the E scale on 1·6 on D, and over 1·7 on D read 1·144 on E. It will be seen that since the scale D is assumed to run from 1 to 10 we are unable to read 16 and 17 on this scale; but it is obvious that the _ratios_ (1·7)/(1·6) and (17)/(16) are identical, and it is with the ratio only that we are, in effect, concerned.

Since an expression of the form _x_^{-_n_} = (1)/(_x^n_) or ((1)/(_x_))^{_n_}, the required value may be obtained by first determining the reciprocal of _x_ and proceeding as before. By using both the direct and reciprocal log.-log. scales (E and -E) in conjunction however, the required value can be read directly from the rule, and the preliminary calculation entirely avoided. In the Davis form of rule, the result can be read on the -E scale, used in conjunction with the D scale of the rule, _x_ on E being set to the index mark in the aperture in the back of the rule.

EX.—Find the value of 1·195^{–1·65}.

Set 1·195 on E to the index in the left aperture in the back of the rule, and over 1·65 on D read 0·745 on the -E scale.

It may be noted in passing that the log.-log. scale affords a simple means for determining the logarithm or anti-logarithm of a number to any base. For this purpose it is necessary to set the base of the given system on E to 1 on D, when _under_ any number on E will be found its logarithm on D. Thus, for common logs., we set the base 10 on E to 1 on D, and under 100 we find 2, the required log. Similarly we read log. 20 = 1·301; log. 55 = 1·74; log. 550 = 2·74, etc. Reading reversely, over 1·38 on D we find its antilog. 24 on E; also antilog. 1·58 = 38; antilog. 1·19 = 15·5, etc.

For logs. of numbers under 10 we set the base 10 to 10 on D; hence the readings on D will be read as one-tenth their apparent value. Thus log. 3 = 0·477; log. 5·25 = 0·72; antilog. 0·415 = 2·6; antilog. 0·525 = 3.·35, etc.

The logs. of the numbers on the lower half of the E scale will also be found on the D scale; but a consideration of Fig. 14 will show that this will be read as _one-tenth_ its face value if the base is set to 1 on D, and as _one-hundredth_ if the base is set to 10.

For natural, hyperbolic, or Napierian logarithms, the base is 2·718. A special line marked ε or _e_ serves to locate the exact position of this value on the E scale, and placing this to 1 on D we read log._{_e_} 4·35 = 1·47; log._{_e_} 7·4 = 2·0; antilog._{_e_} × 2·89 = 18, etc. The other parts of the scale are read as already described for common logs. Calculations involving powers of _e_ are frequently met with, and these are facilitated by using the special graduation line referred to, as will be readily understood.

If it is required to determine the power or root of a number which does not appear on either of the log.-log. scales, we may break up the number into factors. Usually it is convenient to make one of the factors a power of 10.

EX.—3950^{1·97} = 3·95^{1·97} × 10^{3 × 1·97} = 3·95^{1·97} × 10^{5·91}.

Then 3·95^{1·97} = 15, and 10^{5·91} (or antilog.) 5·91 = 812,000. Hence, 15 × 812,000 = 12,180,000 is the result sought.

Numbers which are to be found in the higher part of the log.-log. scale may often be factorised in this way, and greater accuracy obtained than by direct reading.

The form of log.-log. rule which has been mainly dealt with in the foregoing gives a scale of comparatively long range, and the only objection to the arrangement adopted is the use of a separate slide.

The Jackson-Davis Double Slide Rule.—In this instrument a pair of aluminium clips enable the log.-log. slide to be temporarily attached to the lower edge of the ordinary rule, and used, by means of a special cursor, in conjunction with the C scale of the ordinary slide. In this way both the log.-log. and ordinary scales are available without the trouble of replacing one slide by the other. Since the scale of exponents is now on the slide, the value of _x^n_ will be obtained by setting 1 on C to _x_ on E and reading the result on E under _n_ on C.

By using a pair of log.-log. slides, one in the rule and one clamped to the edge by the clips, we have an arrangement which is very useful in deducing empirical formulæ of the type _y_ = _x^n_.

The Yokota Slide Rule.—In this instrument the log.-log. scales are placed on the face of the rule, each set comprising three lines. These, for numbers greater than 1, are found above the A scale while the three reciprocal log.-log. lines are below the D scale. Both sets are used in conjunction with the C scale on the slide. Other features of this rule are:—The ordinary scales are 10 in. long instead of 25 cm. as hitherto usual; hence the logarithms of numbers can be read on the ordinary scale of inches on the edge of the rule. There is a scale of cubes in the centre of the slide and on the back of the slide there is a scale of secants in addition to the sine and tangent scales.

[Illustration: FIG. 15.]

The Faber Log.-log. Rule.—In this instrument shown in Fig. 15, the two log.-log. scales are placed on the face of the rule. One section, extending from 1·1 to 2·9, is placed above the A scale, and the other section, extending from 2·9 to 100,000, is placed below the D scale. These scales are used in conjunction with the C scale of the slide in the manner previously described. The width of the rule is increased slightly, but the arrangement is more convenient than that formerly employed, wherein the log.-log. scales were placed on the bevelled edge of the rule and read by a tongue projecting from the cursor.

[Illustration: FIG. 16.]

Another novel feature of this rule is the provision of two special scales at the bottom of the groove, to which a bevelled metal index or marker on the left end of the slide can be set. The upper of these scales is for determining the efficiency of dynamos and electric motors; the lower for determining the loss of potential in an electric circuit.

The Perry Log.-log. Rule.—In this rule, introduced by Messrs. A. G. Thornton, Limited, Manchester, the log.-log. scales are arranged as in Fig. 16, the E scale, running from 1·1 to 10,000, being placed above the A scale of the rule, and the -E or E^{–1} scale running from 0·93 to 0·0001, below the D scale of the rule. These scales are read in conjunction with the B scales on the slide by the aid of the cursor.

The following tabular statement embodies all the instructions required for using this form of log.-log. slide rule:—

When _x_ is greater than 1.

_x^n_ Set 1 on B to _x_ on E; over _n_ on B read _x^n_ on E _x_^{-_n_} Set 1 on B to _x_ on E; under _n_ on B read _x_^{-_n_} on E^{–1} _x_^{_■/■_} Set _n_ on B to _x_ on E; over 1 on B read _x_^{_■/■_} on E _x_^{_■■/■_} Set _n_ on B to _x_ on E; under 1 on B read _x_^{_■■/■_} on E^{–1}

When _x_ is less than 1.

_x^n_ Set 1 on B to _x_ on E^{–1}; under _n_ on B read _x^n_ on E^{–1} _x_^{-_n_} Set 1 on B to _x_ on E^{–1}; over _n_ on B read _x_^{-_n_} on E _x_^{_■/■_} Set _n_ on B to _x_ on E^{–1}; under 1 on B read _x_^{_■/■_} on E^{–1} _x_^{_■■/■_} Set _n_ on B to _x_ on E^{–1}; over 1 on B read _x_^{_■■/■_} on E

If 10 on B is used in place of 1 on B, read _x_^{_■/■■_} in place of _x^n_ on E, and _x_^{-_■/■■_} in place of _x_^{-_n_} on E^{–1}. If 100 on B is used, these readings are to be taken as _x_^{_■/■■■_} and _x_^{-_■/■■■_} respectively.

In rules with no -E scale the value of _x_^{-_n_} is obtained by the usual rules for reciprocals. We may either determine _x^n_ and find its reciprocal or, first find the reciprocal of _x_ and raise it to the _n_th power. The first method should be followed when the number _x_ is found on the E scale.

EX.—3·45^{–1·82} = 0·105.

Set 1 on C to 3·45 on E, and under 1·82 on C read 9·51 on C. Then set 1 on B to 9·5 on A, and under index of A read 0·105 on B.

When _x_ is less than 1 the second method is more suitable.

EX.—0·23^{–1·77} = ((1)/(0·23))^{1·77} = 4·35^{1·77} = 13·5

Set 1 on B to 0·23 on A, and under index of A read (1)/(0·23) = 4·35 on B.

Set 1 on C to 4·35 on E, and under 1·77 on C read 13·5 on E.

As with the Davis rule, the exponent scale C will be read as ■th its face value if its R.H. index (10) is used in place of 1.

SPECIAL TYPES OF SLIDE RULES.

In addition, to the new forms of log.-log. slide rules previously described, several other arrangements have been recently introduced, notably a series by Mr. A. Nestler, of Lahr (London: A. Fastlinger, Snow Hill). These comprise the “Rietz,” the “Precision,” the “Universal,” and the “Fix” slide rules.

THE RIETZ RULE.—In this rule the usual scales A, B, C, and D, are provided, while at the upper edge is a scale, which, being three times the range of the D scale, enables cubes and cube roots to be directly evaluated and also _n_^{³⁄■} and _n_^■.

A scale at the lower edge of the rule gives the mantissa of the logarithms of the numbers on D.

THE PRECISION SLIDE RULE.—In this rule the scales are so arranged that the accuracy of a 20 in. rule is obtainable in a length of 10 in. This is effected by dividing a 20 in. (50 cm.) scale length into two parts and placing these on the working edges of the rule and slide. On the upper and lower margins of the face of the rule are the two parts of what corresponds to the A scale in the ordinary rule; while in the centre of the slide is the scale of logarithms which, used in conjunction with the 50 cm. scales on the slide, is virtually twice the length of that ordinarily obtainable in a 10 in. rule. The same remark applies to the trigonometrical scales on the under face of the slide. Both the sine and tangent scales are in two adjacent lengths, while on the edge of the stock of the rule, below the cursor groove, is a scale of sines of small angles from 1° 49′ to 5° 44′. This is referred to the 50 cm. scales by an index projection on the cursor.

If C and C′ are the two parts of the scale on the slide and D and D′ the corresponding scales on the rule, it is clear that in multiplying two factors 1 on C can only be set directly to the upper scale D; while 10 on C′ can only be set directly to the lower scale D′. Hence if the first factor is greater than about 3·2, the cursor must be used to bring 1 on C to the first factor on D′. Similarly, in division, numerators and denominators which occur on C and D′ or on C′ and D cannot be placed in direct coincidence but must be set by the aid of the cursor.

Any uncertainty in reading the result can be avoided by observing the following rule: _If in setting the index_ (1 _or_ 10) _in multiplication, or in setting the numerator to the denominator in division, it is necessary to cross the slide, then it will also be necessary to cross the slide to read the product or quotient._

THE UNIVERSAL SLIDE RULE.—In this instrument the stock carries two similar scales running from 1 to 10, to which the slide can be set. Above the upper one is the logarithm scale and under the lower one the scale of squares 1 to 100. On the edge of the stock of the rule, under the cursor groove, is a scale running from 1 to 1000. An index projecting from the cursor enables this scale to be used with the scales on the face of the rule, giving cubes, cube roots, etc.

On the slide, the lower scale is an ordinary scale, 1 to 10. The centre scale is the first part of a scale giving the values of sin _n_ cos _n_, this scale being continued along the upper edge of the slide (marked "sin-cos") up to the graduation 50. On the remainder of this line is a scale running from right to left (0 to 50) and giving the value of cos^2_n_. In surveying, these scales greatly facilitate the calculations for the horizontal distance between the observer's station and any point, and the difference in height of these two points.

On the back of the slide are scales for the sines and tangents of angles. The values of the sines and tangents of angles from 34′ to 5° 44′ differ little from one another, and the one centre scale suffices for both functions of these small angles.

THE FIX SLIDE RULE.—This is a standard rule in all respects, except that the A scale is displaced by a distance $(\pi)/(4)$ so that over 1 on D is found 0·7854 on A. This enables calculations relating to the area and cubic contents of cylinders to be determined very readily.

THE BEGHIN SLIDE RULE.—We have seen that a disadvantage attending the use of the ordinary C and D scales, is that it is occasionally necessary to traverse the slide through its own length in order to change the indices or to bring other parts of the slide into a readable position with regard to the stock. To obviate this disadvantage, Tserepachinsky devised an ingenious arrangement which has since been used in various rules, notably in the Beghin slide rule made by Messrs. Tavernier-Gravêt of Paris. In this rule the C and D scales are used as in the standard rule, but in place of the A and B scales, we have another pair of C and D scales, displaced by one-half the length of the rule. The lower pair of scales may therefore be regarded as running from $10^{_n_}$ to $10^{_n_ + 1}$, and the upper pair as running from $\sqrt{(10)} \times 10^{_n_}$ to $\sqrt{(10)} \times 10^{_n_ + 1}$. With this arrangement, _without moving the slide more than half its length_, to the left or right, it is always possible to compare _all values between_ 1 _and_ 10 _on the two scales_. This is a great advantage especially in continuous working.

Another commendable feature of the Beghin rule is the presence of a reversed C scale in the centre of the slide, thus enabling such calculations as _a_ × _b_ × _c_ to be made with one setting of the slide. On the back of the slide are three scales, the lowest of which, used with the D scale, is a scale of squares (corresponding to the ordinary B scale), while on the upper edge is a scale of sines from 5° 44′ to 90°, and in the centre, a scale of tangents from 5° 43′ to 45°. On the square edge of the stock, under the cursor groove, is the logarithm scale, while on the same edge, above the cursor groove, are a series of gauge points. All these values are referred to the face scales by index marks on the cursor.

THE ANDERSON SLIDE RULE.—The principle of dividing a long scale into sections as in the Precision rule, has been extended in the Anderson slide rule made by Messrs. Casella & Co., London, and shown in Fig. 17. In this the slide carries a scale in four sections, used in conjunction with an exactly similar set of scale-lines in the upper part of the stock. On the lower part of the stock is a scale in eight sections giving the square roots of the upper values. In order to set the index of the slide to values in the stock, two indices of transparent celluloid are fixed to the slide extending over the face of the rule as shown in the illustration. As each scale section is 30 cm. in length, the upper lines correspond to a single scale of nearly 4 ft., and the lower set to one of nearly 8 ft. in length, giving a correspondingly large increase in the number of subdivisions of these scales, and consequently much greater accuracy.

In order to decide upon which line a result is to be found, sets of "line numbers" are marked at each end of the rule and slide and also on the metal frame of the cursor. In multiplication, the line number of the product is the sum of the line numbers of the factors if the left index is used, or 1 more than this sum if the right index is used. The illustration shows the multiplication of 2 by 4. The left index is set to 2 (line number, 1), and the cursor set to 4 on the slide (line number, 2); hence, as the left index is used, the result is found on line No. 3. Similar rules are readily established for division. The column of line numbers headed 0 is used for units, that headed 4 for tens, and so on; one column is given for tenths, headed –4. The square root scale bears similar line numbers, so that the square root of any value on the upper scales is found on the correspondingly figured line below.

[Illustration: FIG. 17.]

THE MULTIPLEX SLIDE RULE differs from the ordinary form of rule in the arrangement of the B scale. The right-hand section of this scale runs from left to right as ordinarily arranged, but the left-hand section runs in the reverse direction, and so furnishes a reciprocal scale. At the bottom of the groove, under the slide, there is a scale running from 1 to 1000, which is used in conjunction with the D scale, readings being referred thereto by a metal index on the end of the slide. By this means cubes, cube roots, etc., can be read off directly. Messrs. Eugene Dietzgen & Co., New York, are the makers.

THE "LONG" SLIDE RULE has one scale in two sections along the upper and lower parts of the stock, as in the "Precision" rule. The scale on the slide is similarly divided, but the graduations run in the reverse direction, corresponding to an inverted slide. Hence the rules for multiplication and division are the reverse of those usually followed (page 30). On the back of the slide is a single scale 1–10, and a scale 1–1000, giving cubes of this single scale. By using the first in conjunction with the scales on the stock, squares may be read, while in conjunction with the cube scale, various expressions involving squares, cubes and their roots may be evaluated.

HALL'S NAUTICAL SLIDE RULE consists of two slides fitting in grooves in the stock, and provided with eight scales, two on each slide, and one on each edge of each groove. While fulfilling the purposes of an ordinary slide rule, it is of especial service to the practical navigator in connection with such problems as the "reduction of an ex-meridian sight" and the "correction of chronometer sights for error in latitude." The rule, which has many other applications of a similar character, is made by Mr. J. H. Steward, Strand, London.

LONG-SCALE SLIDE RULES

It has been shown that the degree of accuracy attainable in slide-rule calculations depends upon the length of scale employed. Considerations of general convenience, however, render simple straight-scale rules of more than 20 in. in length inadmissible, so that inventors of long-scale slide rules, in order to obtain a high degree of precision, combined with convenience in operation, have been compelled to modify the arrangement of scales usually employed. The principal methods adopted may be classed under three varieties: (1) The use of a long scale in sectional lengths, as in Hannyngton's Extended Slide Rule and Thacher's Calculating Instrument; (2) the employment of a long scale laid in spiral form upon a disc, as in Fearnley's Universal Calculator and Schuerman's Calculating Instrument; and (3) the adoption of a long scale wound helically upon a cylinder, of which Fuller's and the "R.H.S." Calculating Rules are examples.

FULLER'S CALCULATING RULE.—This instrument, which is shown in Fig. 18, consists of a cylinder _d_ capable of being moved up and down and around the cylindrical stock _f_, which is held by the handle. The logarithmic scale-line is arranged in the form of a helix upon the surface of the cylinder _d_, and as it is equivalent to a straight scale of 500 inches, or 41 ft. 8 in., it is possible to obtain four, and frequently five, figures in a result.

Upon reference to the figure it will be seen that three indices are employed. Of these, that lettered _b_ is fixed to the handle; while two others, _c_ and _a_ (whose distance apart is equal to the axial length of the complete helix), are fixed to the innermost cylinder _g_. This latter cylinder slides telescopically in the stock _f_, enabling the indices to be placed in any required position relatively to _d_. Two other scales are provided, one (_m_) at the upper end of the cylinder _d_, and the other (_n_) on the movable index.

[Illustration: FIG. 18.]

In using the instrument a given number on _d_ is set to the fixed index _b_, and either _a_ or _c_ is brought to another number on the scale. This establishes a ratio, and if the cylinder is now moved so as to bring any number to _b_, the fourth term of the proportion will be found under _a_ or _c_. Of course, in multiplication, one factor is brought to _b_, and _a_ or _c_ brought to 100. The other factor is then brought to _a_ or _c_, and the result read off under _b_. Problems involving continuous multiplication, or combined multiplication and division, are very readily dealt with. Thus, calling the fixed index F, the upper movable index A, and the lower movable index B, we have for _a_ × _b_ × _c_:—Bring _a_ to F; A to 100; _b_ to A or B; A to 100; _c_ to A or B and read the product at F.

The maximum number of figures in a product is the sum of the number of figures in the factors and this results when all the factors except the first have to be brought to B. Each time a factor is brought to A, 1 is to be deducted from that sum.

For division, as _a_/(_m_ × _n_), bring _a_ to F; A or B to _m_; 100 to A; A or B to _a_; 100 to A and read the quotient at F.

[Illustration: FIG. 19.]

The maximum number of figures in the quotient is the difference between the sum of the number of figures in the numerator factors and those of the denominator factors, _plus_ 1 for each factor of the denominator and this results when A has to be set to all the factors of the denominator and all the factors of the numerator except the first brought to B. Each time B is set to a denominator factor or a numerator factor is brought to A, 1 is to be deducted.

Logarithms of numbers are obtained by using the scales _m_ and _n_ and hence powers and roots of any magnitude may be obtained by the procedure already fully explained. The instrument illustrated is made by Messrs. W. F. Stanley & Co., Limited, London.

THE "R.H.S." CALCULATOR.—In this calculator, designed by Prof. R. H. Smith, the scale-line, which is 50 in. long, is also arranged in a spiral form (Fig. 19), but in this case it is wrapped around the central portion of a tube which is about ¾in. in diameter and 9½in. long. A slotted holder, capable of sliding upon the plain portions of this tube, is provided with four horns, these being formed at the ends of the two wide openings through which the scale is read. An outer ring carrying two horns completes the arrangement.

One of the horns of the holder being placed in agreement with the first factor, and one of the horns of the ring with the second factor, the holder is moved until the third factor falls under the same horn of the ring, when the resulting fourth term will be found under the same (right or left) horn of the holder, at either end of the slot. In multiplication, 100 or 1000 is taken for the second factor in the above proportion, as already explained in connection with Fuller's rule; indeed, generally, the mode of operation is essentially similar to that followed with the former instrument.

The scale shown on one edge of the opening in the holder, together with the circular scale at the top of the spiral, enables the mantissæ of logarithms of numbers to be obtained, and thus problems involving powers and roots may be dealt with quite readily. This instrument is supplied by Mr. J. H. Steward, London.

THACHER'S CALCULATING INSTRUMENT, shown in Fig. 20, consists of a cylinder 4 in. in diameter and 18 in. long, which can be given both a rotary and a longitudinal movement within an open framework composed of twenty triangular bars. These bars are connected to rings at their ends, which can be rotated in standards fixed to the baseboard. The scale on the cylinder consists of forty sectional lengths, but of each scale-line that part which appears on the right-hand half of the cylinder is repeated on the left-hand half, one line in advance. Hence each half of the cylinder virtually contains two complete scales following round in regular order. On the lower lines of the triangular bars are scales exactly corresponding to those on the cylinder, while upon the upper lines of the bars and not in contact with the slide is a scale of square roots.

[Illustration: FIG. 20.]

By rotating the slide any line on it may be brought opposite any line in frame and by a longitudinal movement any graduation on these lines may be brought into agreement. The whole can be rotated in the supporting standards in order to bring any reading into view. As shown in the illustration, a magnifier is provided, this being conveniently mounted on a bar, along which it can be moved as required.

SECTIONAL LENGTH OR GRIDIRON SLIDE RULES.—The idea of breaking up a long scale into sectional lengths is due to Dr. J. D. Everett, who described such a gridiron type of slide rule in 1866. Hannyngton's Extended Slide Rule is on the same principle. Both instruments have the lower scale repeated. H. Cherry (1880) appears to have been the first to show that such duplication could be avoided by providing two fixed index points in addition to the natural indices of the scale. These additional indices are shown at 10′ and 100′ in Fig. 21, which represents the lower sheet of Cherry's Calculator on a reduced scale. The upper member of the calculator consists of a transparent sheet ruled with parallel lines, which coincide with the lines of the lower scale when the indices of both are placed in agreement. To multiply one number by another, one of the indices on the upper sheet is placed to one of the factors, and the position of whichever index falls under the transparent sheet is noted on the latter. Bringing the latter point to the other factor, the result is found under whichever index lies on the card. In other arrangements the inventor used transparent scales, the graduations running in a reverse direction to those of the lower scale. In this case, a factor on the upper scale is set to the other factor on the lower, and the result read at the available index.

[Illustration: FIG. 21.]

PROELL'S POCKET CALCULATOR is an application of the last-named principle. It comprises a lower card arranged as Fig. 21, with an upper sheet of transparent celluloid on which is a similar scale running in the reverse direction. For continued multiplication and division, a needle (supplied with the instrument) is used as a substitute for a cursor, to fix the position of the intermediate results. A series of index points on the lower card enable square and cube roots to be extracted very readily. This calculator is supplied by Messrs. John J. Griffin & Sons, Ltd., London.

CIRCULAR CALCULATORS.

Although the 10 in. slide rule is probably the most serviceable form of calculating instrument for general purposes, many prefer the more portable circular calculator, of which many varieties have been introduced during recent years. The advantages of this type are: It is more compact and conveniently carried in the waistcoat pocket. The scales are continuous, so that no traversing of the slide from 1 to 10 is required. The dial can be set quickly to any value; there is no trouble with tight or ill-fitting slides. The disadvantages of most forms are: Many problems involve more operations than a straight rule. The results being read under fingers or pointers, an error due to parallax is introduced, so that the results generally are not so accurate as with a straight rule. The inner scales are short, and therefore are read with less accuracy. Special scale circles are needed for cubes and cube roots. The slide cannot be reversed or inverted.

[Illustration: FIG. 22.]

[Illustration: FIG. 23.]

THE BOUCHER CALCULATOR.—This circular calculator resembles a stem-winding watch, being about 2 in. in diameter and ■/■■in. in thickness. The instrument has two dials, the back one being fixed, while the front one, Fig. 22 (showing the form made by Messrs. W. F. Stanley, London), turns upon the large centre arbor shown. This movement is effected by turning the milled head of the stem-winder. The small centre axis, which is turned by rotating the milled head at the side of the case, carries two fine needle pointers, one moving over each dial, and so fixed on the axis that one pointer always lies evenly over the other. A fine index or pointer fixed to the case in line with the axis of the winding stem, extends over the four scales of the movable dial as shown. Of these scales, the second from the outer is the ordinary logarithmic scale, which in this instrument corresponds to a straight scale of about 4¾in. in length. The two inner circles give the square roots of the numbers on the primary logarithmic scale, the smaller circle containing the square roots of values between 1 and 3·162 (= $\sqrt{(10)}$), while the other section corresponds to values between 3·162 and 10. The outer circle is a scale of logarithms of sines of angles, the corresponding sines of which can be read off on the ordinary scale.

On the fixed or back dial there are also four scales, these being arranged as in Fig. 23. The outer of these is a scale of equal parts, while the three inner scales are separate sections of a scale giving the cube roots of the numbers taken on the ordinary logarithmic scale and referred thereto by means of the pointers. In dividing this cube-root scale into sections, the same method is adopted as in the case of the square-root scale. Thus, the smallest circle contains the cube roots of numbers between 1 and 10, and is therefore graduated from 1 to 2·154; the second circle contains the cube roots of numbers between 10 and 100, being graduated from 2·154 to 4·657; while the third section, in which are found the cube roots of numbers between 100 and 1000, carries the graduations from 4·657 to 10.

What has been said in an earlier section regarding the notation of the slide rule may in general be taken to apply to the scales of the Boucher calculator. The manner of using the instrument is, however, not quite so evident, although from what follows it will be seen that the operative principle—that of variously combining lengths of a logarithmic scale—is essentially similar. In this case, however, it is seen that in place of the straight scale-lengths shown in Fig. 4, we require to add or subtract arc-lengths of the circular scales, while, further, it is evident that in the absence of a fixed scale (corresponding to the stock of the slide rule) these operations cannot be directly performed as in the ordinary form of instrument. However, by the aid of the fixed index and the movable pointer, we can effect the desired combination of the scale-lengths in the following manner. Assuming it is desired to multiply 2 by 3, the dial is turned in a backward direction until 2 on the ordinary scale lies under the fixed index, after which the movable pointer is set to 1 on the scale. As now set, it is clear that the arc-length 1–2 is spaced off between the fixed index and the movable pointer, and it now only remains to add to this definite arc-length a further length of 1–3. To do this we turn the dial still further backward until the arc 1–3 has passed under the movable pointer, when the result, 6, is read under the fixed index. A little consideration will show that any other scale length may be added to that included between the fixed and movable pointers, or, in other words, any number on the scale may be multiplied by 2 by bringing the number to the movable pointer and reading the result

under the fixed index. The rule for multiplication is now evident.

Rule for Multiplication.—_Set one factor to the fixed index and bring the pointer to 1 on the scale; set the other factor to the pointer and read the result under the fixed index._

With the explanation just given, the process of division needs little explanation. It is clear that to divide 6 by 3, an arc-length 1–3 is to be taken from a length 1–6. To this end we set 6 to the index (corresponding in effect to passing a length 1–6 to the left of that reference point) and set the pointer to the divisor 3. As now set, the arc 1–6 is included between 1 on the scale and the index, while the arc 1–3 is included between 1 on the scale and the pointer. Obviously if the dial is now turned forward until 1 on the scale agrees with the pointer, an arc 1–3 will have been deducted from the larger arc 1–6, and the remainder, representing the result of this operation, will be read under the index as 2.

Rule for Division.—_Set the dividend to the fixed index, and the pointer to the divisor; turn the dial until 1 on the scale agrees with the pointer, and read the result under the fixed index._

The foregoing method being an inversion of the rule for multiplication, is easily remembered and is generally advised. Another plan is, however, preferable when a series of divisions are to be effected with a constant divisor—_i.e._, when _b_ in (_a_)/(_b_) = _x_ is constant. In this case 1 on the scale is set to the index and the pointer set to _b_; then if any value of a is brought to the pointer, the quotient _x_ will be found under the index.

Combined Multiplication and Division, as (_a_ × _b_ × _c_)/(_m_ × _n_) = _x_, can be readily performed, while cases of continued multiplication evidently come under the same category, since _a_ × _b_ × _c_ = (_a_ × _b_ × _c_)/(1 × 1) = _x_. Such cases as _a_/(_m_ × _n_ × _r_) = _x_ are regarded as (_a_ × 1 × 1 × 1)/(_m_ × _n_ × _r_) = _x_; while (_a_ × _b_ × _c_)/(_m_) = _x_ is similarly modified, taking the form (_a_ × _b_ × _c_)/(_m_ × 1) = _x_. In all cases the expression must be arranged so that there is _one more factor in the numerator_ than _in the denominator_, _1's being introduced as often as required_. The simple operations of multiplication and division involve a similar disposition of factors, since from the rules given it is evident that _m_ × _n_ is actually regarded as (_m_ × _n_)/(1), while (_m_)/(_n_) becomes in effect (_m_ × 1)/(_n_). It is important to note the general applicability of this arrangement-rule, as it will be found of great assistance in solving more complicated expressions.

As with the ordinary form of slide rule, the factors in such an expression as (_a_ × _b_ × _c_)/(_m_ × _n_) = _x_ are taken in the order:—1st factor of numerator; 1st factor of denominator; 2nd factor of numerator; 2nd factor of denominator, and so on; the 1st factor as _a_ being set to the index, and the result _x_ being finally read at the same point of reference.

EX.—(39 × 14·2 × 6·3)/(1·37 × 19) = 134.

Commence by setting 39 to the index, and the pointer to 1·37; bring 14·2 to the pointer; pointer to 19; 6·3 to the pointer, and read the result 134 at the index.

It should be noted that after the first factor is set to the fixed index, the _pointer_ is set to each of the _dividing_ factors as they enter into the calculation, while the _dial_ is moved for each of the _multiplying_ factors. Thus the dial is first moved (setting the first factor to the index), then the pointer, then the dial, and so on.

Number of Digits in the Result.—If rules are preferred to the plan of roughly estimating the result, the general rules given on pages 21 and 25 should be employed for simple cases of multiplication and division. For combined multiplication and division, modify the expression, if necessary, by introducing 1's, as already explained, and subtract the sum of the denominator digits from the sum of numerator digits. Then proceed by the author's rule, as follows:—

Always turn dial to the LEFT; _i.e._, _against the hands of a watch_.

Note dial movements only; ignore those of the pointer.

Each time 1 on dial agrees with or passes fixed index, ADD _1 to the above difference of digits_.

Each time 1 on dial agrees with or passes pointer, DEDUCT _1 from the above difference of digits_.

Treat continued multiplication in the same way, counting the 1's used as denominator digits as one less than the number of multiplied factors.

EX.—(8·6 × 0·73 × 1·02)/(3·5 × 0·23) = 7·95 [7·95473+].

Set 8·6 to index and pointer to 3·5. Bring 0·73 to pointer (noting that 1 on the scale passes the index) and set pointer to 0·23. Set 1·02 to pointer (noting that 1 on the scale passes the pointer) and read under index 7·95. There are 1 + 0 + 1 = 2 numerator digits and 1 + 0 = 1 denominator digit; while 1 is to be added and 1 deducted as per rule. But as the latter cancel, the digits in the result will be 2 – 1 = 1.

When moving the dial to the left will cause 1 on the dial to pass _both_ index and pointer (thus cancelling), the dial may be turned back to make the setting.

It will be understood that when 1 is the _first_ numerator, and 1 on the dial is therefore set to the index, no digit addition will be made for this, as the actual operation of calculating has not been commenced.

In the Stanley-Boucher calculator (Fig. 23) a small centre scale is added, on which a finger indicates automatically the number of digits to be added or deducted; the method of calculating, however, differs from the foregoing. To avoid turning back to 0 at the commencement of each calculation, a circle is ground on the glass face, so that a pencil mark can be made thereon to show the position of the finger when commencing a calculation.

To Find the Square of a Number.— Set the number, on one or other of the square root scales, to the index, and read the required square on the ordinary scale.

To Find the Square Root of a Number.—Set the number to the index, and if there is an _odd_ number of digits in the number, read the root on the inner circle; if an even number, on the second circle.

To Find the Cube of a Number.—Set 1 on the ordinary scale to the index, and the pointer (on the back dial) to the number on one of the three cube-root scales. Then under the pointer read the cube on the ordinary scale.

To Find the Cube Root of a Number.—Set 1 to index, and pointer to number. Then read the cube root under the pointer on one of the three inner circles on the back dial. If the number has

1, 4, 7, 10 or –2, –5, etc., digits, use the inner circle. 2, 5, 8, 11 or –1, –4, etc., „ „ second circle. 3, 6, 9, 12 or –0, –3, etc., „ „ third circle.

For Powers or Roots of Higher Denomination.—Set 1 to index, the pointer to the number on the ordinary scale, and read on the outer circle on the back dial the mantissa of the logarithm. Add the characteristic (see p. 46), multiply by the power or divide by the root, and set the pointer to the mantissa of the result on this outer circle. Under the pointer on the ordinary scale read the number, obtaining the number of figures from the characteristic.

To Find the Sines of Angles.—Set 1 to index, pointer to the angle on the outer circle, and read under the pointer the _natural sine_ on the ordinary scale; also under the pointer on the outer circle of the back dial read the _logarithmic sine_.

THE HALDEN CALCULEX.—After the introduction of the Boucher calculator in 1876, circular instruments, such as the Charpentier calculator, were introduced, in which a disc turned within a fixed ring, so that scales on the faces of both could be set together and ratios established as on the slide rule. Cultriss's Calculating Disc is another instrument on the same principle. The Halden Calculex, of which half-size illustrations are given in Figs. 24 and 25, represents a considerable improvement upon these early instruments. It consists of an outer metal ring carrying a fixed-scale ring, within which is a dial. On each side of this dial are flat milled heads, so that by holding these between the thumb and forefinger the dial can be set quickly and conveniently. The protecting glass discs, which are not fixed in the metal ring but are arranged to turn therein, carry fine cursor lines, and as these are on the side next to the scales a very close setting can be made quite free from the effects of parallax. This construction not only avoids the use of mechanism, with its risk of derangement, but reduces the bulk of the instrument very considerably, the thickness being about ¼in.

On the front face, Fig. 24, the fixed ring carries an outer evenly-divided scale, giving logarithms, and an ordinary scale, 1–10, which works in conjunction with a similar scale on the edge of the dial. The two inner circles give the square roots of values on the main scales as in the Boucher calculator. On the back face, Fig. 25, the ring bears an outer scale, giving sines of angles from 6° to 90° and an ordinary scale, 1–10, as on the front face. The scales on the dial are all reversed in direction (running from right to left), the outer one consisting of an ordinary (but inverse) scale, 1–10, while the three inner circles give the cube roots of values on this inverse scale. As the fine cursor lines extend over all the scales, a variety of calculations can be effected very readily and

accurately.

[Illustration: FIG. 24.]

[Illustration: FIG. 25.]

SPERRY'S POCKET CALCULATOR, made by the Keuffel and Esser Company, New York (Fig. 26), has two rotating dials, each with its own pointer and fixed index. The S dial has an outer scale of equal parts, an ordinary logarithmic scale, and a square-root scale. The L dial has a single logarithmic scale arranged spirally, in three sections, giving a scale length of 12½in. The pointers are turned by the small milled head, which is concentric with the milled thumb-nut by which the two dials are rotated. The gearing is such that both the L dial and its pointer rotate three times as fast as the S dial and pointer. All the usual calculations can be made with the spiral scale, as with the Boucher calculator, and the result read off on one or other of the three scale-sections. Frequently the point at which to read the result is obvious, but otherwise a reference to the single scale on the S dial will show on which of the three spirals the result is to be found.

[Illustration: FIG. 26.]

The K and E Calculator, also made by the Keuffel and Esser Company, is shown in Figs. 27 and 28. It has two dials, of which only one revolves. This, as shown in Fig. 27, has an ordinary logarithmic scale and a scale of squares. There is an index line engraved on the glass of the instrument. The fixed dial has a scale of tangents, a scale of equal parts and a scale of sines, the latter being on a two-turn spiral. The pointers, which move together, are turned by a milled nut and the movable dial by a thumb-nut, as in Sperry's Calculator, Fig. 26.

[Illustration: FIG. 27.]

[Illustration: FIG. 28.]

SLIDE RULES FOR SPECIAL CALCULATIONS.

ENGINE POWER COMPUTER.—A typical example of special slide rules is shown in Fig. 29, which represents, on a scale of about half full size, the author's Power Computer for Steam, Gas, and Oil Engines. This, as will be seen, consists of a stock, on the lower portion of which is a scale of cylinder diameters, while the upper portion carries a scale of horse-powers. In the groove between these scales are two slides, also carrying scales, and capable of sliding in edge contact with the stock and with each other.

This instrument gives directly the brake horse-power of any steam, gas, or oil engine; the indicated horse-power, the dimensions of an engine to develop a given power, and the mechanical efficiency of an engine. The calculation of piston speed, velocity ratios of pulleys and gear wheels, the circumferential speed of pulleys, and the velocity of belts and ropes driven thereby, are among the other principal purposes for which the computer may be employed.

[Illustration: FIG. 29.]

THE SMITH-DAVIS PIECEWORK BALANCE CALCULATOR has two scales, 11 feet long, having a range from 1d. to £20, and marked so that they can be used either for money or time calculations. The scales are placed on the rims of two similar wheels and so arranged that the divided edges come together. The wheels are mounted on a spindle carried at each end in the bearings of a supporting stand. The wheels are pressed together by a spring, and move as one.

To set the scales one to the other, a treadle gear is arranged to take the pressure of the spring so that when the fixed wheel is held by the left hand the free wheel can be rotated by the right hand in either direction. When the amount of the balance has been set to the combined weekly wage the treadle is released locking the two wheels together, when the whole can be turned and the amounts respectively due to each man read off opposite his weekly wage. The Smith-Davis Premium Calculator is on the same principle but the scales are about 4 feet 6 inches long and the wheels spring-controlled. Both instruments are supplied by Messrs. John Davis & Son, Ltd., Derby.

THE BAINES SLIDE RULE.—In this rule, invented by Mr. H. M. Baines, Lahore, four slides carrying scales are arranged to move, each in edge contact with the next. The slides are kept in contact and given the desired relative movement one to the other, by being attached (at the back), to a jointed parallelogram. On this principle which is of general application, the inventor has made a rule for the solution of problems covered by Flamant's formula for the flow of water in cast-iron pipes:—V =

76·28_d_^{■/■}_s_^{■/■}, in which _s_ is the sine of the inclination or loss of head; _d_ the diameter of the pipe in inches and V the velocity in feet per second. The formula Q = AV is also included in the scope of the rule, Q being the discharge in cubic feet per second and A the cross sectional area of the pipe in square inches.

FARMAR'S PROFIT-CALCULATING RULE.—The application of the slide rule to commercial calculations has been often attempted, but the degree of accuracy required necessitates the use of a long scale, and generally this results in a cumbersome instrument. In Farmar's Profit-calculating Rule the money scale is arranged in ten sections, these being mounted in parallel form on a roller which takes the place of the upper scale of an ordinary rule. The roller, which is ¾in. in diameter, is carried in brackets secured to each end of the stock, so that by rotating the roller any section of the money scale can be brought into reading with the scale on the upper edge of the slide and with which the roller is in contact. This scale gives percentages, and enables calculations to be made showing profit on turnover, profit on cost, and discount. The lower scale on the slide, and that on the stock adjacent to it, are similar to the A and B scales of an ordinary rule. The instrument is supplied by Messrs. J. Casartelli & Son, Manchester.

CONSTRUCTIONAL IMPROVEMENTS IN SLIDE RULES.

The attention of instrument makers is now being given to the devising of means for ensuring the smooth and even working of the slide in the stock of the rule. In some cases very good results are obtained by slitting the back of the stock to give more elasticity.

In the rules made by Messrs. John Davis & Son, a metal strip, slightly curved in cross section as shown at A (Fig. 30), runs for the full length of the stock to which it is fastened at intervals. Near each end of the rule, openings about 1 in. long are made in the metal backing through which the scales on the back of the slide can be read. To prevent warping under varying climatic conditions both the stock of the rule and the slide are of composite construction. The base of the stock is of mahogany, while the grooved sides, firmly secured to the base, are of boxwood. Similarly the centre portion of the slide is of mahogany and the tongued sides of boxwood. Celluloid also enters into the construction, a strip of this material being laid along the bottom of the groove in the stock. A fine groove runs along the centre of this strip in order to give elasticity and to allow the sides of the stock to be pressed together slightly to adjust the fitting of the slide. As a further means of adjustment the makers fit metal clips at each end of the rule, so that by tightening two small screws the stock can be closed on the slide when necessary.

[Illustration: FIG. 30.]

[Illustration: FIG. 32.]

[Illustration: FIG. 31.]

In the rule made by the Keuffel and Esser Company of New York, one strip is made adjustable (Fig. 32).

THE ACCURACY OF SLIDE RULE RESULTS.

The degree of accuracy obtainable with the slide rule depends primarily upon the length of the scale employed, but the accuracy of the graduations, the eyesight of the operator, and, in particular, his ability to estimate interpolated values, are all factors which affect the result. Using the lower scales and working carefully the error should not greatly exceed 0·15 per cent. with short calculations. With successive settings, the discrepancy need not necessarily be greater, as the errors may be neutralised; but with rapid working the percentage error may be doubled. However, much depends upon the graduation of the scales. Rules in which one or more of the indices have been thickened to conceal some slight inaccuracy should be avoided. The line on the cursor should be sharp and fine and both slide and cursor should move smoothly or good work cannot be done. Occasionally a little vaseline or clean tallow should be applied to the edges of the slide and cursor.

That the percentage error is constant throughout the scale is seen by setting 1 on C to 1·01 on D, when under 2 is 2·02; under 3, 3·03; under 5, 5·05, etc., the several readings showing a uniform error of 1 per cent.

A method of obtaining a closer reading of a first setting or of a result on D has been suggested to the author by Mr. M. Ainslie, B.Sc. If any graduation, as 4 on C, is set to 3 on D, it is seen that 4 main divisions on C (40–44) are equal in scale length to 3 main divisions on D (30–33). Hence, very approximately, 1 division on C is equal to 0·75 of a division on D, this ratio being shown, of course, on D under 10 on C. Suppose √(4·3) to be required. Setting the cursor to 4·3 on A, it is seen that the root is something more than 2·06. Move the slide until a main division is found on C, which exactly corresponds to the interval between 2 and the cursor line, on D. The division 27–28 just fits, giving a reading under 10 on C, of 74. Hence the root is read as 2·074. For the higher parts

of the scale, the subdivisions, 1–1·1, etc., are used in place of main divisions. The method is probably more interesting than useful, since in most operations the inaccuracies introduced in making settings will impose a limit on the reliable figures of the result.

For the majority of engineering calculations, the slide rule will give an accuracy consistent with the accuracy of the data usually available. For some purposes, however, _logarithmic section paper_ (the use of which the author has advocated for the last twenty years) will be found especially useful, more particularly in calculations involving exponential formulæ.

APPENDIX.

NEW SLIDE RULES—FIFTH ROOTS, ETC.—THE SOLUTION OF ALGEBRAIC EQUATIONS—GAUGE POINTS AND SIGNS ON SLIDE RULES—TABLES AND DATA—SLIDE RULE DATA SLIPS.

THE PICKWORTH SLIDE RULE.—In this rule, made by Mr. A. W. Faber, the novel feature is the provision of a scale of cubes (F) in the stock or body of the rule. From Fig. 33 it will be seen that the scale is fixed on the bevelled side of a slotted recess in the back of the rule. The slide carries an index mark, which is seen through the slot and can be set to any graduation of the scale; in its normal position it agrees with 1 on the scale. The C scale on the face of the rule is divided into three equal parts by two special division lines, marked II. and III., which, together with the initial graduation 1 of the scale, serve for setting or reading off values on the D scale. Similar division lines are marked on the D scale.

[Illustration: FIG. 33.]

In using the rule for cubes or cube roots the slide is drawn to the right, this movement never exceeding one-third of the length of the D scale. With this limited movement, and with a single setting of the slide, the values of ■_■a_, ■(_a_ × 10), and ■(_a_ × 100)) (_a_ being less than 10 and not less than 1) are given simultaneously and without any uncertainty as to the scales to use or the values to be read off.

To Find the Cube of a Number.—The marks II. and III. on D divide that scale into three equal sections. If the number to be cubed is in the first section, I. on C is set to it; if in the second section, II. on C is set to it; if in the third section, III. on C is set to it. Then, under the index mark on the back of the slide will be found the significant figures of the cube on the scale F. If I. on C was used for the setting, the cube contains 1 digit; if II. was used, 2 digits; if III. was used, 3 digits. If the first figure of the number to be cubed is not in the units place, the decimal point is moved through _n_ places so as to bring the first significant figure into the units place, the cube found as above, and the decimal point moved in the _reverse direction_ through 3_n_ places.

To Find the Cube Root of a Number.—The index mark is set to the significant figures of the number on scale F, and the cube root is read on D under I., II. or III. on C, according as the number has 1, 2 or 3 digits preceding the decimal point. Numbers which have 1, 2 or 3 figures preceding the decimal point are dealt with directly. Numbers of any other form are brought to one of the above forms by moving the decimal point 3 places (or such multiple of 3 places as may be required), the root found and its decimal point moved 1 place for each 3-place movement, but in the _reverse direction_.

THE "ELECTRO" SLIDE RULE.—In this special rule for electrical calculations, made by Mr. A. Nestler, the upper scales run from 0·1 to 1000, and are marked "Amp." and "sq. mm." respectively. The lower scale on the slide running from 1 to 10,000 is marked M (metres), while the lower scale on the rule (0·1 to 100) is marked "Volt." The latter scale is so displaced that 10 on M agrees with 0·173 on the Volt scale. The four factors involved are the current strength (in Amp.); the area of a conductor (in sq. mm.); the length of the conductor (in metres); and the permissible loss of potential (in volts). Having given any three of these, the fourth can be found very readily. On the back of the slide are a scale of squares, a scale of cubes and a single scale corresponding to the D scale of an ordinary rule. Hence, by reversing the slide, it is possible to obtain the 2nd, 3rd and 4th powers and roots of numbers. In another form of the rule, the scale of metres is replaced by one of yards, while instead of the area of the conductor in sq. mm., the corresponding "gauge" sizes of wires are given.

THE "POLYPHASE" SLIDE RULE.—This instrument, made by the Keuffel & Esser Company, New York, has, in addition to the usual scales, a scale of cubes on the vertical edge of the stock of the rule, while in the centre of the slide there is a reversed C scale; _i.e._, a scale exactly similar to an ordinary C scale but with the graduations running from right to left. The rule is specially useful for the solution of problems containing combinations of three factors and problems involving squares, square roots, cubes, cube roots and many of the higher powers and roots. It is specially adapted for electrical and hydraulic work.

THE LOG-LOG DUPLEX SLIDE RULE.—The same makers have introduced a log-log duplex slide rule, in which the log-log scale is in three sections, placed one above the other, these occupying the position usually taken up by the A scale. These scales are used in the manner already described (page 86), but some advantage is obtained by the manner in which the complete log-log scale is divided, the limits being _e_^{1/■■■} to _e_^■ (on Scale L.L. 1); _e_^■ to _e_ (on Scale L.L. 2); and _e_ to _e_^{10} (on Scale L.L. 3), _e_ being the base of natural or hyperbolic logarithms (2·71828). In this way a total log-log range of from 1·01 to 22,000 is provided, meeting all practical requirements. These log-log scales are read in conjunction with a C scale placed at the upper edge of the slide. A similar C scale, but reversed in direction, is placed at the lower edge of the slide, this having red figures to distinguish it readily. The adjacent scale on the body of the rule is an ordinary D scale, and under this is an equally-divided scale giving the common logarithms of values on D. In the centre of the slide is a scale of tangents.

It will be understood that a "duplex" rule consists of two side strips securely clamped together at the two ends, forming the body of the rule, the slide moving between them; hence both front and back faces of the rule and slide are available, graduations on the one side being referred to those on the other by the cursor which extends around the whole. In this instrument, the scales on the back face are the ordinary scales of the standard rule with the addition of a scale of sines which is placed in the centre of the slide. It will be evident that this instrument is capable of dealing with a very wide range of problems involving exponential and trigonometrical formulæ.

SMALL SLIDE RULES WITH MAGNIFYING CURSORS.—Several makers now supply 5 in. rules having the full graduations of a 10 in. rule, and fitted with a magnifying cursor (Fig. 34). This forms a compact instrument for the pocket, but owing to the closeness of the graduations it is not usually possible to make a setting of the slide without using the cursor. This, of course, involves more movements than with the ordinary instrument. It is also very necessary to use the magnifying cursor in a _direct_ light, if accurate readings are to be obtained. If these slight inconveniences are to be tolerated, the principle could be extended, a 10 in. rule being marked as fully as a 20 in., and fitted with a magnifying cursor. The author has endeavoured, but without success, to induce makers to introduce such a rule.

The magnifying cursor, supplied by Messrs. A. G. Thornton, Limited, has a lens which fills the entire cursor. It has a powerful magnifying effect, and the change from the natural to the magnified reading is less abrupt than with the semicircular lens.

[Illustration: FIG. 34.]

THE CHEMIST'S SLIDE RULE.—A slide rule, specially adapted for chemical calculations, has been introduced recently by Mr. A. Nestler. In this instrument the C and D scales are as usually arranged; but, in place of the A and B scales, there are a number of gauge points or marks denoting the atomic and molecular weights of the most important elements and combinations. The scales on the back of the slide are similarly arranged, so that by reversing the slide the operations can be extended very considerably. The rule finds its chief use in the calculation of analyses. Thus, to find the percentage of chlorine if _s_ grammes of a substance have been used and the precipitate of Ag.Cl. weighs _a_ grammes, we have the equation, _x_ = (Cl.)/(Ag.Cl.) × (_a_)/(_s_). Hence, the mark Ag.Cl. on the upper scale of the slide is set to the mark Cl. on the upper scale of the rule, when under _a_ on the C scale is found the quantity of chlorine on D. By setting the cursor to this value and bringing _s_ on C to the cursor, the percentage required can be read on C over 10 on D.

The rule is also adapted to the solution of various other chemical and electro-chemical calculations.

THE STELFOX SLIDE RULE.—This rule, shown in Fig. 35, has a stock 5 in. long, fitted with a 10 in. slide jointed in the middle of its length by means of long dowels. By separating the parts the compactness of a 5 in. rule is obtained. The upper scales on the rule and slide resemble the usual A and B scales. The D scale on the lower part of the stock is in two sections, the second portion being placed below the first, as shown in the illustration. The centre scale on the slide corresponds to the usual C scale, while on the lower edge of the slide is a similar scale, but with the index (1) in the middle of its length. The arrangement avoids the necessity of resetting the slide, as is sometimes necessary with the ordinary rule, and in general it combines the accuracy of a 10 in. rule with the compactness of a 5 in. rule; but a more frequent use of the cursor is necessary. This rule is made by Messrs. John Davis & Son, Limited, Derby.

[Illustration: FIG. 35.]

ELECTRICAL SLIDE RULE.—Another rule by the same makers, specially useful for electrical engineers, has the usual scales on the working edges of the rule and slide, while in the middle of the slide is placed a scale of cubes. A log-log scale in two sections is

provided; the power portion, running from 1·07 to 2, is found on the lower part of the stock, and the upper portion, running from 2 to 10^3, on the upper part of the stock. The uppermost scale on the stock is in two parts, of which that to the left, running from 20 to 100 and marked "Dynamo," gives the efficiencies of dynamos; that on the right, running from 20 to 100 and marked "Motor," gives the efficiencies of electric motors. The lowest scale on the stock, marked "Volt," gives the loss of potential in copper conductors. The ordinary upper scale on the stock is marked L (length of lead) at the left, and KW (kilowatts) at the right; the ordinary upper scale on the slide is marked A (ampères) and mm^2 (sectional area) at the left, and HP (horse-power) at the right. Additional lines on the cursor enable the electrical calculations to be made either in British or metric units.

THE PICOLET CIRCULAR SLIDE RULE.—A simple form of circular calculator, made by Mr. L. E. Picolet of Philadelphia, is shown in Fig. 36. It consists of a base disc of stout celluloid on which turns a smaller disc of thin celluloid. A cursor formed of transparent celluloid is folded over the discs, and is attached so that the friction between the cursor and the inner disc enables the latter to be turned by moving the former. By holding both discs the cursor can be adjusted as required. The adjacent scales run in opposite directions, so that multiplication and division are performed as with the inverted slide in an ordinary rule. The outer scale, which is two-thirds the length of the main scale, enables cube roots to be found. Square roots are readily determined and continuous multiplication and division conveniently effected. Modified forms of this neatly made little instrument are also available.

[Illustration: FIG. 36.]

OTHER RECENT SLIDE RULES.—Among other special types of slide rule, mention should be made of the _Jakin_ 10 in. rule for surveyors, made by Messrs. John Davis & Son, Limited, Derby. By the provision of a series of short subsidiary scales, the multiplication of a sine or tangent of an angle by a number can be obtained to an accuracy of 1 in 10,000. The _Davis-Lee-Bottomley_ slide rule, by the same makers, has special scales provided for circle spacing. The division of a circle into a number of equal parts, often required in spacing rivets, bolts, etc., and in setting out the teeth of gearwheels, is readily effected by the aid of this instrument. The _Cuntz_ slide rule is a very comprehensive instrument, having a stock about 2¼ in. wide, with the slide near the lower edge. Above the slide are eleven scales, referable to the main scales by the cursor. These scales enable squares and square roots, cubes and cube roots, and areas and circumferences of circles to be obtained by direct reading. A much more compact instrument could be obtained by removing one-half the scales to the back of the rule and using a double cursor.

[Illustration: FIG. 37.]

In one form of 10 in. rule, supplied by Mr. W. H. Harling, London, the body of the rule is made of well-seasoned cane, with the usual celluloid facings. The rule has a metal back, enabling the fit of the slide to be regulated. This backing extends the full length of the rule, openings about 1 in. long being provided at each end, enabling the scales on the back of the slide to be set with greater facility than is possible with the notched recesses usually adopted. The author has long endeavoured, but without success, to induce makers to fit windows of glass or celluloid in place of the notched recesses. This would allow the graduation of the S and T scales to be set more accurately, and enable both to be used at each end of the rule—an advantage in certain trigonometrical calculations. It would have the further advantage of permitting each alternate graduation of the evenly-divided or logarithm scale to be placed at opposite sides of one central line, enabling the reading to be made more accurately and conveniently.

Many special slide rules have lately been devised for determining the time necessary to perform various machine-tool operations and for analogous purposes, while attention has again been given to rules for calculating the weights of iron and steel bars, plates, etc.

THE DAVIS-STOKES FIELD GUNNERY SLIDE RULE.—This rule, which is adapted for calculations involved in "encounter" and "entrenched" field gunnery, is designed for the 18 pr. quick-firing gun. The upper and lower portions of the boxwood stock are united by a flexible centre of celluloid, thus providing grooves front and rear to receive boxwood slides. Each of the nineteen scales is marked with its name, and corresponding scales are coloured red or black. The front edge is bevelled and carries a scale of 1 in 20,000. The rule solves displacement problems, map angles of sight, changes of corrector and range corrections for changes in temperature, wind and barometer, etc. A special feature for displacement calculations is the provision of a 50 yd. sub-base angle scale, by which the apex angle is read at one setting.

THE DAVIS-MARTIN WIRELESS SLIDE RULE.—In wireless telegraphy it is frequently necessary to determine wave-length, capacity or self-induction when one or other of the factors of the equation, $\lambda = 59{\cdot}6\sqrt{(LC)}$ is unknown. The Davis-Martin wireless rule is designed to simplify such calculations. The upper scale in the stock (inductance) runs from 10,000 to 1,000,000; the adjacent scale on the slide (capacity) runs from 0·0001 to 0·01 but in the reverse direction. The lower scale on the stock (wave-length) runs

from 100 to 1000, giving square roots of the upper scale; while on the lower edge of the scale are several arrows to suit the various denominations in which the wave-length and capacity may be expressed.

IMPROVED CURSORS.—In some slide-rule operations, notably in those involved in solving quadratic and cubic equations, it not infrequently happens that readings are obscured by the frame of the cursor. Frameless cursors have been introduced to obviate this defect. A piece of thick transparent celluloid is sometimes employed, but this is liable to become scratched in use. Fig. 37 shows a recent form of frameless glass cursor made by the Keuffel & Esser Company, Hoboken, N.J., which is satisfactory in every way.

Cursors having three hair lines are now fitted to some rules, the distance apart of the lines being equal to the interval 0·7854–1 on the A scale.

THE DAVIS-PLETTS SLIDE RULE.—In this rule a single log.-log. scale and its reciprocal scale are arranged opposite the ordinary upper log. scale. Thus, common logarithms can be read directly, while by taking advantage of the properties of characteristics and mantissas of common logarithms, the scale can be extended indefinitely. As 10 is the highest number on the log.-log. scale, it is carried down to within 0·025 of unity. The reading of log.-log. values above 10 is effected in a very simple manner. There is also a scale in the centre of the slide which, used in conjunction with the upper log. scale enables the natural logarithm of any number between 0·0001 and 10,000 to be read direct, while any number on the upper log. scale can be multiplied or divided by _e^x_ if the latter is between these limits. On the back of the slide are scales for all circular and hyperbolic functions, these being used in conjunction with the upper log. scales.

THE CROMPTON-GALLAGHER BOILER EFFICIENCY CALCULATOR has a stock in the thickness of which is a slot admitting a chart which can be moved at right angles to the two separate slides. On the bevelled edge of one slide, the graduations are continued so as to read against curves on the chart, through an opening in the stock.

THE DAVIS-GRINSTED COMPLEX CALCULATOR.—This slide rule is of considerable service in connection with calculations involving the conversion of complex quantities from the form _a_ + _j_ _b_ to the form R∠θ, and _vice versa_. The usual process of conversion necessitates repeated reference to trigonometrical tables, and is both tedious and time-taking. The Complex Calculator enables the conversions to be effected without reference to tables and with the minimum expenditure of time and labour.

The rule, which is about 16 in. long, has five scales. The upper one (A) is an ordinary logarithmic scale thrice-repeated. The adjacent scales on the slide comprise (1) a logarithmic scale of tangents (B) ranging from 0·1° to 45°, and (2) a logarithmic scale of secants (C) from 0° to 45°. The lower scales D and E are identical with the A scale, and are provided to enable multiplication, etc., to be performed without the need for a separate slide rule. Readings can be transferred from A to the lower scales by means of the cursor.

In using the rule to convert _a_ + _j_ _b_ to R∠θ, the index (45°) of the B scale is set to the larger component and the cursor to the smaller component, on scale A. Then θ (or its complement if _b_ is greater than _a_) is read on B under the cursor. The cursor is then set to θ on the C scale, and R is read on A under the cursor. The rule is made by Messrs. John Davis & Son, Limited, Derby.

THE SOLUTION OF ALGEBRAIC EQUATIONS.

The slide rule finds an interesting application in the solution of equations of the second and third degree; and although the process is essentially one of trial and error, it may often serve as an efficient substitute for the more laborious algebraic methods, particularly when the conditions of the problem or the operator's knowledge of the theory of equations enables some idea to be obtained as to the character of the result sought. The principle may be thus briefly explained:—If 1 on C is set to _x_ on D (Fig. 38), we find _x_(_x_) = _x_^2 on D under _x_ on C. If, however, with the slide set as before, instead of reading under _x_, we read under _x_ + _m_ on C, the result on D will now be _x_(_x_ + _m_) = _x_^2 + _mx_ = _q_. Hence to solve the equation _x_^2 + _mx_ – _q_ = 0, we reverse the above process, and setting the cursor to _q_ on D, we move the slide until the number on C under the cursor, and that on D under 1 on C, _differ by m_. It is obvious from the setting that the _product_ of these numbers = _q_, and as their difference = _m_, they are seen to be the roots of the equation as required. For the equation _x_^2 – _mx_ + _q_ = 0, we require _m_ to equal the _sum_ of the roots. Hence, setting the cursor as before to _q_ on D, we move the slide until the number on C under the cursor, and that on D under 1 on C, are _together equal to_ _m_, these numbers being the roots sought. The alternative equations _x_^2 – _mx_ – _q_ = 0, and _x_^2 + _mx_ + _q_ = 0 are deducible from the others by changing the signs of the roots, and need not be further considered.

[Illustration: FIG. 38.]

EX.—Find the roots of _x_^2 – 8_x_ + 9 = 0.

Set the cursor to 9 on D, and move the slide to the right until when 6·64 is found under the cursor, 1·355 on D is under 1 on C. These numbers are the roots required.

The upper scales can of course be used; indeed, in general they are to be preferred.

EX.—Find the roots of _x_^2 + 12·8_x_ + 39·4 = 0.

Set the cursor to 39·4 on A, and move the slide to the right until we read 7·65 on B under the cursor, and 5·15 on A over 1 on B. The roots are therefore –7·65 and –5.15.

With a little consideration of the relative value of the upper and lower scales, the student interested will readily perceive how equations of the third degree may be similarly resolved. The subject is not of sufficient general importance to warrant a detailed examination being made of the several expressions which can be dealt with in the manner suggested; but the author gives the following example as affording some indication of the adaptability of the method to practical calculations.

EX.—A hollow copper ball, 7·5 in. in diameter and 2 lb. in weight, floats in water. To what depth will it sink?

The water displaced = 27·7 × 2 = 55·4 cub. in. The cubic contents of the immersed segment will be (π)/(3)(3_r_ _x_^2 – _x_^3), _r_ being the radius and _x_ the depth of immersion. Hence (π)/(3)(3_r_ _x_^2 – _x_^3) = 55·4, and 11·25_x_^2 – _x_^3 = 52·9.

To solve this equation we place the cursor to 52·9 on A, and move the slide until the reading on D under 1 and that on B under the cursor together amount to 11·25. In this way find 2·45 on D under 1, with 8·8 on B under the cursor _c_, _c_, as a pair of values of which the sum is 11·25. Hence we conclude that _x_ = 2·45 in. is the result sought.

With the rule thus set (Fig. 39) the student will note that the slide is displaced to the right by an amount which represents _x_ on D, and therefore _x_^2 on A; while the length on B from 1 to the cursor line represents 11·25 – _x_. Hence the upper scale setting gives _x_^2(11·25 – _x_) = 11·25_x_^2 – _x_^3 = 52·9 as required.

[Illustration: FIG. 39.]

When in doubt as to the method to be pursued in any given case, the student should work synthetically, building up a simple example of an analogous character to that under consideration, and so deducing the plan to be followed in the reverse process.

SCREW-CUTTING GEAR CALCULATIONS.

The slide rule has long found a useful application in connection with the gear calculations necessary in screw-cutting, helical gear-cutting, and spiral gear work.

SINGLE GEARS.—For simple cases of screw-cutting in the lathe it is only necessary to set the threads per inch to be cut to the threads per inch in the guide screw (or the pitch in inches in each case, if more convenient). Then any pair of coinciding values on the two scales will give possible pairs of wheels.

EX.—Find wheels to cut a screw of 1■ threads per inch with a guide screw of 2 threads per inch.

Setting 1·625 on C to 2 on D, it is seen that 80 (driver) and 65 (driven) are possible wheels.

COMPOUND GEARS.—When wheels so found are of inconvenient size, a compound train is used, consisting (usually) of two drivers and two driven wheels, the product of the two former and the product of the two latter being in the same ratio as the simple wheels. Thus with 60 and 40 as drivers, and 65 and 30 as driven, we have, (60 × 40)/(65 × 30) = (2400)/(1950) = (2)/(1·625) as before.

With the slide set as above, values convenient for splitting up into suitable wheels are readily obtainable. Thus, (1600)/(1300); (2400)/(1950); (4000)/(3250); (4800)/(3900) are a few suggestive values which may be readily factorised.

SLIDE RULES FOR SCREW-CUTTING CALCULATIONS.—Special circular and straight slide rules for screw-cutting gear calculations have long been employed. For compound gears these usually entail the use of six scales, two on each of the two slides and two on the stock. The upper scale on the stock may be a scale of threads per inch to be cut, the adjacent scale (on the upper slide) a scale of threads per inch in the guide screw. Setting the guide screw-graduation to the threads to be cut, the lower slide is adjusted until a convenient pair of drivers is found in coincidence on the central pair of scales, while a pair of driven wheels are in coincidence on the two lower scales.

Some years ago, a slide rule was introduced by which compound gears could be obtained with a single slide. Assuming the set of wheels usually provided—20 to 120 teeth advancing by 5 teeth—the products of 20 × 25, 20 × 30, etc., up to 115 × 120 were calculated. These products were laid out along each of the two lower scales. The upper scales were a scale of threads per inch to be cut and a scale of the threads per inch of various guide screws. Setting the guide screw-graduation to the threads to be cut, any coinciding graduations on the lower scales gave the required pairs of drivers and driven wheels.

FRACTIONAL PITCH CALCULATIONS.—The author has long advocated the use of the slide rule for determining the wheels necessary for cutting fractional pitch threads, and it is gratifying to find its value in this connection is now being appreciated. For the best results a good 20 in. rule is desirable, but with care very close approximations can be found with an accurate 10 in. rule. In any case a magnifying cursor or a hand reading-glass is of great assistance.

EX.—Find wheels to cut a thread of 0·70909 in. pitch; guide screw, 2 threads per inch.

To 0·70909 on D, set 0·5 (guide screw pitch in inches) on C. To make this setting as accurately as possible, the method described on page 112 may be used. Set 10 on C to about 91 on D, and note that the interval 77–78 on C represents 0·91 of the interval 70–71 on D. Set the cursor to 78 on C and bring 5 to the cursor. The slide is then set so that 5 on C agrees with 7·091 on D.

Inspection of the two scales shows various coinciding factors in the ratio required. The most accurate is seen to be (55 on C)/(78 on D). These values may be split up into (55 × 50)/(65 × 60) to form a suitable compound train of gears.

GAUGE POINTS AND SIGNS ON SLIDE RULES.

Many slide rules have the sign (Prod.)/(–1) at the right-hand end of the D scale, while on the left is (Quot.)/(+1.) It is somewhat unfortunate that these signs refer to rules for determining the number of digits in products and quotients, which are used to a considerable extent on the Continent, and conflict with those used in this country. By the Continental method the number of digits in a product is equal to the sum of the digits in the two factors, if the result is obtained on the LEFT _of the first factor_; but if the result is found on the RIGHT of the first factor, it is equal to this sum – 1. The sign (Prod.)/(–1) the _right_-hand end of the D scale provides a visible reminder of this rule.

Similarly for division:—The number of digits in a quotient is equal to the number of the digits in the dividend, minus those in the divisor, if the quotient appears on the RIGHT _of the dividend_, and to this difference + 1, if the quotient appears on the LEFT of the dividend. The sign (Quot.)/(+1) at the _left_-hand end of the D scale provides a visible reminder of this rule.

The sign

+■– ■■■ –■+

found at both ends of the A scale is of general application but of questionable utility. It is assumed to represent a fraction, the vertical line indicating the position of the decimal point. If the number 455 is to be dealt with in a multiplication on the lower scales, we may suppose the decimal point moved two places to the left, giving 4·55, a value which can be actually found on the scale. If we use this value, then to the number of digits in this result, as many must be added as the number of places (two in this case) by which the decimal point was moved. If the point is moved to the right, the number of places must be subtracted. Similarly, in division, if the decimal point in the divisor is moved _n_ places to the left, then _n_ places must be subtracted at the end of the operation; while if the point is moved through _n_ places to the right, then _n_ places must be added. The sign referred to, which, of course, applies to all scales, completely indicates these processes and is submitted as a reminder of the procedure to be followed by those using the method described.

The signs π, _c_, _c′_, and M are explained in the Section on “Gauge Points,” p. 53.

On some rules additional signs are found on the D scale. One, locating the value $(180 \times 60)/(\pi) = 3437{\cdot}74$ and hence giving the number of minutes in a radian, is marked ρ'. Another, representing the value $(180 \times 60 \times 60)/(\pi) = 206265$, and hence giving the number of seconds in a radian is marked ρ''. A third point, marked $\rho_{■}$, placed at the value $(200 \times 100 \times 100)/(\pi) = 636620$, is used when the newer graduation of the circle is employed.

These gauge points are useful when converting angles into circular measure, or _vice versa_, and also for determining the functions of small angles.

A gauge point is sometimes marked at 1146 on the A and B scales. This is known as the "Gunner's Mark," and is used in artillery calculations involving angles of less than 20°, when, for the purpose in view, the tangent and circular measure of the angle may be regarded as equal. For this constant, the angle is taken in minutes, the auxiliary base in feet, and the base in yards. The auxiliary base in feet on B is set to the angle in minutes on A when over 1146 on B is the base in yards on A. The value $(1)/(1146) = (\pi \times 3)/(180 \times 60)$.

TABLES AND DATA.

MENSURATION FORMULAE.

Area of a parallelogram = base × height.

Area of rhombus = ½ product of the diagonals.

Area of a triangle = ½ base × perpendicular height.

Area of equilateral triangle = square of side × 0·433.

Area of trapezium = ½ sum of two parallel sides × height.

Area of any right-lined figure of four or more unequal sides is found by dividing it into triangles, finding area of each and adding together.

Area of regular polygon = (1) length of one side × number of sides × radius of inscribed circle; or (2) the sum of the triangular areas into which the figures may be divided.

Circumference of a circle = diameter × 3·1416.

Circumference of circle circumscribing a square = side × 4·443.

Circumference of circle = side of equal square × 3·545.

Length of arc of circle = radius × degrees in arc × 0·01745.

Area of a circle = square of diameter × 0·7854.

Area of sector of a circle = length of arc × ½ radius.

Area of segment of a circle = area of sector – area of triangle.

Side of square of area equal to a circle = diameter × 0·8862.

Diameter of circle equal in area to square = side of square × 1·1284.

Side of square inscribed in circle = diameter of circle × 0·707.

Diameter of circle circumscribing a square = side of square × 1·414.

Area of square = area of inscribed circle × 1·2732.

Area of circle circumscribing square = square of side × 1·5708.

Area of square = area of circumscribing circle × 0·6366.

Area of a parabola = base x ■ height.

Area of an ellipse = major axis × minor axis × 0·7854.

Surface of prism or cylinder = (area of two ends) + (length × perimeter).

Volume of prism or cylinder = area of base × height.

Surface of pyramid or cone = ½(slant height × perimeter of base) + area of base.

Volume of pyramid or cone = (■)(area of base × perpendicular height).

Surface of sphere = square of diameter × 3·1416.

Volume of sphere = cube of diameter × 0·5236.

Volume of hexagonal prism = square of side × 2·598 × height.

Volume of paraboloid = ½ volume of circumscribing cylinder.

Volume of ring (circular section) = mean diameter of ring × 2·47 × square of diameter of section.

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS.

METALS. ■■■

■■■■■■■■■■■■■■■■■■■■ π = 3·142 ■ 0·318■ 9·870■ 31·006■ 1·772■ 0·564■ 1·465■ 0·683 2π= 6·283 ■ 0·159■ 39·478■ 248·050■ 2·507■ 0·399■ 1·845■ 0·542 (π)/(2) = 1·571 ■ 0·637■ 2·467■ 3·878■ 1·253■ 0·798■ 1·162■ 0·860 (π)/(3) = 1·047 ■ 0·955■ 1·097■ 1·148■ 1·023■ 0·977■ 1·016■ 0·985 (4)/(3)π = 4·189■ 0·239■ 17·546■ 73·496■ 2·047■ 0·489■ 1·612■ 0·622 (π)/(4) = 0·785 ■ 1·274■ 0·617■ 0·484■ 0·886■ 1·128■ 0·923■ 1·084 (π)/(6) = 0·524 ■ 1·910■ 0·274■ 0·144■ 0·724■ 1·382■ 0·806■ 1·241 π^2 = 9·870 ■ 0·101■ 97·409■ 961·390■ 3·142■ 0·318■ 2·145■ 0·466 π^3 = 31·006 ■ 0·032■961·390■29,809·910■ 5·568■ 1·796■ 3·142■ 0·318 (π)/(32) = 0·098■ 10·186■ 0·0095■ 0·001■ 0·313■ 3·192■ 0·461■ 2·168 _g_ = 32·2 ■ 0·031■1036·84■ 33,386·24■ 5·674■ 0·176■ 3·181■ 0·314 2_g_ = 64·4 ■ 0·015■4147·36■ 267,090■ 8·025■ 0·125■ 4·007■ 0·249 ■■■■■■■■■■■■■■■■■■■

OBLIQUE-ANGLED TRIANGLES.

_s_ = ½(_a + b + c_)

[Illustration: [Oblique-angled Triangle]]

■■■

Volume „ „ = 0·5236 _d_^3.

„ „ cone = 0·2618 _d_^2 _h_.

Radian = (180°)/(π) = 57·29 deg.

Base of nat. or hyp. log. = e = 2·7183.

Nat. or hyp. log. = com. log. × 2·3026.

g (at London) 32·18 ft. per sec., per sec.

Abs. temp. = deg. F. + 461° = deg. C. + 274°.

C.° = (5)/(9)(F.° – 32°); F.° = (9)/(5)C.° + 32°.

Cal. pr.—Ther. units per lb.: Coal, 14,300;

petrol'm, 20,000; coal gas per cu. ft., 700.

Sp. heat:—Wt. iron, 0·1138; C.I., 0·1298;

copper, brass, 0·095; lead, 0·0314.

Inch = 25·4 mil'metres; mil'metre = 0·03937 in.

Foot = 0·3048 metres; metre = 3·2809 feet.

Yard = 0·91438 metre; metre = 1·0936 yards.

Mile = 1·6093 kilomtrs.; kilomtr. = 0·6213 mile.

Sq. in. = 6·4513 sq. cm.; sq. cm. = 0·155 sq. in.

Sq. ft. = 9·29 sq. decmtr.; sq. decmtr. = 0·1076 sq. ft.

Sq. yd. = 0·836 sq. metre; sq. metre = 1·196 sq. yds.

Sq. ml. = 258·9 hectares; hectare = 0·00386 sq. ml.

Cu. in. = 16·386 c. cm.; c. cm. = 0·06102 cu. in.

Cu. ft. = 0·0283 c. metre; c. metre = 35·316 cu. ft.

Grain = 0·0648 gramme; gram. = 15·43 grs.

Ounce = 28·35 grams.; „ = 0·03527 oz.

Pound = 0·4536 kilogm.; kilogm. = 2·204 lb.

Ton = 1·016 tonnes; tonne = 0·9842 ton.

Mile per hr. = 1·466 ft., or 44·7 cm., per sec.

Lb. per cu. in. = 0·0276 kilogram per cu. cm.

Kilogram per cu. cm. = 36·125 lb. per cu. in.

Lb. per cu. ft. = 16·019 kilogm. per cu. mtre.

Grain per gall. = 0·01426 gramme per litre.

Gramme per litre = 70·116 grains per gall.

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[Illustration: [Slide Rule]]

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[Illustration: [Centre Screw Spring Bow Half Set]]

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[Illustration: [Rope]]

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ANCIENT AND MODERN ENGINEERING

AND THE ISTHMIAN CANAL.

BY WILLIAM H. BURR, C.E.,

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INTRODUCTION.

This book is the outcome of a course of six lectures delivered at the Cooper Union in the city of New York in February and March, 1902, under the auspices of Columbia University. It seemed desirable by the President of the University that the subject-matter of the lectures should be prepared for ultimate publication. The six Parts of the book, therefore, comprise the substance of the six lectures, suitably expanded for the purposes of publication.

It may be interesting to state that the half-tone illustrations have, with scarcely an exception, been prepared from photographs of the actual subjects illustrated. All such illustrations in Parts V and VI devoted to the Nicaragua and Panama Canal routes are made from photographs at the various locations by members of the force of the Isthmian Canal Commission; they are, therefore, absolutely true representations of the actual localities to which they apply.

For other illustrations the author wishes to express his indebtedness to Messrs. G. P. Putnam's Sons, Messrs. Turneaure and Russell, John Wiley & Sons, The Morrison-Jewell Filtration Company, Mr. H. M. Sperry, Signal Engineer, _The Engineering News_, _The Railroad Gazette_, The American Society of Civil Engineers, The Standard Switch and Signal Company, The Baldwin Locomotive Works, the American Locomotive Works, Mr. Clemens Herschel, and the International Pump Company, and to others from whom the author has received courtesies which he deeply appreciates.

The classification or division of the matter of the text, and the table of contents, have been made so complete, with a view to convenience even of the desultory reader in seeking any particular subject or paragraph, that no index has been prepared, as it is believed that the table of contents, as arranged, practically supplies the information ordinarily given by a comprehensive index.

Complete and detailed treatments of the purely technical matters covered by Part II will be found in the author's "Elasticity and Resistance of Materials" and in his "Stresses in Bridge and Roof Trusses, Arched Ribs and Suspension Bridges."

W. H. B.

COLUMBIA UNIVERSITY, October 24, 1902.

CONTENTS.

PART I. _ANCIENT CIVIL-ENGINEERING WORKS._

CHAPTER I. ART. PAGE 1. Introductory 1 2. Hydraulic Works of Chaldea and Egypt 2 3. Structural Works in Chaldea and Egypt 4 4. Ancient Maritime Commerce 7 5. The Change of the Nile Channel at Memphis 8 6. The Pyramids 8 7. Obelisks, Labyrinths, and Temples 12 8. Nile Irrigation 13 9. Prehistoric Bridge-building 14 10. Ancient Brick-making 15 11. Ancient Arches 16

CHAPTER II. 12. The Beginnings of Engineering Works of Record 19 13. The Appian Way and other Roman Roads 20 14. Natural Advantages of Rome in Structural Stones 22 15. Pozzuolana Hydraulic Cement 24 16. Roman Bricks and Masonry 25 17. Roman Building Laws 27 18. Old Roman Walls 27 19. The Servian Wall 28 20. Old Roman Sewers 29 21. Early Roman Bridges 31 22. Bridge of Alcantara 35 23. Military Bridges of the Romans 35 24. The Roman Arch 36

CHAPTER III. 25. The Roman Water-supply 37 26. The Roman Aqueducts 38 27. Anio Vetus 39 28. Tepula 40 29. Virgo 40 30. Alsietina 40 31. Claudia 41 32. Anio Novus 42 33. Lengths and Dates of Aqueducts 42 34. Intakes and Settling-basins 43 35. Delivery-tanks 44 36. Leakage and Lining of Aqueducts 44 37. Grade of Aqueduct Channels 45 38. Qualities of Roman Waters 46 39. Combined Aqueducts 46 40. Property Rights in Roman Waters 46 41. Ajutages and Unit of Measurement 47 42. The Stealing of Water 49 43. Aqueduct Alignment and Design of Siphons 49

CHAPTER IV. 44. Antiquity of Masonry Aqueducts 52 45. Pont du Gard 52 46. Aqueducts at Segovia, Metz, and other Places 53 47. Tunnels 54 48. Ostia, the Harbor of Rome 56 49. Harbors of Claudius and Trajan 58

CHAPTER V. 50. Ancient Engineering Science 60 51. Ancient Views of the Physical Properties of Materials 61 52. Roman Civil Engineers Searching for Water 62 53. Locating and Designing Conduits 63 54. Siphons 64 55. Healthful Sites for Cities 65 56. Foundations of Structures 65 57. Pozzuolana and Sand 66 58. Lime Mortar 66 59. Roman Bricks according to Vitruvius 66 60. Roman Timber 67 61. The Rules of Vitruvius for Harbors 67 62. The Thrusts of Arches and Earth; Retaining-walls and Pavements 68 63. The Professional Spirit of Vitruvius 68 64. Mechanical Appliances of the Ancients 69 65. Unlimited Forces and Time 69

PART II. _BRIDGES._

CHAPTER VI. 66. Introductory 70 67. First Cast-iron Arch 70 68. Early Timber Bridges in America 71 69. Town Lattice Bridge 72 70. Howe Truss 74 71. Pratt Truss 76 72. Squire Whipple's Work 77 73. Character of Work of Early Builders 77

CHAPTER VII. 74. Modern Bridge Theory 78 75. The Stresses in Beams 79 76. Vertical and Horizontal Shearing Stresses 80 77. Law of Variation of Stresses of Tension and Compression 82 78. Fundamental Formulæ of Theory of Beams 83 79. Practical Applications 85 80. Deflection 86 81. Bending Moments and Shears with Single Load 87 82. Bending Moments and Shears with any System of Loads 89 83. Bending Moments and Shears with Uniform Loads 92 84. Greatest Shear for Uniform Moving Load 94 85. Bending Moments and Shears for Cantilever Beams 96 86. Greatest Bending Moment with any System of Loading 97 87. Applications to Rolled Beams 99

CHAPTER VIII. 88. The Truss Element or Triangle of Bracing 100 89. Simple Trusses 101 90. The Pratt Truss Type 102 91. The Howe Truss Type 105 92. The Simple Triangular Truss 106 93. Through- and Deck-Bridges 108 94. Multiple Systems of Triangulation 108 95. Influence of Mill and Shop Capacity on Length of Span 109 96. Trusses with Broken or Inclined Chords 109 97. Position of any Moving Load for Greatest Webb Stress 110 98. Application of Criterions for both Chord and Web Stresses 111 99. Influence Lines 112 100. Influence Lines for Moments both for Beams and Trusses 113 101. Influence Lines for Shears both for Beams and Trusses 115 102. Application of Influence-line Method to Trusses 118

CHAPTER IX. 103. Lateral Wind Pressure on Trusses 122 104. Upper and Lower Lateral Bracing 124 105. Bridge Plans and Shopwork 125 106. Erection of Bridges 126 107. Statically Determinate Trusses 126 108. Continuous Beams and Trusses—Theorem of Three Moments 128 109. Application to Draw- or Swing-bridges 130 110. Special Method for Deflection of Trusses 130 111. Application of Method for Deflection of Triangular Frame 133 112. Application of Method for Deflection to Truss 134 113. Method of Least Work 137 114. Application of Method of Least Work to General Problem 138 115. Application of Method of Least Work to Trussed Beam 139 116. Removal of Indetermination by Methods of Least Work and Deflection 141

CHAPTER X. 117. The Arched Rib, of both Steel and Masonry 142 118. Arched Rib with Ends Fixed 144 119. Arched Rib with Ends Jointed 144 120. Arched Rib with Crown and Ends Jointed 145 121. Relative Stiffness of Arched Ribs 145 122. General

Conditions of Analysis of Arched Ribs 146

CHAPTER XI. 123. Beams of Combined Steel and Concrete 149

CHAPTER XII. 124. The Masonry Arch 154 125. Old and New Theories of the Arch 155 126. Stress Conditions in the Arch-ring 158 127. Applications to an Actual Arch 158 128. Intensities of Pressure in the Arch-ring 162 129. Permissible Working Pressures 163 130. Largest Arch Spans 163

CHAPTER XIII. 131. Cantilever and Stiffened Suspension Bridges 166 132. Cantilever Bridges 166 133. Stiffened Suspension Bridges 168 134. The Stiffening Truss 170 135. Location and Arrangement of Stiffening Trusses 171 136. Division of Load between Cables and Stiffening Truss 173 137. Stresses in Cables and Moments and Shears in Trusses 174 138. Thermal Stresses and Moments in Stiffened Suspension Bridges 175 139. Formation of the Cables 176 140. Economical Limits of Spans 177

PART III. _WATER-WORKS FOR CITIES AND TOWNS._

CHAPTER XIV. 141. Introductory 179 142. First Steam-pumps 180 143. Water-supply of Paris and London 181 144. Early Water-pipes 181 145. Earliest Water-supplies in the United States 182 146. Quality and Uses of Public Water-supply 182 147. Amount of Public Water-supply 183 148. Increase of Daily Consumption and the Division of that Consumption 183 149. Waste of Public Water 186 150. Analysis of Reasonable Daily Supply per Head of Population 188 151. Actual Daily Consumption in Cities of the United States 189 152. Actual Daily Consumption in Foreign Cities 191 153. Variations in Rate of Daily Consumption 192 154. Supply of Fire-streams 193

CHAPTER XV. 155. Waste of Water, Particularly in the City of New York 196 156. Division of Daily Consumption in the City of New York 197 157. Daily Domestic Consumption 198 158. Incurable and Curable Wastes 199 159. Needless and Incurable Waste in City of New York 200 160. Increase in Population 200 161. Sources of Public Water-supplies 202 162. Rain-gauges and their Records 204 163. Elements of Annual and Monthly Rainfall 204 164. Hourly or Less Rates of Rainfall 207 165. Extent of Heavy Rain-storms 207 166. Provision for Low Rainfall Years 208 167. Available Portion of Rainfall or Run-off of Watersheds 209 168. Run-off of Sudbury Watershed 211 169. Run-off of Croton Watershed 211 170. Evaporation from Reservoirs 213 171. Evaporation from the Earth's Surface 215

CHAPTER XVI. 172. Application of Fitzgerald's Results to the Croton Watershed 216 173. The Capacity of the Croton Watershed 217 174. Necessary Storage for New York Supply to Compensate for Deficiency 218 175. No Exact Rule for Storage Capacity 220 176. The Color of Water 221 177. Stripping Reservoir Sites 222 178. Average Depth of Reservoirs should be as Great as Practicable 224 179. Overturn of Contents of Reservoirs Due to Seasonal Changes of Temperature 224 180. The Construction of Reservoirs 225 181. Gate-houses, and Pipe-lines in Embankments 229 182. High Masonry Dams 230

CHAPTER XVII. 183. Gravity Supplies 234 184. Masonry Conduits 234 185. Metal Conduits 236 186. General Formula for Discharge of Conduits—Chezy's Formula 237 187. Kutter's Formula 239 188. Hydraulic Gradient 241 189. Flow of Water in Large Masonry Conduits 244 190. Flow of Water through Large Closed Pipes 245 191. Change of Hydraulic Gradient by Changing Diameter of Pip 250 192. Control of Flow by Gates at Upper End of Pipe-line 251 193. Flow in Old and New Cast-iron Pipes—Tubercles 251 194. Timber-stave Pipes 253

CHAPTER XVIII. 195. Pumping and Pumps 254 196. Resistances of Pumps and Main—Dynamic Head 258 197. Duty of Pumping-engines 260 198. Data to be Observed in Pumping-engine Tests 261 199. Basis of Computations for Duty 262 200. Heat-units and Ash in 100 Pounds of Coal, and Amount of Work Equivalent to a Heat-unit 262 201. Three Methods of Estimating Duty 265 202. Trial Test and Duty of Allis Pumping-engine 265 203. Conditions Affecting Duty of Pumping-engines 266 204. Speeds and Duties of Modern Pumping-engines 266

CHAPTER XIX. 205. Distributing-reservoirs and their Capacities 267 206. System of Distributing Mains and Pipes 268 207. Diameters of and Velocities in Distributing Mains and Pipes 269 208. Required Pressures in Mains and Pipes 270 209. Fire-hydrants 270 210. Elements of Distributing Systems 270

CHAPTER XX. 211. Sanitary Improvement of Public Water-supplies 276 212. Improvement by Sedimentation 277 213. Sedimentation Aided by Chemicals 279 214. Amount of Solid Matter Removed by Sedimentation 279 215. Two Methods of Operating Sedimentation-basins 279 216. Sizes and Construction of Settling-basins 280 217. Two Methods of Filtration 281 218. Conditions Necessary for Reduction of Organic Matter 282 219. Slow Filtration through Sand—Intermittent Filtration 283 220.

Removal of Bacteria in the Filter 286 221. Preliminary Treatment—Sizes of Sand Grains 286 222. Most Effective Sizes of Sand Grains 288 223. Air and Water Capacities 288 224. Bacterial Efficiency and Purification—Hygienic Efficiency 290 225. Bacterial Activity near Top of Filter 290 226. Rate of Filtration 291 227. Effective Head on Filter 291 228. Constant Rate of Filtration Necessary 292 229. Scraping of Filters 293 230. Introduction of Water to Intermittent Filters 294 231. Effect of Low Temperature 294 232. Choice of Intermittent or Continuous Filtration 294 233. Size and Arrangement of Slow Sand Filters 295 234. Design of Filter-beds 296 235. Covered Filters 299 236. Clear-water Drain-pipes of Filters 299 237. Arrangement of the Sand at Lawrence and Albany 300 238. Velocity of Flow through Sand 302 239. Frequency of Scraping and Amount Filtered between Scrapings 303 240. Cleaning the Clogged Sand 303 241. Controlling or Regulating Apparatus 305 242. Cost of Slow Sand Filters 307 243. Cost of Operation of Albany Filter 308 244. Operation and Cost of Operation of Lawrence Filter 309 245. Sanitary Results of Operation of Lawrence and Albany Filters 310 246. Rapid Filtration with Coagulants 311 247. Operation of Coagulants 312 248. Principal Parts of Mechanical Filter-plant—Coagulation and Subsidence 313 249. Amount of Coagulant—Advantageous Effect of Alum on Organic Matter 314 250. High Heads and Rates for Rapid Filtration 315 251. Types and General Arrangement of Mechanical Filters 316 252. Cost of Mechanical Filters 318 253. Relative Features of Slow and Rapid Filtration 318

PART IV. _SOME FEATURES OF RAILROAD ENGINEERING._

CHAPTER XXI. 254. Introductory 320 255. Train Resistances 322 256. Grades 322 257. Curves 324 258. Resistance of Curves and Compensation in Grades 324 259. Transition Curves 325 260. Road-bed, including Ties 327 261. Mountain Locations of Railroad Lines 328 262. The Georgetown Loop 331 263. Tunnel-loop Location, Rhætian Railways, Switzerland 331

CHAPTER XXII. 264. Railroad Signalling 335 265. The Pilot Guard 335 266. The Train-Staff 335 267. First Basis of Railroad Signalling 336 268. Code of American Railway Association 337 268_a_. The Block 338 269. Three Classes of Railroad Signals 338 270. The Banner Signal 338 271. The Semaphore 340 272. Colors for Signalling 340 273. Indications of the Semaphore 341 274. General Character of Block System 342 275. Block Systems in Use 343 276. Locations of Signals 344 277. Home, Distant, and Advance Signals 344 278. Typical Working of Auto-controlled Manual System 345 279. General Results 348 280. Distant Signals 349 281. Function of Advance Signals 349 282. Signalling at a Single-track Crossing 350 283. Signalling at a Double-track Crossing 352 284. Signalling for Double-track Junction and Cross-over 352 285. General Observations 353 286. Interlocking-machines 354 287. Methods of Applying Power in Systems of Signalling 357 288. Train-staff Signalling 358

CHAPTER XXIII. 289. Evolution of the Locomotive 363 290. Increase of Locomotive Weight and Rate of Combustion of Fuel 365 291. Principal Parts of a Modern Locomotive 366 292. The Wootten Fire-box and Boiler 367 293. Locomotives with Wootten Boilers 370 294. Recent Improvements in Locomotive Design 372 295. Compound Locomotives with Tandem Cylinders 373 296. Evaporative Efficiency of Different Rates of Combustion 375 296_a_. Tractive Force of a Locomotive 376 297. Central Atlantic Type of Locomotive 378 298. Consolidation Engine, N. Y. C. & H. R. R. R. 379 299. P., B. & L. E. Consolidation Engine 380 300. L. S. & M. S. Fast Passenger Engine 381 301. Northern Pacific Tandem Compound Locomotive 382 302. Union Pacific Vauclain Compound Locomotive 384 303. Southern Pacific Mogul with Vanderbilt Boiler 384 304. The “Soo” Decapod Locomotive 385 305. The A., T. & S. F. Decapod, the Heaviest Locomotive yet Built 386 306. Comparison of Some of the Heaviest Locomotives in Use 389

PART V. _THE NICARAGUA ROUTE FOR A SHIP-CANAL._

307. Feasibility of Nicaragua Route 390 308. Discovery of Lake Nicaragua 390 309. Early Maritime Commerce with Lake Nicaragua 391 310. Early Examination of Nicaragua Route 392 311. English Invasion of Nicaragua 392 312. Atlantic and Pacific Ship-canal Company 392 313. Survey and Project of Col. O. W. Childs 393 314. The Project of the Maritime Canal Company 393 315. The Work of the Ludlow and Nicaragua Canal Commissions 394 316. The Route of the Isthmian Canal Commission 395 317. Standard Dimensions of Canal Prism 396 318. The San Juan Delta 397 319. The San Carlos and Serapiqui Rivers 398 320. The Rapids and Castillo Viejo 399 321. The Upper San Juan 399 322. The Rainfall from Greytown to the Lake 399 323. Lake-surface Elevation and Slope of the River 400 324. Discharges of the San Juan, San Carlos, Serapiqui 401 325. Navigation on the San Juan 401 326. The Canal Line through the Lake and Across the West Side 402 327. Character of the Country West of the Lake 403 328. Granada to Managua, thence to Corinto 404 329. General Features of the Route 404 330. Artificial Harbor at Greytown 405 331. Artificial Harbor at Brito 407 332. From Greytown Harbor to Lock No. 2 408 333. From Lock No. 2 to the Lake 409 334. Fort San Carlos to Brito 410 335. Examinations by Borings 411 336. Classification and Estimate of Quantities 412 337. Classification and Unit Prices 413 338. Curvature of the Route 413 339. The Conchuda Dam and Wasteway 414 340. Regulation of the Lake Level 417 341. Evaporation and Lockage 418 342. The Required Slope of the Canalized River Surface 419 343. All Surplus Water to be

Discharged over the Conchuda Dam 419 344. Control of the Surface Elevation of the Lake 420 345. Greatest Velocities in Canalized River 425 346. Wasteways or Overflows 427 347. Temporary Harbors and Service Railroad 427 348. Itemized Statement of Length and Cost 427

PART VI. _THE PANAMA ROUTE FOR A SHIP-CANAL._

349. The First Panama Transit Line 429 350. Harbor of Porto Bello Established in 1597 429 351. First Traffic along the Chagres River, and the Importance of the Isthmian Commerce 431 352. First Survey for Isthmian Canal Ordered in 1520 431 353. Old Panama Sacked by Morgan and the Present City Founded 431 354. The Beginnings of the French Enterprise 432 355. The Wyse Concession and the International Congress of 1870 432 356. The Plan without Locks of the Old Panama Canal Company 433 357. The Control of the Floods in the Chagres 434 358. Estimate of Time and Cost—Appointment of Liquidators 435 359. The "Commission d'Etude" 435 360. Extensions of Time for Completion 436 361. Organization of the New Panama Canal Company, 1894 437 362. Priority of the Panama Railroad Concession 437 363. Resumption of Work by the New Company—The Engineering Commission and the Comité Technique 438 364. Plan of the New Company 439 365. Alternative Plan of the New Panama Canal Company 440 366. The Isthmian Canal Commission and its Work 441 367. The Route of the Isthmian Canal Commission that of the New Panama Canal Company 441 368. Plan for a Sea-level Canal 443 369. Colon Harbor and Canal Entrance 443 370. Panama Harbor and Entrance to Canal 444 371. The Route from Colon to Bohio 445 372. The Bohio Dam 446 373. Variation in Surface Elevation of Lake 448 374. The Extent of Lake Bohio and the Canal Line in It 448 375. The Floods of the Chagres 449 376. The Gigante Spillway or Waste-weir 450 377. Storage in Lake Bohio for Driest Dry Season 451 378. Lake Bohio as a Flood Controller 452 379. Effect of Highest Floods on Current in Channel in Lake Bohio 453 380. Alhajuela Reservoir not Needed at Opening of Canal 453 381. Locks on Panama Route 454 382. The Bohio Locks 454 383. The Pedro Miguel and Miraflores Locks 454 384. Guard-gates near Obispo 455 385. Character and Stability of the Culebra Cut 455 386. Length and Curvature 456 387. Small Diversion-channels 457 388. Principal Items of Work to be Performed 457 389. Lengths of Sections and Elements of Total Cost 458 390. The Twenty Per Cent Allowances for Exigencies 459 391. Value of Plant, Property, and Rights on the Isthmus 460 392. Offer of New Panama Coal Company to Sell for $40,000,000 461 393. Annual Costs of Operation and Maintenance 462 394. Volcanoes and Earthquakes 463 395. Hygienic Conditions on the Two Routes 464 396. Time of Passage Through the Canal 465 397. Time for Completion on the Two Routes 466 398. Industrial and Commercial Value of the Canal 469 399. Comparison of Routes 471

PART I.

ANCIENT CIVIL-ENGINEERING WORKS.

CHAPTER I.

=1. Introductory.=—It is a common impression even among civil engineers that their profession is of modern origin, and it is frequently called the youngest of the professions. That impression is erroneous from every point of view. Many engineering works of magnitude and of great importance to the people whom they served were executed in the very dawn of history, and they have been followed by many other works of at least equal magnitude and under circumstances scarcely less noteworthy, of which we have either remains or records. During the lapse of the arts and of almost every process of civilization throughout the darkness of the Middle Ages there was little if any progress made in the art of the engineer, and what little was done was executed almost entirely under the name of architecture. With the revival of intellectual activity and with the development of science the value of its practical application to the growing nations of the civilized world caused the modern profession of civil-engineering to take definite shape and to be known by the name which it now carries, but which was not known to ancient peoples. Unfortunately the beginnings of engineering cannot be traced; there is no historical record running back far enough to render account of the earliest engineering works whose ruins remain as enduring evidence of what was then accomplished.

It is probably correct to state that the material progress of any people has always been concurrent with the development of the art of civil-engineering, and, hence, that the practice of civil engineering began among the people who made the earliest progress in civilization, to whom "the art of directing the Great Sources of Power in Nature for the use and convenience of man" became an early and imperative necessity. Indeed that conclusion is confirmed by the most ancient ruins of what may be termed public works that archæological investigations have revealed to us, among which are those to be found in the Chaldean region, in India, and in Egypt. Obviously, anything like a detailed account of the structural and other works of such ancient character must be lacking, as

some of them were built before even the beginnings of history. Our only data, therefore, are the remains of such works, and unfortunately they have too frequently been subject to the destructive operations of both man and nature.

=2. Hydraulic Works of Chaldea and Egypt.=—It is absolutely certain that the populous centres of prehistoric times could not have existed nor have been served with those means of communication imperatively necessary to their welfare without the practice of the art of engineering, under whatever name they may have applied to it. It is known beyond any doubt that the anciently populous and prosperous country at the head of the Persian Gulf and watered by the Euphrates and the Tigris was irrigated and served by a most complete system of canals, and the same observation can be made in reference to the valley of the Nile. It is not possible at this period of that country's history to determine to what extent irrigation was practised or how extensively the former country was served by water transportation conducted along artificial channels; but hydraulic works, including dams and sluices with other regulating appliances designed to bring waters from the rivers on to the land, were certainly among the earliest executed for the benefit of the communities inhabiting those regions. The remains of those works, spread over a large territory in the vicinity of ancient Babylon, Nippur, and other centres of population, show beyond the slightest doubt that there existed a network of water communication throughout what was in those days a country rich in agricultural products and which supported the operations of a most prosperous commerce. These canals were of ample dimensions to float boats of no mean size, although much smaller than those occupied in our larger systems of canal transportation. They were many miles in length, frequently interlacing among themselves and intersecting both the Tigris and the Euphrates. The remains of these canals, some of them still containing water, show that they must originally have been filled to depths varying from five or six to fifteen or twenty feet, and that their widths may have been twenty-five or thirty feet or more. Another curious feature is their occasional arrangement in twos and threes alongside of each other with embankments only between. The entire Euphrates-Tigris valley from the head of the Persian Gulf at least to modern Baghdad (i.e., Babylonia) and possibly to ancient Nineveh was served by these artificial waterways. Later, when Alexander the Great made one of his victorious expeditions through the Assyrian country, he found in the Tigris obstructions to the passage of his ships down-stream in the shape of masonry dams. This was between 356 and 322 B.C. These substantial dams were built across the river for the purpose of intakes to irrigating-canals for the benefit of the adjacent country. These canals, like those of Egypt, were fitted with all the necessary regulating-devices of sluices or gates, both of a crude character, but evidently sufficiently effective for their purpose.

[Illustration]

It is known that there were in those early days interchanges of large amounts and varieties of commodities, and it is almost if not quite certain that the countries tributary to the Persian Gulf not only produced sufficient grain for their own needs, but also carried on considerable commerce with the Asiatic coast. We have no means of ascertaining either the volume or the precise character of the traffic, but there is little or no doubt of its existence. It is established also that the waters of the Red Sea and the Nile were connected by a canal about 1450 B.C. Recent investigations about Nippur and other sites of ancient cities in that region confirm other indications that the practice of some branches of hydraulic engineering had received material development from possibly two to four thousand years before the Christian era.

=3. Structural Works in Chaldea and Egypt.=—The ruins of ancient buildings which have been unearthed by excavations in the same vicinity show with the same degree of certainty that the art of constructing buildings of considerable dimensions had also made material progress at the same time, and in many cases must have involved engineering considerations of a decided character both as to structural materials and to foundations. Bricks were manufactured and used. Stones were quarried and dressed for building purposes and applied so as to produce structural results of considerable excellence. Even the arch was probably used to some extent in that locality in those early days, but stone and timber beams were constantly employed. In the prehistoric masonry constructions of both the Egyptians and Chaldeans and probably other prehistoric peoples, lime or cement mortar was not employed, but came into use at a subsequent period when the properties of lime and cement as cementing materials began to be recognized. The first cementing material probably used in Egypt was a sticky clay, or possibly a calcareous clay or earth. The same material was also used in the valley of the Euphrates, but in the latter country there are springs of bitumen, where that material exudes from the earth in large quantities. The use of this asphaltic cement at times possibly involved that of sand or gravel in some of the early constructions. Later, lime mortar and possibly a weak hydraulic cement came to be employed, although there is little if any evidence of the latter material.

Iron was manufactured and used at least in small quantities, and for some structural purposes, even though in a crude manner. Bituminous or other asphaltic material was found as a natural product at various points, and its value for certain structural purposes

was well known; it was used both for waterproofing and for cement. It is practically certain that the construction of engineering works whose interesting ruins still remain involved a considerable number of affiliated engineering operations of which no evidence has yet been found, and of the employment of tools and appliances of which we have no record. So far as these works were of a public character they were constructed by the aid of a very different labor system from that now existing. The kings or ruling potentates of those early times were clothed with the most arbitrary authority, sometimes exercised wisely in the best interests of their people, but at other times the ruling motive was selfishness actuated by the most intense egotism and brutal tyranny. Hence all public works were executed practically as royal enterprises and chiefly by forced labor, perhaps generally without compensation except mere sustenance. Under such conditions it was possible to construct works on a scale out of all proportion to national usefulness and without structural economy. When it is remembered that these conditions existed without even the shadow of engineering science, it is obvious that structural economy or the adaptation of well-considered means to an end will not be found to characterize engineering operations of prehistoric times. Nevertheless there are evidences of good judgment and reasonable engineering design found in connection with some of these works, particularly with those of an hydraulic character. Water was lifted or pumped by spiral or screw machines and by water-wheels, and it is not improbable that other appliances of power served the purposes of many industrial and crude manufacturing operations which it is now impossible for us to determine.

[Illustration: FIG. 1.—Home Built on Piles in the Land of Punt.]

It is an interesting fact that while many ancient works were exceedingly massive, like the pyramids, the largest of those of which the ruins have been preserved seldom seem to show little or any evidence of serious settlement. Whether the ancients had unusually sound ideas as to the design of foundation works, or whether those only have come down to us that were founded directly upon rock, we have scarcely any means of deciding. Nor can we determine at this time what special recourses were available for foundation work on soft ground. Probably one of the earliest recognized instances, if not the earliest, of the building of structures on piles is that given by Sir George Rawlinson, when he states that a fleet of merchant vessels sent down the northeast African coast by the Egyptian queen Hatasu, probably 1700 B.C. or 1600 B.C., found a people whose huts were supported on piles in order to raise them above the marshy ground and possibly for additional safety. A representation (Fig. 1) of one of these native homes on piles is found among Egyptian hieroglyphics of the period of Queen Hatasu.

=4. Ancient Maritime Commerce.=—It is well known that both the Chaldean region and the Nile valley and delta, at least from Ethiopia to the Mediterranean Sea, were densely populated during the period of two to four or five thousand years before the Christian era. By means of the irrigation works to which reference has already been made both lands became highly productive, and it is also well known that those peoples carried on a considerable commerce with other countries, as did the Phœnicians also, at least between the innumerable wars which seemed to be the main business of states in those days. These commercial operations required not only the construction of fleets of what seem to us small vessels for such purposes, but also harbor-works at least suitable to the vessels then in use. The marine activity of the Phœnicians is undoubted, and there is strong reason to believe that there was also similar activity between Babylonian ports and those east of them along the shores of the Indian Ocean, perhaps even as far as ancient Cathay, and possibly also to the eastern coast of Africa.

Investigations in the early history of Egypt have shown that a Phœnician fleet, constructed at some Egyptian port on the Red Sea, undoubtedly made the complete circuit of Africa and returned to Egypt through the Mediterranean Sea the third year after setting out, over 2100 years (about 600 B.C.) before the historic fleet of the Portuguese explorer Vasco da Gama sailed the same circuit in the opposite direction. It is therefore probable, in view of these facts, that at least simple harbor-works of sufficient efficiency for those early days found place in the public works of the ancient kingdoms bordering upon the Mediterranean and Red seas and the Persian Gulf.

=5. The Change of the Nile Channel at Memphis.=—Although such obscure accounts as can be gathered in connection with the founding of the city of Memphis are so shadowy as to be largely legendary, it has been established beyond much if any doubt that prior to its building the reigning Egyptian monarch determined to change the course of the Nile so as to make it flow on the easterly side of the valley instead of the westerly. This was for the purpose of securing ample space for his city on the west of the river, and, also, that the latter might furnish a defence towards the east, from which direction invading enemies usually approached. He accordingly formed an immense dam or dike across the Nile as it then existed, and compelled it to change its course near the foot of the Libyan Hills on the west and seek a new channel nearer the easterly side of the valley. This must have been an engineering work of almost appalling magnitude in those early times, yet even with the crude means and limited resources of that early period, possibly, if not probably, at least 5000 B.C., the work was successfully accomplished.

=6. The Pyramids.=—Among the most prominent ancient structural works are the pyramids of Egypt, those royal tombs of which so much has been written. These are found chiefly in the immediate vicinity of Memphis on the Nile. There are sixty or seventy of them in all, the first of which was built by the Egyptian king Khufu and is known as the "Great Pyramid" or the "First Pyramid of Ghizeh." They have been called "the most prodigious of all human constructions." Their ages are uncertain, but they probably date from about 4000 B.C. to about 2500 B.C. These are antedated, however, by two Egyptian pyramidal constructions of still more ancient character whose ages cannot be determined, one at Meydoum and the other at Saccarah.

[Illustration: A Corner of the Great Pyramid.

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[Illustration: FIG. 2.—Section of the Great Pyramid.]

[Illustration: FIG. 3.]

The pyramids at Memphis are constructed of limestone and granite, the latter being the prominent material and used entirely for certain portions of the pyramids where the stone would be subjected to severe duty. The great mass of most of the pyramids consists of roughly hewn or squared blocks with little of any material properly considered mortar. The interior portions, especially of the later pyramids, were sometimes partially composed of chips, rough stones, mud bricks, or even mud, cellular retaining-walls being used in the latter cases for the main structural features. In all pyramids, however, the outer or exposed surfaces and the walls and roofs of all interior chambers were finished with finely jointed large stones, perhaps usually polished. The Great Pyramid has a square base, which was originally 764 feet on a side, with a height of apex above the surface of the ground of over 480 feet. This great mass of masonry contains about 3,500,000 cubic yards and weighs nearly 7,000,000 tons. The area of its base is 13.4 acres. The Greek historian Herodotus states that its construction required the labor of 100,000 men for twenty years. An enormous quantity of granite was required to be transported about 500 miles down the Nile from the quarries at Syene. Some of the blocks at the base are 30 feet long with a cross-section of 5 feet by 4 or 5 feet. The bulk of the entire mass is of comparatively small stones, although so squared and dressed as to fit closely together. Familiar descriptions of this work have told us that the small passages leading from the exterior to the sepulchral chambers are placed nearly in a vertical plane through the apex. The highest or king's chamber, as it is called, measures 34 feet by 17 feet and is 19 feet high, and in it is placed the sarcophagus of King Khufu. It is composed entirely of granite most exactly cut and fitted and beautifully polished. The construction of the roof is remarkable, as it is composed of nine great blocks "each nearly 19 feet long and 4 feet wide, which are laid side by side upon the walls so as to form a complete ceiling." There is a singular feature of construction of this ceiling designed to remove all pressure from it and consisting of five alternate open spaces and blocks of granite placed in vertical series, the highest open space being roofed over with inclined granite slabs leaning or strutted against each other like the letter V inverted. This arrangement relieves the ceiling of the sepulchral chamber from all pressure; indeed only the inclined highest set of granite blocks or slabs carry any load besides their own weight. There are two small ventilating- or air-shafts running in about equally inclined directions upward from the king's chamber to the north and south faces of the pyramid. These air-shafts are square and vary between 6 and 9 inches on a side. The age of this pyramid is probably not far from 5000 years.

[Illustration: Entrance to the Great Pyramid.]

The second pyramid is not much inferior in size to the Great Pyramid, its base being a square of about 707 feet on a side, and its height about 454 feet. The remaining pyramids are much inferior in size, diminishing to comparatively small dimensions, and of materials much inferior to those used in the earlier and larger pyramids.

=7. Obelisks, Labyrinths, and Temples.=—Among other constructions of the Egyptians which may be called engineering in character, as well as architectural, are the obelisks, the "Labyrinth" so called, on the shore of Lake Mœris, and the magnificent temples at the ancient capital Thebes, which are the most remarkable architectural creations probably that the world has ever known. These latter were not completed by one king, as was each of the pyramids. They were sometimes despoiled and largely wrecked by invading hosts from Assyria, and then reconstructed in following periods by successive Egyptian kings and again added to by still subsequent monarchs, whose reigns were characterized by statesmanship, success in war, and prosperity in the country. Their construction conclusively indicates laborious operations and transportation of great blocks of stone characteristic of engineering development of the highest order for the days in which they took place. The dates of these constructions are by no means well defined, but they extend over the period running from probably about 2500 B.C. to about 400 B.C., with the summit of excellence about midway between.

Another class of ancient structures which can receive but a passing notice, although it deserves more, is the elaborate rock tombs of some of the old Egyptian monarchs in the rocks of the Libyan Hills. They were very extensive constructions and contained numerous successions of "passages, chambers, corridors, staircases, and pillared halls, each further removed from the entrance than the last, and all covered with an infinite number of brilliant paintings." These tombs really constituted rock tunnels with complicated ramifications which must have added much to the difficulty of the work and required the exercise of engineering skill and resources of a high order.

[Illustration]

=8. Nile Irrigation.=—The value of the waters of the Nile for irrigation and fertilization were fully appreciated by the ancient Egyptians. They also apparently realized the national value of some means of equalizing the overflow, although the annual régimen of the Nile was unusually uniform. There were, however, periods of great depression throughout the whole Nile valley consequent upon the phenomenal failure of overflow to the normal extent. One of the earliest monarchs who was actuated by a fine public spirit undertook to solve the problem of providing against such depressions by diverting a portion of the flood-waters of the Nile into an enormous reservoir, so that during seasons of insufficient inundation the reservoir-waters could be drawn upon for the purpose of irrigation. This monarch is known as the good Amenemhat, although the Greeks call him Mœris. In the Nile valley, less than a hundred miles above Memphis, on the left side or to the west of the river, there is a gap in the Libyan Hills leading to an immense depression, the lower parts of which are much below the level of the water in the Nile. This topographical depression, perhaps 50 miles in length by 30 in breadth, with an area between 600 and 700 square miles, now contains two bodies of water or lakes, one known as the Birket Keroun and the other as Lake Mœris. The vicinity of this depression is called the Fayoum. A narrow rocky gorge connects it with the west branch of the Nile, known as Bahr el Yousuf, and it is probable that during extreme high water in the Nile there was a natural overflow into the Fayoum. The good Amenemhat, with the judgment of an engineer, or guided by advisers who possessed that judgment, appreciated the potential value of this natural depression as a possible reservoir for the surplus Nile waters and excavated a channel, possibly a natural channel enlarged, of suitable depth from it to the Bahr el Yousuf. As a consequence he secured a storage-reservoir of enormous capacity and which proved of inestimable value to the lowlands along the Nile in times of shortage in the river-floods.

Investigators have differed much in their conclusions as to the extent of this reservoir. Some have maintained that only the lower depressions of the Fayoum were filled for reservoir purposes, while others, like Mr. Cope Whitehouse, believe that the entire depression of the Fayoum was utilized with the exception of a few very high points, and that the depth of water might have been as much as 300 feet in some places. In the latter case the circuit of the lake would have been from 300 to 500 miles. Whatever may have been the size of the lake, however, its construction and use with its regulating-works was a piece of hydraulic engineering of the highest type, and it indicates an extraordinary development of that class of operations for the period in which it was executed. The exact date of this construction cannot be determined, but it may have been as early as 2000 B.C., or perhaps earlier.

=9. Prehistoric Bridge-building.=—The development of the art of bridge-building seems to have lagged somewhat in the prehistoric period. The use of rafts and boats prevented the need of bridges for crossing streams from being pressing. It is not improbable that some small and crude pile or other timber structures of short spans were employed, but no remains of this class of construction have been found. Large quantities of timber and much of an excellent quality were used in the construction of buildings. That much is known, but there is practically no evidence leading to the belief that timber bridges of any magnitude were used by prehistoric people. It is highly probable that single-timber-beam crossings of small streams were used, but that must be considered the limit of ancient bridging until other evidence than that now available is found.

=10. Ancient Brick-making.=—It has already been seen that stone as a building material has been used since the most ancient periods, and the use of brick goes back almost as far. Fortunately it was frequently a custom of the ancient brick-makers to stamp proprietary marks upon their bricks, and we know by these marks that bricks were made in the Chaldean regions certainly from 3000 to 4000 years before the Christian era. In Egypt also the manufacture of brick dates back nearly or quite as far. Some of these Chaldean bricks, as well as those in other parts of the ancient world, were of poor quality, readily destroyed by water or even a heavy storm of rain when driving upon them. Other bricks, however, were manufactured of good quality of material and by such methods as to produce results which compare favorably with our modern building-bricks. The ruins of cities, at least in Assyria and Chaldea, show that enormous buildings, many of them palaces of kings, were constructed largely of these bricks, although they were elaborately decorated with other material. The walls were heavy, indeed so massive that many of the ruin-mounds are frequently formed almost entirely of the disintegrated brick of poorer quality. These old builders not only executed their work on a

large scale, but did not hesitate to pile up practically an artificial mountain of earth, or other suitable material, on which to construct a palace or temple. The danger of water to these native bricks was so well known and recognized that elaborate and very excellent systems of subsurface drains or sewers were frequently constructed to carry off the storm-water as fast as it fell.

=11. Ancient Arches.=—In the practice of these building operations it became necessary to form many openings and to construct roofs for the sewers or drains, and the arch, both true and false, came to be used in the Euphrates valley, in that of the Nile, and in other portions of the ancient world. Pointed sewer-arches of brick have been found in what is supposed to be the palace of Nimrod on the Tigris River, possibly of the date about 1300 B.C. Excavations at Nippur have revealed a mud-brick pointed arch supposed to date back to possibly 4000 B.C. Also semicircular voussoir arches have been discovered at the ruins of Khorsabad near Nineveh with spans of 12 to 15 feet. These arches are supposed to belong to the reign of Sargon, an Assyrian king who flourished about 705 to 722 B.C. Again, the ancient so-called treasury of Atreus at Mycenæ in Greece, although a dome, exhibits an excellent example of the method of forming the false arch, the date of the construction being probably about 1000 B.C. The main portion of this structure consists of a pointed dome, the diameter of the base being 48 feet and the interior central height 49 feet. A central section shows a beehive shape, as in Fig. 6.

[Illustration: VAULTED DRAIN, KHORSABAD FIG. 4.]

[Illustration: VAULTED DRAINS, KHORSABAD. FIG. 5.]

The exterior approach is between two walls 20 feet apart, the intermediate entrance to the dome or main chamber being a passage 9 feet 6 inches wide at the bottom and 7 feet 10 inches at the top and about 19 feet high. At right angles to the entrance there is a chamber 27 feet by 20 feet cut into the adjacent rock, entered through a doorway about 4 feet 6 inches wide and 9 feet 6 inches high. Both the main entrance to the dome and the doorway to the adjacent chamber are covered or roofed with large flat lintel-stones, over which are the triangular relieving (false) arches, so common in ancient construction, by which the lintels are relieved of load, the triangular openings being closed by single, great upright flat stones. There are a considerable number of these in Greece. The stone used is a "hard and beautiful breccia" from the neighboring hills and Mount Eubora near by. The courses of stone are about two feet thick and closely fitted without cement.

[Illustration: FIG. 6.—Plan and Section of the Treasury of Atreus at Mycenæ.]

1. Plan of the Treasury of Atreus: _A_, rock-cut chamber, probably a tomb; _B_, doorway; _C_, approach.

2. Section of the above: _B_, doorway; _C_, approach filled up with earth; _D_, slope of the ground; _E_, wall on north side of approach; _F_, lintel stone, weight 133 tons; _G_, door to rock-cut chamber.

The great majority, or perhaps all, of the Assyrian true arches, so far discovered, are formed of wedge-shaped bricks, most of them being semicircular, although some are pointed, the span being not over about 15 feet. The most of the arches found at Nineveh and Babylon belong to a period reaching possibly from 1300 to 800 B.C., but some of the Egyptian arches are still older. Egyptians, Assyrians, Greeks, and other ancient people used false arches formed by projecting each horizontal course of stones or bricks over that below it on either side of an opening. The repetition of this procedure at last brings both sides of the opening together at the top of the arch, and they are surmounted at that point with a single flat stone, brick, or tile. It has been supposed by some that these false arches, whose sides may be formed either straight or curved, exhibit the oldest form of the arch, and that the true arch with its ring or rings of wedge-shaped voussoirs was a subsequent development. It is possible that this is true, but the complete proof certainly is lacking. In Egypt and Chaldea both styles of arches were used concurrently, and it is probably impossible to determine which preceded the other. Again, some engineers have contended that two flat slabs of stone leaning against each other, each inclined like the rafters of a roof, was the original form of the arch, as found in the pyramids of Egypt; but it is probable that the true arch was used in Chaldea prior to the time of the pyramids. Indeed crude arches of brick have been found at Thebes in Egypt dating back possibly to 2500 B.C., or still earlier. Aside from that, however, such an arrangement of two stones is not an arch at all, either true or false. The arrangement is simply a combination of two beams. A condition of stress characteristic of that in the true arch is lacking.

The ancient character of the engineering works whose ruins are found in Chaldea and Assyria is shown by the simple facts that Babylon was destroyed about the year 690 B.C. and Nineveh about the year 606 B.C.

CHAPTER II.

=12. The Beginnings of Engineering Works of Record.=—In a later period of the world's history we reach a stage in the development of engineering works of which we have both records and remains in such well-defined shape that the characteristics of the profession may be realized in a definite manner. This is particularly true of the civil-engineering works of the Romans. In their sturdy and unyielding character, with their limitless energy and resolution, the conditions requisite for the execution of engineering works of great magnitude are found. An effeminate or generally æsthetic nation like the Greeks would furnish but indifferent opportunity for the inception and development of great engineering works, but the resolute and vigorous Roman nation offered precisely the conditions needed. They appreciated among other things the absolute necessity of the freest possible communication with the countries which they conquered and made part of their own empire. They recognized water transportation as the most economical and effective, and used it wherever possible. They also realized the advantages of roads of the highest degree of solidity and excellence. No other roads have ever been constructed so direct, so solid, and so admirably adapted to their purposes as those built by the Romans. They virtually ignored all obstacles and built their highways in the most direct line practicable, making deep cuts and fills with apparently little regard for those features which we consider obstacles of sufficient magnitude to be avoided. They regarded this system of land communication so highly that they made it radiate from the Golden Mile-stone in the Roman Forum. The point from which radiated these roads was therefore in the very centre of Roman life and authority, and it fitly indicated the importance which the Roman government gave to the system of communication that bound together with the strongest bonds all parts of the republic and of the empire.

The design and construction of these roads must have been a matter to which their constructors gave the most careful attention and study. They were works involving principles deduced from the most careful thought and extended experience. There were incorporated in them the most effective materials of construction then known, and it was evidently the purpose of their constructors that they should possess indefinite endurance. The existence of some of them at the present time, with no other attention given to them than required for ordinary maintenance, demonstrates that the confidence of the builders was not misplaced.

[Illustration: Street Fountain and Watering-trough in Pompeii. Called the Fountain of Plenty, from the figure with Horn of Plenty on the perforated upright post.]

=13. The Appian Way and other Roman Roads.=—Probably the oldest and most celebrated of these old Roman roads is the Appian Way. It was the most substantially built, and the breadth of roadway varied from 14 to 18 feet exclusive of the footwalks. Statius called it the Queen of Roads. It was begun by Appius Claudius Cæcus, 312 years before the Christian era. He carried its construction from the Roman gate called Porta Capena to Capua, but it was not entirely completed till about the year 30 B.C. Its total length was three hundred and fifty miles, and it formed a perfect highway from Rome to Brundisium, an important port on what may be called the southeastern point of Italy. It was built in such an enduring manner that it appears to have been in perfect repair as late as 500 to 565 A.D.

The plan of construction of these roads was so varied as to suit local conditions, but only as required by sound engineering judgment. They wisely employed local materials wherever possible, but did not hesitate to transport proper material from distant points wherever necessary. This seemed to be one of their fundamental principles of road construction. In this respect the old Romans exhibited more engineering and business wisdom than some of the American states in the beginnings of improved road construction in this country. An examination of the remains of some Roman roads now existing appears to indicate that in earth the bottom of the requisite excavation was first suitably compacted, apparently by ramming, although rollers may have been used. On this compacted subgrade were laid two or three courses of flat stones on their beds and generally in mortar. The second layer placed on the preceding was rubble masonry of small stones or of coarse concrete. On the latter was placed the third layer of finer concrete. The fourth or surface course, consisting of close and nicely jointed polygonal blocks, was then put in place, and formed an excellent unyielding pavement. This resulted in a most substantial roadway, sometimes exceeding 3 feet in total thickness. It is difficult to conceive of a more substantial and enduring type of road construction. The two lower layers were omitted when the road was constructed in rock. Obviously the finer concrete constituting the second layer from the top surface was a binder between the pavement surface and the foundation of the roadway structure.

The paved part of a great road was usually about 16 feet in width, and raised stone causeways or walls separated it from an unpaved way on each side having half the width of the main or paved portion. This seemed to be the type of the great or main Roman roads. Other highways of less important character were constructed of inferior materials, earth or clay sometimes being used instead of mortar; but in such cases greater crowning was employed, and the road was more elevated, possibly for better drainage. Then, as now, adequate drainage was considered one of the first features of good road design. City streets were paved with the nicely jointed polygonal blocks to which reference has already been made, while the footways were paved with rectangular

slabs much like our modern sidewalks.

[Illustration: EXAMPLE OF EARLY BASALT ROAD.

BY THE TEMPLE OF SATURN ON THE CLIVUS CAPITOLINUS.

FIG. 7.]

The smooth polygonal pavements of the old Romans put to the keenest shame the barbarous cobblestone street surfaces with which the people of American cities have been and are still so tortured.

The beneficial influence of these old Roman highways has extended down even to the present time in France, where some of them were built. The unnecessarily elaborate construction has not been followed, but the recognition of the public benefits of excellent roads has been maintained. The lower course of the foundation-stones apparently began to be set on edge toward the latter part of the eighteenth century, the French engineer Tresaguet having adopted that practice in 1764. At the same time he reduced the thickness of the upper layers. His methods were but modifications of the old Roman system, and they prevailed in France until the influence of the English engineers Macadam and Telford began to be felt.

=14. Natural Advantages of Rome in Structural Stones.=—Although the ancient Romans were born engineers, possessing the mental qualities and sturdy character requisite for the analytic treatment and execution of engineering problems, it is doubtful whether they would have attained to such an advanced position in structural matters had not the city of Rome been so favorably located.

The geological character of the great Roman plain and the Roman hills certainly contributed most materially to the early development of some of the most prominent of the Roman engineering works. The plain surrounding the city of Rome is composed largely of alluvial and sandy deposits, or of the emissions of neighboring volcanoes, of which the Alban Hills form a group. While these and other volcanic hills in the vicinity are, and have been for a long period, quiescent, they were formerly in a very active state. The scoriæ, or matter emitted in volcanic eruptions, is found there in all possible degrees of coherence or solidity, from pulverulent masses to hard rock. The characteristic Roman material called tufa is a mixture of volcanic ash and sand, loose and friable, as dropped from the eruptions in large quantities or again compressed into masses with all degrees of hardness. The hard varieties of yellow or brown tufa form building material much used, although a considerable percentage of it would not be considered fit building material for structures of even moderate height at the present time. The most of it weathers easily, but forms a fairly good building-stone when protected by a coating of plaster or stucco.

Another class of building-stones found at or in the vicinity of Rome is the so-called “peperino,” consisting chiefly of two varieties of conglomerate of ash, gravel, broken pieces of lava, and pieces of limestone, some possessing good weathering qualities, while others do not. Ancient quarries of these stones exist whence millions of cubic yards have been removed, and are still being worked. The better varieties of “peperino” possess good resisting qualities, and were much used in those portions of masonry construction where high resistance was needed, as in the ring-stones of arches, heavily loaded points of foundations, and other similar situations.

Some of the prehistoric masonry remains of the Romans show that their earliest constructors appreciated intelligently the qualities of this stone for portions of works where the duty was most severe.

Lava from the extinct volcanoes of the Alban Hills called “silex” was used for paving roads and for making concrete. It was hard and of gray color. At times considerable quantities of this stone were employed. A species of pure limestone called “travertine,” of a creamy white color, was quarried at Tibur or Tivoli, and began to be used about the second century B.C. Vitruvius speaks of its having good weathering qualities, but naturally it is easily calcined. Its structure is crystalline, and it is strong in consequence of that quality only when it is laid on its bed.

=15. Pozzuolana Hydraulic Cement.=—The most valuable of all building materials of old Rome was the “pozzuolana,” as it furnished the basis of a strong, enduring, and economic concrete, and permitted almost an indefinite development of masonry construction. Had there not been at Rome the materials ready at hand to be manufactured into an excellent cementing product, it is highly probable that neither the structural advance nor the commercial supremacy of the Roman people could have been attained. It is at least certain that the majority of the great masonry works constructed by the Romans could not have been built without the hydraulic cementing material produced with so little difficulty and in such large quantities from the volcanic earth called pozzuolana.

The name is believed to have its origin from the large masses of this material at Pozzuoli near Naples. Great beds are also found at and near Rome. The earliest date of its use cannot be determined, but it has given that strong and durable character to Roman concrete which has enabled Roman masonry to stand throughout centuries, to the admiration of engineers.

It is a volcanic ash, generally pulverulent, of a reddish color, but differs somewhat in appearance and texture according to the locality from which it is taken. It consists chiefly of silicate of alumina, but contains a little oxide of iron, alkali, and possibly other components. The Romans therefore pulverized the pozzuolana and mixed it with lime to make hydraulic cement. This in turn was mixed with sand and gravel and broken stone to form mortar and concrete, and that process is carried on to this day. The concrete was hand-mixed, and treated about as it is at present. After having been well mixed the Romans frequently deposited it in layers of 6 to 9 or 10 inches thick, and subjected it to ramming. In connection with this matter of mortar and concrete production, Vitruvius observes that pit-sand is preferable to either sea or river sand.

=16. Roman Bricks and Masonry.=—The Romans produced bricks both by sun-baking and by burning, although there are now remaining apparently no specimens of the former in Rome. Bricks were used very largely for facing purposes, such as a veneer for concrete work. The failure to recognize this fact has led some investigators and writers into error. As matter of fact bricks were used as a covering for concrete work, the latter performing all the structural functions.

The old Roman aqueducts were frequently lined with concrete, made of a mixture of pozzuolana, lime, and crushed (pounded) bricks or potsherds. The same material was also used for floors under the fine mortar in which the mosaics were imbedded.

Marble came into use in Rome about 100 B.C., from Luna, near modern Carrara, Mt. Hymettus, and Mt. Pentelicus, near Athens and the Isle of Paros, nearly all being for sculpture purposes. Colored and structural marbles were brought from quarries in various parts of Italy, Greece, Phrygia, Egypt, near Thebes (oriental alabaster or “onyx”), Arabia, and near Damascus.

From the latter part of the first century B.C. the hard building-stones like granites and basalts were brought to Rome in large quantities. Most of the granites came from Philæ on the Nile. The basalts came both from Lacedæmonia and Egypt. Both emery (from the island of Naxos in the Ægean Sea) and diamond-dust drills were used in quarrying or working these stones. Ships among the largest, if not the largest, of those days, were built to transport obelisks and other large monoliths.

The quality of ancient Roman mortar varies considerably as it is now found. That of the first and second centuries is remarkably hard, and made with red pozzuolana. In the third century it began to be inferior in quality, brown pozzuolana sometimes being used. The reason for this difference in quality cannot be confidently assigned. The deterioration noted in the third century work may be due to the introduction of bad materials, or to the wrong manipulation of material intrinsically good, or it is not unlikely the deterioration is due to a combination of these two influences. The use of mortar indicates a class of early construction; it is found in the Servian wall on the Aventine, of date 700 B.C., or possibly earlier.

[Illustration: Dovetail Wooden Tenon. Wooden Dowel. FIG. 8.]

Under the empire (27 B.C. to A.D. 475) large blocks of tufa, limestone (travertine), or marble were set with very close joints, with either no mortar or, if any, as thin as paper; end, top, and bottom clamps of iron were used to bond such stones together. It was also customary, in laying such large, nicely finished blocks of stone without mortar, to use double dovetailed wooden ties, or, as in the case of columns, a continuous central dowel of wood, as shown in the figures.

The joints were frequently so close as to give the impression that the stones might have been fitted by grinding together. In rectangular dimension stonework (ashlar) great care was taken, as at present, to secure a good bond by the use of judiciously proportioned headers and stretchers. Foundation courses were made thicker than the body of the superincumbent wall, apparently to distribute foundation weights precisely as done at present. Weaker stone was used in thicker portions of walls, and strong stone in thinner portions. Also at points of concentrated loading, piers or columns of strong stone are found built into the bodies of walls of softer or weaker stone. Quarry chips, broken lava, broken bricks, or other suitable refuse fragments were used for concrete in the interest of economy, the broken material always being so chosen as to possess a sharp surface to which the cement would attach itself in the strongest possible bond.

At the quarries where the stones were cut the latter were marked apparently to identify their places in the complete structure, or for other purposes. The remains of the quarries themselves as seen at present are remarkable both for their enormous extent and for the system on which the quarrying was conducted. It appears that the systems employed were admirably adapted to the character of the stone worked, and that the quarrying operations were executed as efficiently and with as sound engineering judgment as

those employed in great modern quarries.

=17. Roman Building Laws.=—So much depended upon the excellence of the building in Rome, and upon the materials and methods employed, that building laws or municipal regulations were enacted in the ancient city, prescribing kind and quality of material, thickness of walls, maximum height of buildings, minimum width of streets, and many other provisions quite similar to those enacted in our modern cities. The differences appear to arise from the different local conditions to be dealt with, rather than from any failure on the part of the old Romans to reach an adequate conception of the general plans suitable for the masses of buildings in a great city. Prior to the great fire A.D. 64 in Nero's reign, an act prescribing fire-proof exterior coverings of buildings was under consideration, and subsequently to that conflagration it was enacted into law. Many of the city roads or streets were paved with closely fitting irregular polygonal blocks of basalt, laid on concrete foundations, and with limestone (travertine) curbs and gutters, producing an effect not unlike our modern streets.

=18. Old Roman Walls.=—In no class of works did the ancient Romans show greater engineering skill or development than in the massive masonry structures that were built not only in and about the city of Rome, but also in distant provinces under Roman jurisdiction. Among the home structures various walls, constituting strong defences against the attacks of enemies, stand in particular prominence. Some of these great structures had their origin prior even to historic times. The so-called "Wall of Romulus," around the famous Roma Quadrata of the Palentine, is among the latter. It is supposed by many that this wall formed the primitive circuit of the legendary city of Romulus. That, however, is an archæological and not an engineering question, and, whatever its correct answer may be, the wall itself is a great engineering work; it demonstrates that the early Romans, whatever may have been their origin, had attained no little skill in quarrying and in the building of dry masonry, no mortar being used in this ancient wall. Portions of it 40 feet high and 10 feet thick at bottom, built against a rocky hill, are still standing. The courses are 22 to 24 inches thick, and they are laid as alternate headers and stretchers; the lengths of the blocks being 3 to 5 feet, and the width from 19 to 22 inches. The ends of the blocks are carefully worked and true, as are the vertical joints in much of the wall, although some of the latter, on the other hand, are left as much as 2 inches open.

Civil engineers, who are familiar with the difficulties frequently experienced in laying up dry walls of considerable height, as evidenced by many instances of failure probably within the knowledge of every experienced engineer, will realize that this great dry masonry structure must have been put in place by men of no little engineering capacity. The rock is soft tufa, and marks on the blocks indicate that chisels from ¼ to ¾ inch in width were used, as well as sharp-pointed picks. In all cases the faces of the blocks were left undressed, i.e., in modern terms they were "quarry-faced."

=19. The Servian Wall.=—Later in the history of Rome the great Servian Wall, built chiefly by Servius Tullius to enclose the seven hills of Rome, occupies a most prominent position as an engineering work. Part of the wall, all of which belongs to the regal period (753 to 509 B.C.), is supposed to be earlier than Servius, and may have been planned and executed by Tarquinius Priscus. A part only of the stones of this wall were laid in cement mortar, and concrete was used, to some extent at least, in its foundation and backing. The presence of cement mortar in this structure differentiates it radically from the wall of Romulus. Probably the discovery of pozzuolana cement, and the fabrication of mortar and concrete from it, had been made in the intervening period between the two constructions. Tufa, usually the softer varieties but of varying degrees of hardness, was mostly used in this wall, and the blocks were placed, as in the previous instance, as alternate headers and stretchers in courses about two feet thick. Portions of the wall 45 feet high and about 12 feet thick have been uncovered. At points it was pierced with arched openings of 11 feet 5 inches span, possibly as embrasures for catapults or other engines of war. The upper parts of these openings are circular arches with the usual wedge-like ring-stones. The voussoirs were cut from peperino stone. This wall, like that of Romulus, was constructed as a military work of defence, and at some points it was built up from the bottom of a wide foss 30 feet deep. At such places it was counterforted or buttressed, a portion of wall 11 feet 6 inches long being found between two counterforts, each of the latter being 9 feet wide and projecting 7 feet 9 inches out from the wall.

[Illustration: FIG. 9.—Part of Servian Wall on Aventine.]

[Illustration: FIG. 10.—Wall and Agger of Servius.]

=20. Old Roman Sewers.=—It is demonstrable by the writings of Vitruvius and others that the old Romans, or at any rate the better educated of them, possessed a correct general idea of some portions of the science of Sanitary Engineering, so far as anything of the nature of science could then be known. Their sanitary views were certainly abreast of the scientific knowledge of that early day. The existence of the "cloacæ," or great sewers, of the ancient city of Rome showed that its people, or at least its rulers, not only

appreciated the value of draining and sewering their city, but also that they knew how to secure the construction of efficient and enduring sewers or drains. It has been stated, and it is probably true, that this system of cloacæ, or sewers, was so complete that every street of the ancient city was drained through its members into the Tiber. They were undoubtedly the result of a gradual growth in sewer construction and did not spring at once into existence, but they date back certainly to the beginning of the period of the kings (753 B.C.). The famous Cloaca Maxima, as great as any sewer in the system, and certainly the most noted, is still in use, much of it being in good order. The mouth of the latter where it discharges into the Tiber is 11 feet wide and 12 feet high, constituting a large arch opening with three rings of voussoirs of peperino stone. Many other sewers of this system are also built with arch tops of the same stone, with neatly cut and closely fitting voussoirs. We do not find, unfortunately, any detailed accounts of the procedures involved in the design of these sewers, yet it is altogether probable that the old Roman civil engineers formed the cross-sections, grades, and other physical features of their sewer system by rational processes, although they would doubtless appear crude and elementary at the present time. It would not be strange if they made many failures in the course of their structural experiences, but they certainly left in the old Roman sewers examples of enduring work of its kind.

Some portions of this ancient sewer system are built with tops that are not true arches, and it is not impossible that they antedate the regal period. These tops are false arches formed of horizontal courses of tufa or peperino, each projecting over that below until the two sides thus formed meet at the top. The outline of the crowns of such sewers may therefore be triangular, curved, or polygonal; they were usually triangular. Smaller drains forming feeders to the larger members of the system were formed with tops composed of two flat stones laid with equal inclination to a vertical line so as to lean against each other at their upper edges and over the axis of the sewer. This method of forming the tops of the drains by two inclined flat stones was a crude but effective way of accomplishing the desired purpose.

The main members of this great sewer system seem to have followed the meandering courses of small rivers or streams, constituting the natural drainage-courses of the site of the city. The Cloaca Maxima has an exceedingly crooked course and it, along with others, was probably first formed by walling up the sides of a stream and subsequently closing in the top. Modern engineers know that such an alignment for a sewer is viciously bad, and while this complicated system of drains is admirably constructed in many ways for its date, it cannot be considered a perfect piece of engineering work in the light of present engineering knowledge. It is probable that the walling in of the sides of the original streams began to be done in Rome at least as early as the advent of the Tarquins, possibly as early as 800 B.C. or earlier.

We know little about the original outfalls or points of discharge into the Tiber, except that, as previously stated, these points were made through the massive quay-walls constructed during the period of the kings along both shores of the Tiber, probably largely for defence as originally built. The discharge of the old Roman sewers through the face of this quay-wall and into the river is precisely the manner in which the sewers of New York City in many places are discharged into the North, East, and Harlem rivers.

The Cloaca Maxima is not the only great ancient sewer thus far discovered. There are at least two others equal to it, and some of the single stones with which they are built contain as much as 45 cubic feet each. These cloacæ were not mere sewers; indeed they were more drains than sewers, for they carried off flood-waters and the natural drainage as well as the sewerage. They were therefore combined sewers and drains closely akin to the sewers of our "combined" systems. The openings into them were made along the streets of Rome and in public buildings or some other public places. There is no evidence that they were ventilated except through these openings, and from each noxious gases were constantly rising to be taken into the lungs of the passers-by. It is a rather curious as well as important fact that so far as excavations have been made there is practically no evidence that a private residence in Rome was connected with the sewers. The "latrines" were generally located adjacent to the Roman kitchens and discharged into the cloacæ.

=21. Early Roman Bridges.=—The early Romans were excellent bridge-builders as well as constructors in other lines of engineering work. Although the ancient city was first located on the left bank of the Tiber, apparently it was but a comparatively short time before the need of means for readily crossing from bank to bank was felt. The capacity of the Roman engineers was equal to the demands of the occasion, and it is now known that seven or eight ancient bridges connected the two shores of the river Tiber. The oldest bridge is that known as Pons Sublicius. No iron was used in its construction, as bronze was the chief metal employed in that early day. The structure was probably all of timber except possibly the abutments and the piers. A French engineer, Colonel Emy, has exhibited in his "Traité de l'Art de la Charpenterie" a plan of this structure restored as an all-timber bridge with pile foundations. Lanciani, on the other hand, believes that the abutments and piers must have been of masonry. The masonry structures, however, known to exist at a later day may have been parts of the work of rebuilding after the two destructions by floods. The date of its construction is not known, but tradition places it in the time of Ancus Marcius. This may or may not be

correct. A flood destroyed the bridge in 23 B.C., and again in the time of Antoninus Pius, but on both occasions it was rebuilt. The structure has long since disappeared. The piers only remained for a number of centuries, and the last traces of them were removed in 1877 in order to clear the bed of the river.

Fig. 11 shows Colonel Emy's restoration of the plan for the pile bridge which Julius Cæsar built across the Rhine in ten days for military purposes. This plan may or may not include accurate features of the structure, but it is certain that such a timber bridge was built, and well preserved pieces of the piles have been taken from under water at the site little the worse for wear after two thousand years of submersion.

The censor Ælius Scaurus built a masonry arch across the Tiber about a mile and a half from Rome in the year 100 B.C. This bridge is now known as the Ponte Molle, and some parts of the original structure are supposed to be included in it, having been retained in the repeated alterations. The arches vary in span from 51 to 79 feet, and the width of the structure is a little less than 29 feet.

In or about the year 104 A.D. the emperor Trajan constructed what is supposed to be a wooden arch bridge with masonry piers across the Danube just below the rapids of the Iron Gate.

[Illustration: Cross-section at Pier.]

[Illustration: Plan at Pier.

FIG. 11.—Bridge thrown across the Rhine by Julius Cæsar.]

A _bas relief_ on the Trajan Column at Rome exhibits the timber arches, but fails to give the span lengths, which have been the subject of much controversy, some supposing them to have been as much as 170 feet.

The ancient Pons Fabricius, now known as Ponte Quattiro Capi, still exists, and it is the only one which remains intact after an expiration of nearly two thousand years. It has three arches, the fourth being concealed by the modern embankment at one end; a small arch pierces the pier between the other two arches. This structure is divided into two parts by the island of Æsculapius. It is known that a wooden bridge must have joined that island with the left bank of the Tiber as early as 192 B.C., and a similar structure on the other side of the island is supposed to have completed the structure. While Lucius Fabricius was Commissioner of Roads in the year 62 B.C. he reconstructed the first-named portion into a masonry structure of arches. An engraved inscription below the parapets shows that the work was duly and satisfactorily completed, and further that it was the custom to require the constructors or builders of bridges to guarantee their work for the period of forty years. Possession of the last deposit, made in advance as a guarantee of the satisfactory fulfilment of the contract, could not be regained until the forty-first year after completion.

[Illustration: FIG. 12.—Trajan's Bridge.]

The Pons Cestius is a bridge since known as the Pons Gratianus and Ponte di S. Bartolomeo. Its first construction is supposed to have been completed in or about 46 B.C., and it was rebuilt for the first time in A.D. 365. A third restoration took place in the eleventh century. The modern reconstruction in 1886-89 was so complete that only the middle arch remains as an ancient portion of the structure. The island divides the bridge into two parts, the Ship of Æsculapius lying between the two, but it is not known when or by whom the island was turned into that form.

Another old Roman bridge, of which but a small portion is now standing, is Pons Æmilius, the piers of which were founded in 181 B.C., but the arches were added and the bridge completed only in 143 B.C. It was badly placed, so that the current of the river in times of high water exerted a heavy pressure upon the piers, and in consequence it was at least four times carried away by floods, the first time in the year A.D. 280.

The discovery of what appears to be a row of three or four ruins of piers nearly 340 feet up-stream from the Ponte Sisto seems to indicate that a bridge was once located at that point, although little or nothing is known of it as a bridge structure. Some suppose it to be the bridge of Agrippa.

The most historical of all the old Roman bridges is that which was called Pons Ælius, now known as Ponte S. Angelo, built by Hadrian A.D. 136. Before the reconstruction of the bridge in 1892 six masonry arches were visible, and the discovery of two more since that date makes a total of eight, of which it is supposed that only three were needed in a dry season. The pavement of the approach to this bridge as it existed in 1892 was the ancient roadway surface. Its condition at that time was an evidence of the

substantial character of the old Roman pavement.

Below the latter bridge remains of another can be seen at low water. It is supposed that this structure was the work of Nero, although its name is not known.

The modern Ponte Sisto is a reconstruction of the old Pons Valentinianus or bridge of Valentinian I. The latter was an old Roman bridge, and it was regarded as one of the most impressive of all the structures crossing the river. It was rebuilt in A.D. 366-67.

The most of these bridges were built of masonry and are of the usual substantial type characteristic of the early Romans. They were ornamented by masonry features in the main portions and by ornate balustrades along either side of the roadway and sidewalks. The roadway pavements were of the usual irregular polygonal old Roman type, the sidewalk surfaces being composed of the large slabs or stones commonly used in the early days of Rome for that purpose.

=22. Bridge of Alcantara.=—Among the old Roman bridges should be mentioned that constructed at Alcantara in Spain, supposedly by Trajan, about A.D. 105. It is 670 feet long and its greatest height is 210 feet. One of its spans is partially destroyed. The structure is built of blocks of stone without cementing material. In this case the number of arches is even, there being six in all, the central two having larger spans than those which flank them. It is a bridge of no little impressiveness and beauty and is a most successful design.

=23. Military Bridges of the Romans.=—In the old Roman military expeditions the art of constructing temporary timber structures along lines of communication was well known and practised with a high degree of ability. Just what system of construction was employed cannot be determined, but piles were constantly used. At least some of these timber military bridges, and possibly all, were constructed with comparatively short spans, the trusses being composed of such braces and beams as might be put in place between bents of piles. As already observed, some of the sticks of these bridges have been found in the beds of German rivers, and at other places, perfectly preserved after an immersion of about two thousand years. These instances furnish conclusive evidence of the enduring qualities of timber always saturated with water.

=24. The Roman Arch.=—The Romans developed the semicircular arch to a high degree of excellence, and used it most extensively in many sewers, roads, and aqueducts. While the aqueduct spans were usually made with a length of about 18 or 20 feet, they built arches with span lengths as much as 120 feet or more, comparing favorably with our modern arch-bridge work. They seldom used any other curve for their arches than the circular, and when they built bridges an odd number of spans was usually employed, with the central opening the largest, possibly in obedience to the well-known esthetic law that an odd number of openings is more agreeable to the eye than an even number. Apparently they were apprehensive of the safety of the piers from which their arches sprang, and it was not an uncommon rule to make the thickness of the piers one third of the clear span. Nearly one fourth of the entire length of the structure would thus be occupied by the pier thicknesses. Although the use of mortar, both lime and cement, early came into use with the Romans, they usually laid up the ring-stones of their arches dry, i.e., with out the interposition of mortar joints.

CHAPTER III.

=25. The Roman Water-supply.=—There is no stronger evidence of engineering development in ancient Rome, nor of the advanced state of civilization which characterized its people, than its famous system of water-supply, which was remarkable both for the volume of water daily supplied to the city and for the extensive aqueducts, many of whose ruins still stand, as impressive monuments of the vast public works completed by the Romans. These ruins, and those of many other works, would of themselves assure us of the elaborate system of supply, but fortunately there has been preserved a most admirable description of it, the laws regulating consumption, the manner of administering the water department of the government of the ancient city, and much other collateral information of a most interesting character. In the work entitled, in English, “The Two Books on the Water-supply of the City of Rome,” by (Sextus) Julius Frontinus, an eminent old Roman citizen, who, besides having filled the office of water commissioner[1] of the city, was governor of Britain and three times consul, as well as having enjoyed the dignity of being augur. He may properly be called a Roman engineer, although he evidently was a man of many public affairs, and so esteemed by the emperors who ruled during his time that he accompanied them in various wars as a military man of high rank. He wrote seven books at least, viz., “A Treatise on Surveying,” “Art of War,” “Strategematics,” “Essays on Farming,” “Treatise on Boundaries, Roads, etc.,” “A Work on Roman Colonies,” and his account of the water-works of Rome, entitled “De Aquis.” It is the latter book in which engineers are particularly interested. The translation of this book from the original Latin is made from what is termed the

"Montecassino Manuscript," an account of which with the translation is given by Mr. Clemens Herschel in his entertaining work, "Frontinus, and the Water-supply of the City of Rome."

[1] The first permanent water commissioner in Rome was M. Agrippa, son-in-law of Cæsar Augustus, who took office B.C. 34. He was one of the greatest Roman engineers and constructors, if indeed he was not the first in rank.

As near as can be determined Frontinus lived from about A.D. 35 to A.D. 103 or 104. Judging from the offices which Frontinus held and the honors which he enjoyed throughout his life, it would appear that he was a patrician; he was certainly a man of excellent executive capacity, of intellectual vigor and refined taste, and a conscientious public servant. The water-supply of the city was held by the Romans to be one of the most important of all its public works, and its administration during the life of Frontinus was entrusted to what we should call a water commissioner, appointed by the emperor. It was considered to be an office of dignity and honor, and the proper discharge of its responsibilities was a public duty which required a high order of talent, as well as great integrity of character.

=26. The Roman Aqueducts.=—Frontinus states that from the foundation of the city of Rome until 313 B.C., i.e., for a period of 441 years, the only water-supply was that drawn either from the river Tiber or from wells or springs. The veneration of the Romans for springs is a well-known feature of their religious tenets. They were preserved with the greatest care, and hedged about with careful safeguards against irreverent treatment or polluting conditions. Apparently after this date the people of Rome began to feel the need of a public water-supply adequate to meet the requirements of a great city. At any rate, in the year 313 B.C. the first aqueduct, called the Appia, for bringing public water into the city of Rome was attempted by Censors Appius Claudius, Crassus, and C. Plautius, the former having constructed the aqueduct, and the latter having found the springs. Appius must have been an engineer of no mean capacity, for it was he who constructed the first portion of the Appian Way. The origin of this water-supply is some springs about 10 miles from Rome, and they may now be seen at the bottom of stone quarries in the valley of the Anio River. This aqueduct, Aqua Appia, is mostly an underground waterway, only about 300 feet of it being carried on masonry arches. At the point where it enters the city it was over 50 feet below the surface; its clear cross-section is given as 2½ feet wide by 5 feet high. The elevation of its water surface in Rome was probably under 60 feet above sea-level.

[Illustration: Claudia, of dimension stone, and Anio Novus, of brick and concrete, on top of it.]

=27. Anio Vetus.=—The next aqueduct built for the water-supply of Rome was called Anio Vetus. It was built 272-269 B.C., and is about 43 miles long; it took its water from the river Anio. About 1100 feet of its length was carried above ground on an artificial structure. It also was a low-level aqueduct, the elevation at which it delivered water at Rome being about 150 feet above sea-level. It was built of heavy blocks of masonry, laid in cement, and the cross-section of its channel was about 3.7 feet wide by 8 feet high. In the year 144 B.C. the Roman senate made an appropriation equal to about $400,000 of our money to repair the two aqueducts already constructed, and to construct a new one called Aqua Marcia, to deliver water to the city at an elevation of about 195 feet above sea-level. This aqueduct was finished 140 B.C.; it is nearly 58 miles long, and carried water of most excellent quality through a channel which, at the head of the aqueduct, was 5■ feet wide by $8^{3}/■■$ feet high, but farther down the structure was reduced to 3 feet wide by 5■/■■ feet high. The excellent water of these springs is used for the present supply of Rome, and is brought in the Aqua Pia, built in 1869, as a reconstruction of the old Aqua Marcia. This aqueduct, like its two predecessors, is built of dimension stone, 18 inches by 18 inches by 42 inches, or larger, laid in cement; but concrete and brick were used in the later aqueducts, with the exception of Claudia.

=28. Tepula.=—The aqueduct called Aqua Tepula, about 11 miles in length, and completed 125 B.C., was constructed to bring into the city of Rome a slightly warm water from the volcanic springs situated on the hill called Monte Albani (Alban Hills) southeast of Rome. The temperature of these springs is about 63° Fahr. In the year B.C. 33 Agrippa caused the water from some springs high up the same valley to be brought in over the aqueduct Aqua Julia, 14 miles long. This latter water was considerably colder than that of the Tepula Springs. The two waters were united before reaching Rome and allowed to flow together far enough to be thoroughly mixed. They were then divided and carried into Rome in two conduits. The volume of water carried in the Aqua Julia was about three times that taken from the Tepula Springs, the cross-section of the latter being only 2.7 feet wide by 3.3 feet high, while that of Julia was 2.3 feet by 4.6 feet. The water from Aqua Julia entered Rome at an elevation of about 212 feet above sea-level, and that from Aqua Tepula about 11 feet lower.

=29. Virgo.=—The sixth aqueduct in chronological order was called Virgo, and it was completed 19 B.C. It takes water from springs about 8 miles from Rome and only about 80 feet above sea-level, but the length of the aqueduct is about 13 miles. The delivery of

water in the city by this aqueduct is about 67 feet above that level. The cross-section of this channel is about 1.6 feet wide and 6.6 feet high.

=30. Alsietina.=—The preceding aqueducts are all located on the left or easterly bank of the Tiber, but one early structure was located on the right bank of the Tiber to supply what was called the Trans-Tiberine section of the city, and it was known as Aqua Alsietina. The emperor Augustus had this aqueduct constructed during his reign, and it was finished in the year A.D. 10. Its source is a small lake of the same name with itself, about 20 miles from Rome. The elevation of this lake is about 680 feet above sea-level, while the water was delivered at an elevation of about 55 feet above the same level. The water carried by this aqueduct was of such a poor quality that Frontinus could not "conceive why such a wise prince as Augustus should have brought to Rome such a discreditable and unwholesome water as the Alsietina, unless it was for the use of Naumachia." The latter was a small artificial lake or pond in which sham naval fights were conducted.

[Illustration:

Sand and Pebble Catch-tanks near Tivoli. Dimension-stone aqueducts of Marcia at either end of the tank built of small stone; _opus incretum_. The arches are chambers of the tanks.]

=31. Claudia.=—The eighth aqueduct described by Frontinus is the Aqua Claudia, built of dimension stone, which he calls a magnificent work on account of the large volume of water which it supplied, its good quality, and the impressive character of considerable portions of the aqueduct itself, between 9 and 10 miles being carried on arches. It was built in 38-52 A.D. and is forty-three miles long. The sources of its supply are found in the valley of the Anio, and consequently it belongs to the system on the left bank of the Tiber. The cross-section of its channel was about 3.3 feet wide by 6.6 feet high. It was a work greatly admired by the Roman people, as is evidenced by the praise "given to it by Roman authors who wrote at that time." It delivered water at the Palatine 185 feet above sea-level. According to Pliny, the combined cost of it and the Aqua Anio Novus was 55,500,000 sestertii, or nearly $3,000,000. This aqueduct probably belongs to the highest type of Roman hydraulic engineering. It follows closely the location of the Aqua Marcia, although its alignment now includes a cut-off tunnel about 3 miles long, the latter having been constructed about thirty-six years after the aqueduct was opened. Mr. Clemens Herschel observes that the total sum expended for these two aqueducts makes a cost of about $6 per lineal foot for the two. The arches of this aqueduct and those of the Anio Novus have clear spans of 18 to 20 feet, with a thickness at the crown of about 3 feet.

=32. Anio Novus.=—The ninth aqueduct described by Frontinus is called Anio Novus. It was also constructed in the years A.D. 38-52. This aqueduct has a length of about 54 miles and takes its supply from artificial reservoirs constructed by Nero at his country-seat in the valley of the Anio near modern Subiaco. This structure is built of brick masonry lined with concrete. That portion of the Aqua Claudia which is located on the Campagna carries for 7 miles the Anio Novus, and it forms the long line of aqueduct ruins near Roma Vecchia. The upper surface of the arch-ring at the crown forms the bottom of the channel of the aqueduct. The cross-section of the channel of the Anio Novus was 3.3 feet wide by 9 feet high. The elevation of the water in this, as in the Claudia, when it reached the Palatine was about 185 feet above sea-level. The Anio Novus in some respects would seem to be a scarcely less notable work than the Claudia. About 8 miles of its length is carried on arches, some of them reaching a height of about 105 feet from the ground.

=33. Lengths and Dates of Aqueducts.=—These nine aqueducts constituted all those described by Frontinus, as no others were completed prior to his time. Five others were, however, subsequently completed between the years 109 A.D. and 306 A.D., but enough has already been shown in connection with the older structures to show the character of the water-supply of ancient Rome.

The following tabular statement is a part of that given by Mr. F. W. Blackford in "The Journal of the Association of Engineering Societies," December, 1896. It shows the dates and lengths of the ancient aqueducts of Rome between the years 312 B.C. and 226 A.D., with the length of the arch portions. The list includes those built up to the end of the Empire. It will be observed that the total length of the aqueducts is 346 miles, and that of the arch portions 44 miles. The figures vary a little from those given by Lanciani and others, but they are essentially accurate.

+----------+--------+----------+----------+ | | | Total |Length of | | Name. | Date. |Length in |Arches in | | | B.C. | Miles. | Miles. | +----------+--------+----------+----------+ |Appia | 312 | 11 | Little | |Vetus | 272-264| 43 | " | |Marcia | 145 | 61 | 12 | |Tepula | 126 | 13 | Little | |Julia | 34 | 15 | 6 | |Virgo | 21 | 14 | Little | | | | | | | | A.D. | | | |Alsietina | 10 | 22 | Little | |Augusta | 10 | 6 | " | |Claudia | 50 | 46 | 10 | |Anio Novus | 52 | 58 | 9 | |Triana | 109 | 42 | Little | |Alexandrina | 226 | 15 | 7 | | +--------+----------+----------+ | Totals | 346 | 44 | +----------+--------+----------+----------+

=34. Intakes and Settling-basins.=—The preceding brief descriptions of the old Roman aqueducts give but a superficial idea of the real features of those great works and of the system of water-supply of which they were such essential portions. Enough has been shown, however, to demonstrate conclusively that the engineers and constructors of old Rome were men who, on the one hand, possessed a high order of engineering talent and, on the other, ability to put in place great structures whose proportions and physical characteristics have commanded the admiration of engineers and others from the time of their completion to the present day. If a detailed statement were to be made in regard to the water-supply of ancient Rome, it would appear that much care was taken to insure wholesome and potable water. At the intakes of a number of the aqueducts, reservoirs or basins were constructed in which the waters were first received and which acted as settling-basins, so that as much sedimentation as possible might take place. Similar basins (picinæ) were also constructed at different points along the aqueducts for the same purpose and for such other purposes as the preservation of the water in a portion of the aqueduct in case another portion had to be repaired or met with an accident which for the time being might put it out of use. These basins were usually constructed of a number of apartments, the water flowing from one to the other, very much as sewage in some sewage-disposal works flows at the present time through a series of settling-basins. The object of these picinæ was the clearing of the water by sedimentation. Indeed there was in some cases a use of salt in the water to aid in clarifying it. This is an early type of the modern process of clarifying water by chemical precipitation, not the best of potable water practice, but one that is sometimes permissible.

=35. Delivery-tanks.=—The aqueducts brought the water to castellæ or delivery-tanks, i.e., small reservoirs, both inside the city and outside of it, and from these users were obliged by law to take their supplies; that is, for baths, for fountains, for public uses, for irrigation, and for private uses. When Frontinus wrote his "De Aquis" a little less than three tenths of all the water brought to Rome by the aqueducts was used outside of the city. The remainder was distributed in the city from 247 delivery-tanks or small reservoirs, about one sixth of it being consumed by 39 ornamental fountains and 591 water-basins.

=36. Leakage and Lining of Aqueducts.=—These aqueducts were by no means water-tight. Indeed they were subject to serious leakage, and Frontinus shows that forces of laborers were constantly employed in maintaining and repairing them. As has been stated, the older aqueducts were built of dimension stones, while the later were constructed of concrete or bricks and concrete. The channels of these aqueducts, as well as reservoirs and other similar structures, were made as nearly water-tight as possible by lining them with a concrete in which pottery, broken into fine fragments, was mixed with mortar.

[Illustration: Claudia and Anio Novus near Porta Furba. Repairs in brickwork and in a composite of concrete and brickwork.]

=37. Grade of Aqueduct Channels.=—The fall of the water surface in these aqueducts cannot be exactly determined. The levelling-instruments used by the Romans were simple and, as we should regard them, crude, although they served fairly well the purposes to which they were applied. They were not sufficiently accurate to determine closely the slope or grade of the water surface in the aqueduct channels. The deposition of the lime from the water along the water surface on the sides of the channels in many cases would enable that slope to be determined at the present time, but sufficiently careful examinations have not yet been made for that purpose. Lanciani states that the slopes in the Aqua Anio Vetus vary from about one in one thousand to four in one thousand. An examination of the incrustation on the sides of the Aqua Marcia near its intake makes it appear that the slope of the surface was about .06 foot per 100 feet, which would produce a velocity, according to the formula of Darcy, of about 3.3 feet per second. In some aqueducts built in Roman provinces it would appear that slopes have been found ranging from one in six hundred to one in three thousand.

=38. Qualities of Roman Waters.=—The chief characteristic in most of the old Roman waters was their extreme hardness. They range from 11° to 48° of hardness, the latter belonging to the water of the Anio, while the potable waters in this country scarcely reach 5°. The old Romans recognized these characteristics of their waters and, as has been intimated, used the best of them for table purposes, while the less wholesome were employed for fountains, flushing sewers, and other purposes not affected by undesirable qualities. The water from Claudia, for instance, was used for the imperial table. The water from the Aqua Marcia was also of excellent quality, while that brought in by the Aqua Alsietina was probably not used for potable purposes at all.

=39. Combined Aqueducts.=—In several cases a number of aqueduct channels were carried in one aqueduct. A marked instance of this kind was that of Julia, Tepula, and Marcia, all being carried in vertical series in one structure. Numerous instances of this sort occurred.

=40. Property Rights in Roman Waters.=—In reading the two books of Frontinus one will be impressed by the property values which the old Romans created in water rights. The laws of Rome were exceedingly explicit as to the rights of water-users and as to

the manner in which water should be taken from the aqueducts and from the pipes leading from the reservoirs in and about the city. The proper methods for taking the water and using it were carefully set forth, and penalties were prescribed for violations of the laws pertaining to the use of water. There were many abuses in old Rome in the administration of the public water-supply, and one of the most troublesome duties which Frontinus had to perform lay in reforming those abuses and preventing the stealing of water. The unit of use of water (a "quinaria," whose value is not now determinable) was the volume which would flow from an orifice .907 inch in diameter and having an area of about .63 of a square inch. Mr. Herschel shows that in consequence of the failure of the Romans to understand the laws of the discharge of water under varying heads, the quinaria may have ranged from .0143 cubic foot to .0044 cubic foot per second or between even wider limits.

=41. Ajutages and Unit of Measurement.=—Frontinus describes twenty-five ajutages of different diameter, officially approved in connection with the Roman system of public water-supply; but only fifteen of these were actually used in his day. All of these were circular in form, although two others had been used prior to that time. They varied in diameter from .907 to 8.964 English inches and were originally made of lead, but that soft metal lent itself too easily to the efforts of unscrupulous water-users to enlarge them by thinning the metal. In his time they were made of bronze, which was a hard metal and could not be tampered with so as to enlarge its cross-section. The discharge through the smallest of these ajutages was the quinaria, the unit in the scale of water rights. The largest of the above ajutages had a capacity of a little over 97 quinariæ.

This unit (the quinaria) was based wholly on superficial area, and had no relation whatever to the head over the orifice or to the velocity corresponding to that head. Although Frontinus refers in several cases to the fact that the deeper the ajutage is placed below the water surface the greater will be the discharge through it, also to the fact that a channel or pipe of a given area of cross-section will pass more water when the latter flows through it with a high velocity, he and other Roman engineers seem to have failed completely to connect the idea of volume of discharge to the product of area of section by velocity. In the Roman mind of his day, and for perhaps several hundred years after that, the area of the cross-section of the prism of water in motion was the only measure of the volume of discharge. This seems actually preposterous at the present time, and yet, as observed by Mr. Herschel, possibly a majority of people now living have no clearer idea of the volume of water flowing in either a closed or open channel. Existing statutes even respecting water rights bear out this statement, improbable as it may at first sight appear. This early Roman view of the discharge is, however, in some respects inexplicable, for Hero of Alexandria wrote, probably in the period 100-50 B.C., that the section of flow only was not sufficient to determine the quantity of water furnished by a spring. He proceeded to set forth that it was also necessary to know the velocity of the current, and further explained that by forming a reservoir into which a stream would discharge for an hour the flow or discharge of that stream for the same length of time would be equal to the volume of water received by the reservoir. His ideas as to the discharge of a stream of water were apparently as clear as those of a hydraulic engineer of the present time. Indeed the method which he outlines is one which is now used wherever practicable.

It has been a question with some whether Frontinus and other Roman engineers were acquainted with the fact that a flaring or outward ajutage would increase the flow or discharge through the orifice. The evidence seems insufficient to establish completely that degree of knowledge on their part. At the same time, in the CXII chapter of Frontinus' book on the "Water-supply of the City of Rome," he states that in some cases pipes of greater diameter than that of the orifice were improperly attached to legal ajutages. He then states: "As a consequence the water, not being held together for the lawful distance, and being on the contrary forced through the short restricted distance, easily filled the adjoining larger pipe." He was convinced that the use of a pipe with increased diameter under such circumstances would give the user of the water a larger supply than that to which he was entitled, and he was certainly right in at least most cases.

The actual unit orifice through which the unit volume of water called the quinaria was discharged was usually of bronze stamped by a proper official, thus making its use legal for a given amount of water. The Roman engineers understood that such an orifice should be inserted accurately at right angles to the side of the vessel or orifice, and that was the only legal way to make the insertion. Furthermore, the law required that there should be no change in the diameter of the pipe within 50 feet of the orifice. It was well known that a flaring pipe of increased diameter applied immediately at the orifice would largely increase the discharge, and unscrupulous people resorted to that means for increasing the amount of water to be obtained for a given price.

=42. The Stealing of Water.=—It appears also that Frontinus experienced much trouble from clandestine abstraction of water from reservoirs and water-pipes. The administration of the water commissioner's office had been exceedingly corrupt prior to his induction into office, and some of his most troublesome official work arose from his efforts to detect water-thieves, and to guard the supply system from being tapped irregularly or illegally. We occasionally hear of similar instances of water-stealing at the present time, which shows that human nature has not altogether changed since the time of Frontinus.

=43. Aqueduct Alignment and Design of Siphons.=—The alignment of some of the Roman aqueducts followed closely the contours of the hills around the heads of valleys, while others took a more direct line across the valleys on suitable structures, frequently series of arches. Judging from our own point of view it may not be clear at first sight why such extensive masonry constructions were used when the aqueduct could have been kept in excavation by following more closely the topography of the country. There is little doubt that the Romans knew perfectly well what they were about. Indeed it is definitely stated in some of the old Roman writings that the structures were built across valleys for the specific purpose of saving distance which, in most instances at least, meant saving in cost.

These masonry structures, it must be remembered, were built of material immediately at hand. Furthermore, these aqueducts were generally only made of sufficient width for the purpose of carrying water-channels. They were not wide structures. In some cases they were not more than 8 feet or 9 feet wide for a height of nearly 100 feet. The cost of construction was thus largely reduced below that of wide structures.

[Illustration: Old Roman Lead and Terra-cotta Pipe.]

The Romans were perfectly familiar with the construction of inverted siphons. As a matter of fact Vitruvius, in Chapter VII of his Eighth book, describes in detail how they should be designed. His specific descriptions relate to lead pipes, but it is clear from what he states at other points that he considered earthenware pipes equally available. He sets forth how the pipes should be carried down one slope, along the bottom of the valley, and up the other slope, the lowest portion being called the "venter." He realized the necessity of guarding all elbows in the pipe by using a single piece of stone as a detail for the elbow, a hole being cut in it in each direction in which the adjoining sections of pipe should be inserted, the sections of lead pipe being 10 feet long, and even goes so far as to describe the stand-pipes that should be inserted for the purpose of allowing air to escape. Vitruvius also advises that the water should not only be admitted to inverted siphons in a gradual manner, but that ashes should be thrown into the water when the siphon is first used in order that they may settle into the joints or open places so as to close any existing leaks. Lead pipe siphons, 12 to 18 inches in diameter, with 1 inch thickness of metal under 200 feet head, built in ancient times, have been found at Lyons in France. Also a drain-pipe siphon with masonry reinforcement was built at Alatri in Italy 125 B.C. to carry water under a head of about 340 feet. There are other notable instances of inverted siphons constructed and used during the ancient Roman period, some of them being of lead pipe imbedded in concrete.

CHAPTER IV.

=44. Antiquity of Masonry Aqueducts.=—Masonry aqueducts, either solid or with open arches, were not first constructed by the city of Rome; their origin was much farther back in antiquity than that. The Greeks at least used them before the Roman engineers, and it is not unlikely that the latter drew their original ideas from the former, if indeed they were not instructed by them. Nor during the times of the Romans was the construction of aqueducts confined to Rome. Wherever Roman colonies were created it would appear that vast sums were expended in the construction of aqueducts for the purpose of suitably supplying cities with water. Such constructions are found at many points in Spain, France, and other countries which were in ancient times Roman colonies. It is probable that there are not less than one hundred, and perhaps many more, of such structures in existence at the present time.

=45. Pont du Gard.=—Among the more prominent aqueducts constructed during the old Roman period and outside of Italy were the Pont du Gard at Nismes in the south of France, and those at Segovia and Tarragona in Spain. The Pont du Gard has three tiers of arches with a single channel at the top. The greatest height above the river Gardon is about 180 feet, and the length of the structure along the second tier of arches is 885 feet. The arches in the lowest tier are 51 feet, 63 feet, and 80.5 feet in span, while the arches in the highest tier are uniformly 15 feet 9 inches in span. The thickness of the masonry at the top of the structure from face to face is 11 feet 9 inches, and 20 feet 9 inches at the lower tier of arches, the thickness at the intermediate tier being 15 feet.

The largest arch has a depth of keystone of 5 feet 3 inches, while the other arches of the lower tier have a depth of keystone of 5 feet. The depth of the ring-stones of the small upper arches is 2 feet 7 inches. This structure forms a sort of composite construction, the lower arches constituting four separate arch-rings placed side by side, making a total thickness of 20 feet 9 inches. The intermediate arches consist of three similar series of narrow arches placed side by side, but the masonry of the upper tier is continuous throughout from face to face. The three and four parallel series of arches of the middle and lowest tiers are in no way bonded or connected with each other. There is no cementing material in any of the arch-rings, but cement mortar was used in rubble masonry or concrete around the channel through which the water flowed above the upper tier of small arches. This structure is supposed to have been built between the years 31 B.C. and 14 A.D.

=46. Aqueducts at Segovia, Metz, and Other Places.=—The Segovia aqueduct was built by the emperor Trajan about A.D. 100-115. It is built without mortar, and has 109 arches, but 30 are modern, being reproductions of the old. It has a length of over 2400 feet, and in places its height is about 100 feet. The old Tarragona aqueduct is built with two series of arches, 25 being in the upper series and 11 in the lower. It is 876 feet long and has a maximum height of over 80 feet. At Mayence there are ruins of an aqueduct about 16,000 feet long. In Dacia, Africa, and Greece there are other similar ruins. Near Metz are the remains of a large old Roman aqueduct. It consisted of a single row of arches, and had no features of particular prominence. This latter observation, however, could not be made of one of the bridges in the aqueduct at Antioch. Although the masonry and design of this latter structure were crude, its greatest height is 200 feet, and its length 700 feet. The lower portion of this structure was a solid wall with the exception of two openings, the arches extending in a single row along its upper portion. On the island of Mytilene are the ruins of another old aqueduct about 500 feet long, with a maximum height of about 80 feet.

The building of these remarkable aqueducts was practised at least down to the later periods of the Roman empire, that of Pyrgos, near Constantinople,—built not earlier than the tenth century,—being an excellent example. It consists of two branches at right angles to each other. The greater branch is 670 feet long, and its greatest height 106 feet. There are three tiers of arches, the two upper being of semicircular and the lower of Gothic outline. The number in each tier for a given height is the same, but with an increasing length of span in rising from the lowest to the highest tier. Thus the highest tier of piers is the lightest, relieving the top of the structure of weight. The lowest row of piers is reinforced by counterforts or buttresses. At the top of the structure the width or thickness is 11 feet, but the thickness increases uniformly to 21 feet at the bottom. The smaller branch of the aqueduct is 300 feet long, and was built with twelve semicircular arches.

=47. Tunnels.=—The construction of tunnels, especially in connection with the building of aqueducts, constituting a branch of engineering procedure, was frequently practised by the ancient nations. Large tunnel-works were executed many times by the ancient Greeks and Romans. It would seem that the Greeks were the instructors of the Romans in this line of engineering operations. As early as B.C. 625 we are told that the Greek engineer Eupalinus constructed a tunnel 8 feet broad, 8 feet high, and 4200 feet long, through which was built a channel for carrying water to the city of Athens.

Sixty-five years later a similar work was constructed for the same Grecian city. Indeed it appears that tunnels were constructed in the time of the earliest history of aqueducts built to supply ancient Greek and Roman cities with water.

It is certain that at the beginning of the Christian era tunnelling processes were well known among the Romans. Vitruvius writes, in speaking of the construction of aqueducts, in Chapter VII of the Eighth Book: "If hills intervene between the city wall and spring head, tunnels underground must be made, preserving the fall above assigned; if the ground cut through be sandstone or stone, the channel may be cut therein; but if the soil be earth or gravel, side walls must be built, and an arch turned over, and through this the water may be conducted. The distance between the shafts over the tunnelled part is to be 120 feet."

The Romans pierced rock in their tunnel-work, not only by chiselling, but sometimes by building fire against the rock so as to heat it as hot as possible. The heated rock was then drenched with cold water, so that it might be cracked and disintegrated to as great an extent as practicable. According to Pliny vinegar was used instead of water in some cases, under the impression that it was more efficacious.

[Illustration: Roman water-pipe made of bored-out blocks of stone.]

One of the methods mentioned by Vitruvius is plainly "the cut and cover" procedure of the present day. In Duruy's history of Rome a tunnel over three miles long is mentioned on a line of an aqueduct at Antibes in France, as well as another constructed to drain Lake Fucinus in Italy, about A.D. 50. It is there stated that the latter required eleven years' labor of 30,000 men to build a rock tunnel with a section of 86 to 96 square feet 18,000 feet long.

Lanciani, in his "Ancient Rome," states that about A.D. 152 a Roman engineer (Nonius Datus) began the construction of a tunnel in Algeria, and after having carefully laid out the axis of the tunnel across the ridge "by surveying, and taking the levels of the mountains," left the progress of the work in the hands of the contractor and his workmen. After the rather long absence from such a work of four years he was called back by the Roman governor to ascertain why the two opposite sections of the tunnel, as constructed, would not meet, and to take the requisite measures for the completion of the work through which water was to be conducted to Saldæ in a suitable channel. He explains that there should have been no difficulty, and that the failure of the two headings to meet was due to the negligence of the contractor and his assistant, whom he states "had committed blunder upon blunder," although he writes, "As always happens in these cases, the fault was attributed to the engineer." He solved the problem

by connecting the two approximately parallel tunnels by a transverse tunnel, so that water was finally brought to the city of Saldæ.

The art of tunnel construction has been one of the most widely practised branches of Civil-Engineering from the times of the ancient Assyrians, Egyptians, Greeks, Romans, and other ancient nations down to the present.

=48. Ostia, the Harbor of Rome.=—The capacity of the ancient Romans to build harbor-works is shown by what they did at Ostia, which was then at the mouth of the Tiber, but is now not less than four miles inland from the present shore line. At the Ostia mouth of the river the present annual average advance seaward is not less than 30 feet, and at the Fiumicino mouth about one third of that amount.

[Illustration: FIG. 13.—Plan of Ostia and Porto.]

The ancient port of Ostia is supposed to have been founded during the reign of the fourth king Ancus Marcius, but it attained its period of greatest importance during the reign of Claudius and Trajanus. At that time the fertile portions of the Campania had been so largely taken up by the country-places of the wealthy Romans that it was no longer possible for the peasantry to cultivate sufficient ground to yield the grain required by the home market of the Romans. Large fleets were consequently engaged in the foreign grain-trade of Rome. The wheat and other grain required in great quantities was grown mostly in Egypt, although Carthage and other countries supplied large amounts. The great fleets occupied in this trade made ancient Ostia their Roman port. At the present time it has no inhabitants, but is a group of complete ruins, with its streets of tombs, baths, palaces, and temples, deeply covered with the accumulations of many centuries. Enough excavations have been made along the shores of the Tiber at this point to show that the river was bordered with continuous and substantial masonry quays, flanked on the land side by successions of great warehouses, obviously designed to receive grain, wine, oil, and other products of the time. The entrance to this harbor was difficult, as the mouth of the river was shallow, with bars apparently obstructing its approach. There were no jetties, or other seaward works for the protection of vessels desiring to make the harbor. It is stated that during one storm nearly or quite two hundred vessels were destroyed while they were actually in the harbor.

=49. Harbors of Claudius and Trajan.=—The difficulty in entering the mouth of the Tiber prompted the emperor Claudius to construct another harbor to accommodate the vast commerce then centring at the port of Rome. Instead of increasing the capacity of Ostia and opening the mouth of the river by deepening it, he constructed a new harbor on what was then the seashore, a short distance from Ostia, and connected it with the Tiber by a canal, the extension of which by the natural forces of the river has become the Fiumicino, the only present navigable entrance to the river. This harbor was enclosed by two walls stretching out from the shore, and converging on the sea side to a suitable opening left for the entrance of ships. The superficial area of this harbor was about 175 acres, but it became insufficient during the time of Trajan. He then proceeded to excavate inland a hexagonal harbor with a superficial area of about 100 acres, which was connected both with the harbor of Claudius and the canal connecting the latter with the Tiber. These harbor-works were elaborate in their fittings for the accommodation of ships, and were built most substantially of masonry. They showed that at least in some branches of harbor-work the old Romans were as good engineers as in the construction of aqueducts, bridges, and other internal public works. The harbors at ancient Ostia, including those of Claudius and Trajan, were not the only works of their class constructed by the Romans, but they are sufficient to show as great advancement in harbor and dock work as in other lines of engineering.

These harbors were practically defenceless and exposed to the incursions of pirates, which came to be frequently and successfully made in the days of the declining power of Rome. It was therefore rather early in the Christian era that these attacks discouraged, and ultimately drove away, first, the maritime business of the Romans and, subsequently, all the inhabitants of these ports, leaving the pillaged remnants of the vast harbor-works, warehouses, palaces, temples, and other buildings in the ruined condition in which they are now found.

CHAPTER V.

=50. Ancient Engineering Science.=—The state of what may be called the philosophy or science of engineering construction in ancient Rome is admirably illustrated by the work on Architecture by Marcus Vitruvius Pollio, who is ordinarily known as Vitruvius, and who wrote probably a little more than two thousand years ago. He calls himself an architect, and his work is a classic in that profession of which he claims to be a member. Although much of his work was purely architectural, a great portion of it, on the other hand, was not architecture as we now know it, but civil-engineering in the best sense of the term. It must be remembered, therefore, that what is here written applies to that large portion of his work which is purely civil-engineering.

It will be seen that although he understood really little or nothing about the science of civil-engineering as we now comprehend it, he perceived many of the general and fundamental principles of the best practice of that profession and frequently applied them in a manner which would do credit to a modern civil engineer. He not only laid down axioms to govern the design of civil-engineering structures and machinery for the transmission of power, but he also set forth many considerations bearing upon public and private health and the practice of sanitary engineering in a way that was highly creditable to the state of scientific knowledge in his day. Speaking of the general qualifications of an architect, remembering that that word as he understood it includes the civil engineer, he states: "An architect should be ingenious, and apt in the acquisition of knowledge; ... he should be a good writer, a skilful draughtsman, versed in geometry and optics, expert at figures, acquainted with history, informed on the principles of natural and moral philosophy, somewhat of a musician, not ignorant of the sciences both of law and physics, nor of the motions, laws, and relations to each other of the heavenly bodies." Again he adds: "Moral philosophy will teach the architect to be above meanness in his dealings and to avoid arrogance; it will make him just, compliant, and faithful to his employer; and, what is of the highest importance, it will prevent avarice gaining an ascendency over him; for he should not be occupied with the thoughts of filling his coffers, nor with the desire of grasping everything in the shape of gain, but by the gravity of his manners and a good character should be careful to preserve his dignity."

These quaint statements of the desirable qualities of a professional man are worthy to be considered rules of good professional living at this time fully as much as they were in the days of old Rome. His esteem for his profession was evidently high, but not higher than the value which every civil engineer should put upon his professional life. The need of a general education for a civil engineer is greater now even than in his day, although musical accomplishments need not be considered as essential in modern engineering practice. That qualification, it is interesting to observe in passing, was inserted by Vitruvius in order to illustrate the wide range of engineering practice in those days when the architect-engineer was called upon, among other things, to construct catapults and other engines of war, in which a nice adjustment of gut ropes was determined by the musical tones emitted under the desired tension.

=51. Ancient Views of the Physical Properties of Materials.=—When it is remembered that the chemical constitution of materials used in engineering was absolutely unknown, that no quantitative determination of physical qualities had been made, and that the first correct conception of engineering science had yet to be acquired, it is a matter of wonder that there had been attained the engineering development evidenced both by ancient writings like those of Vitruvius and great engineering works like those of Rome, in the Babylonian Plain and in Egypt. In discussing the problem of water-supply, he mentions that certain learned ancients, "physiologists and philosophers, maintained that there are four elements—air, fire, water, and earth—and that their mixture, according to the difference of the species, formed a natural mode of different qualities. We must recollect that not only from these elements are all things generated, but that they can neither be nourished nor grow without their assistance." This view of the construction of material things was not conducive to a clear comprehension of those physical laws which lie at the foundation of engineering science, and it is absolutely essential that these elementary considerations be kept constantly in view in considering the engineering attainments of the Romans and other ancient peoples.

=52. Roman Civil Engineers Searching for Water.=—In ancient times, as at present, it was very important in many cases to know where to look for water, and how to make what might promise to be a successful search for it. Vitruvius states that the sources of water for a supply may easily be found "if the springs are open and flowing above ground." If the sources are not so evident, but are more obscure, he recommends that "before sunrise one must lie down prostrate in the spot where he seeks to find it, and, with his chin placed on the ground and fixed, look around the place; for, the chin being fixed, the eye cannot range upwards further than it ought and is confined to the level of the place. Then where the vapors are seen curling together and rising into the air, there dig, because those appearances are not discovered in dry places." This method of discovering water-supply would be considered by modern engineers at least somewhat awkward as well as damp and disagreeable in the early morning hours. It is not more fantastic, however, or less philosophical than the use of the divining-rod, which has been practised in modern times as well as ancient, and is used even in some country districts at the present time.

Vitruvius does not forget that the local features, including both those of soil and of an artificial character, may affect the quality of the water and possibly make it dangerous. He, therefore, sets forth general directions by which good potable water may be found and that of a dangerous nature avoided. The necessity of distinguishing between good and bad water was as present to his mind and to the minds of the old Roman engineers as to civil engineers of the present day, but the means for making a successful discrimination were crude and obviously faulty, and very often unsuccessful. He set forth, what is well known, that rain-water when collected from an uncontaminated atmosphere is most wholesome, but proceeds to give reasons which would not now be

considered in the highest degree scientific.

In Chapter V of his Eighth Book there are described some "means of judging water" so quaint and amusing that they may now well be quoted even though no civil engineer would be bold enough to cite them in modern hydraulic practice. He says: "If it be of an open and running stream, before we lay it on, the shape of the limbs of the inhabitants of the neighborhood should be looked to and considered. If they are strongly formed, of fresh color, with sound legs and without blear eyes, the supply is of good quality." At another point he comes rather closely to our modern requirements which look to the exclusion of minute and elementary vegetable growths, when he says: "Moreover, if the water itself, when in the spring, is limpid and transparent, and the places over which it runs do not generate moss, nor reeds, nor other filth be near it, everything about it having a clean appearance, it will be manifest by these signs that such water is light and exceedingly wholesome."

=53. Locating and Designing Conduits.=—In treating of the manner of conducting water in pipes or other conduits, he adverts to the necessity of accurate levelling and the instruments that were used for that purpose. The three instruments which he mentions as being used are called the dioptra, the level (_libra aquaria_), and the chorobates, the latter consisting of a rod about 20 feet in length, having two legs at its extremities of equal length and at right angles to it. Cross-pieces were fastened between the rod and the legs with vertical lines accurately marked on them. These vertical lines were placed in a truly vertical position by means of plumb-lines so that the top of the rod was perfectly level, and the work could thus be made level in reference to it.

In Rome the water was generally conducted either by means of open channels, usually built in masonry for the purpose, or in lead pipes, or in "earthen tubes." Vitruvius states that the open channels should be as solid as possible, and have a fall of not less than one half a foot in 100 feet. The open channels were covered with an arch top, so that the sun might be kept from striking the water. After bringing the water to the city it was divided into three parts. One was for the supply of pools and fountains, another for the supply of baths, and a third for the supply of private houses. A charge was made for the use of water for the pools, fountains, and baths, and in this way a yearly revenue was obtained. A further charge was also made for the water used in private houses, the revenue from which was applied for the maintenance of the aqueduct which supplied the water. The treatment to be given to the different soils, rocks, and other materials through which the conduit was built which brought the supply to Rome is duly set forth by Vitruvius, and he describes the conditions under which tunnels were constructed. He also described the methods of classifying the lead pipes through which water was conducted from the reservoirs to the various points in the city after stating that they must be made in lengths of not less than 10 feet. The sheets of lead employed in the manufacture of the pipes he describes as ranging in width from 5 inches to 100 inches. The diameter of the pipe would obviously equal very closely the width of the sheet divided by the ratio between the circumference and the diameter of the corresponding circle.

=54. Siphons.=—He speaks of passing valleys in the construction of the conduits by means of what we now call siphons, and prescribes a method for relieving it of the accumulated air. In speaking of earthen tubes or pipes he says that they are to be provided not less than 2 inches thick and "tongued at one end so that they may fit into one another," the joints being coated with quicklime and oil. He further observes that water conducted through earthen pipes is more wholesome than that through lead, and that water conveyed in lead must be injurious because from it white lead is obtained, which is said to be injurious to the human system. Indeed the effects of lead-poisoning were recognized in those early days, and its avoidance was attempted. In the digging of wells he wisely states that "the utmost ingenuity and discrimination" must be used in the examination of the conditions under which wells were to be dug. He also appreciated the advantage of sedimentation, for he advises that reservoirs be made in compartments so that, as the water flows from one to another, sedimentation may take place and the water be made more wholesome.

=55. Healthful Sites for Cities.=—In the location of cities, as well as of private residences, Vitruvius lays down the general principle that the greatest care should be taken to select sites which are healthy and subject only to clean and sanitary surroundings. Marshy places and those subject to fogs, especially those "charged with the exhalations of the fenny animals," are to be avoided. Apparently this reference to "fenny animals" may have beneath it the fundamental idea of bacteria, but that is not certain. The main point of all these directions for the securing of sanitary conditions of living is that, so far as his technical knowledge permitted him to go, he insists on the same class of wholesome conditions that would be prescribed by a modern sanitary engineer.

=56. Foundations of Structures.=—Similarly in Chapter V of his First Book, on "Foundations of Walls and Towers," Vitruvius shows a realization of the principal conditions needful and requisite for the suitable founding of heavy buildings. After a sanitary site for a city is determined and one that can be put in communication with other people "by good roads, and river or sea navigation for the transportation of merchandise," he proceeds to state that "foundations should be carried down to solid bottom, if such can be found,

and that they should be built thereon of such thickness as may be necessary for the proper support of that part of the wall standing above the natural level of the ground. They should be of the soundest workmanship, and materials of greater thickness than the walls above." Again, in speaking of the foundations supporting columns, he states: "The intervals between the foundations brought up under the columns should be either rammed down hard, or arched, so as to prevent the foundation-piers from swerving. If solid ground cannot be come to, and the ground be loose or marshy, the place must be excavated, cleared, and either alder, olive, or oak piles, previously charred, must be driven with a machine as close to each other as possible and the intervals between the piles filled with ashes. The heaviest foundations may be laid on such a base." It is thus seen that pile foundations were used by the Romans, and that the piles were driven with a machine. It would be difficult to give sounder general rules of practice even after more than two thousand years' additional experience.

=57. Pozzuolana and Sand.=—Of all the materials which were useful to the Romans in their various classes of construction, including the foundations of roads, "pozzuolana" must have been the most useful, and that which contributed more to the development of successful construction in Rome than any other single agent. Vitruvius speaks of it frequently and gives rules not only for the use of it in the production of mortar and concrete, but also lays down at considerable length the treatment which should be given to lime in order to produce the best results. It was common, according to his statements, to use two measures of "pozzuolana" with one of lime in order to obtain a suitable cementing material. This mixture was used in varying proportions with sand and gravel or broken stone to produce concrete. He describes the various grades of sands to be found about Rome and the manner of using them. The statement is made that sand should be free of earth and that the best of it was such as to yield a "grating sound" when "rubbed between the fingers." This is certainly a good engineering test of sand. He prefers pit-sand to either river- or sea-sand; indeed throughout all his directions regarding this particular class of construction his rules might be used at the present time with perfect propriety.

=58. Lime Mortar.=—The old Romans had also discovered the advisability of allowing lime to stand for a considerable period of time after slaking. This insured the slaking of all those small portions which were possibly a little hydraulic and therefore slaked very slowly. He prescribes as a good proportion two parts of sand to one of lime, and also mentions the proportion of three to one. He attempts to explain the setting, as we term it, of lime, but his explanation in obscure terms, involving qualities of the elements of fire and air, is not very satisfactory.

=59. Roman Bricks according to Vitruvius.=—As is well known, the Romans were good brick-makers, and they were well aware that bricks made from "ductile and cohesive" "red or white chalky" earth were far preferable to those made of more gravelly or sandy clay. The Roman bricks were both sun-dried and kiln-burned.

=60. Roman Timber.=—Timber was a material much used by the Romans, and the greater part of that which they used probably was grown in Italy, although considerable quantities were imported from other localities. Vitruvius writes in considerable detail concerning the selection of timber while standing, as well as in reference to its treatment before being used in structures. Like every material used by the old Romans in construction, the various kinds and qualities of timber received careful study from them, and they were by no means novices in the art of producing the best results from those kinds of timber with which they were familiar.

=61. The Rules of Vitruvius for Harbors.=—In Chapter XII of his Fifth Book Vitruvius lays down certain general rules for the selection and formation of harbors, and it is known that the Romans were familiar with elaborate and effective harbor construction, as is shown by that at Ostia. He appreciates that a natural harbor is one which has "rocks or long promontories jutting out, which from the shape of the place form curves or angles," and that in such places "nothing more is necessary than to construct portices and arsenals around them, or passages to the markets." He then proceeds to state that if such a natural formation is not to be found, and that if "on one side there is a more proper shore than on the other, by means of building or of heaps of stones, a projection is run out, and in this the enclosures of harbors are formed." He then proceeds to explain how "pozzuolana" and lime, in the proportion of two of the former to one of the latter, are used in subaqueous construction. He also prescribed a mode of building a masonry wall up from the bottom of an excavation made within what we should call a coffer-dam, formed, among other things, "of oaken piles tied together with chain pieces." The Romans knew well how to select harbors and how to construct in an effective manner the artificial works connected with them, although it appears that the effects of tidal and river currents in estuaries were neither well understood in themselves nor in their transporting power of the solid material which those currents eroded.

=62. The Thrusts of Arches and Earth; Retaining-walls and Pavements.=—Although the Romans possessed little or no knowledge of analytical mechanics they attained to some good qualitative mechanical conceptions. Among other things they understood fairly well the general character of the thrust of an arch and the tendency of the earth to overthrow a retaining-wall. They knew that a

massive abutment was needed to receive safely the thrust of an arch, and they counterforted or buttressed retaining-walls in order to hold them firmly in place. They also realized the danger of wet earth pressing against a retaining-wall, and even made a series of offsets or teeth on the inside of the wall on which the earth rested in order to aid in holding the wall in place. Vitruvius recommends as a safeguard against the pressure of earth wet by winter rains that "the thickness of the wall must be proportioned to the weight of earth against it," and that counterforts or buttresses be employed "at a distance from each other equal to the height of the foundations, and of the same width as the foundations," the projections at the bottom being equal in thickness to that of the wall, and diminishing toward the top.

He gives in considerable detail instructions for the forming of pavements and stucco work, so many examples of which are still existing in Rome. These rules are in many respects precisely the same as would govern the construction of similar work at the present time. There are also described in a general way the methods of producing white and red lead, as pigments of paints, and a considerable number of other pigments of different colors.

=63. The Professional Spirit of Vitruvius.=—It is evident, from many passages in the writings of this Roman architect-engineer, that the ways of the professional men in old Rome were not always such as led to his peace of mind. Vitruvius utters bitter complaints which show that he did not consider purely professional knowledge and service to be adequately recognized or appreciated by his countrymen. He writes that in the city of Ephesus an ancient law provided that if the cost of a given work completed under the plans and specifications of an architect did not exceed the estimate, he was commended "with decrees and honors," but if the cost exceeded the estimate with 25 per cent added thereto, he "was required to pay that excess out of his own pocket." Then he exclaims, "Would to God that such a law existed among the Roman people, not only in respect to their public but also to their private buildings, for then the unskilful could not commit their depredations with impunity, and those who were the most skilful in the intricacies of the art would follow the profession!"

=64. Mechanical Appliances of the Ancients.=—It is well known that the ancients possessed at least some simple types of machines, for the reason that they raised many great stones to a considerable height in completed works after having transported them great distances from the quarries whence they were taken. Undoubtedly these machines were of a simple and crude character and were made effective largely by the power of great numbers of men. We are not acquainted with all the details of these machines, although the general types are fairly well known. The elementary machines, including the lever, the inclined plane, the pulley, and the screw, which is only an application of the inclined plane, were all used not only by the Romans, but probably by every civilized ancient nation. Vitruvius describes a considerable number of these machines, and from his descriptions it is clear that they had wide application in the structural works of the Romans. The block and fall, as we term the pulley at the present time, was a common machine in the plant of a Roman constructor, as were also various modifications and applications of the lever, the roller, and the inclined plane.

=65. Unlimited Forces and Time.=—It is neither surprising nor very remarkable that with the use of these simple machines, aided by a practically unlimited number of men, the necessary raising or other movement of heavy weights was accomplished by the Romans and other ancient peoples. It is to be borne in mind that the element of time was of far less consequence in those days than at present, and that the rate of progress made in the construction of most if not all ancient engineering works was what we should consider intolerably slow.

PART II.

BRIDGES.

CHAPTER VI.

=66. Introductory.=—Although the bridge structures of to-day serve the same general purposes as those served by the most ancient structures, they are very different engineering products. It is not long, in comparison with the historic and prehistoric periods during which bridges have been built, since the science of mechanics has been sufficiently developed to make bridge design a rational procedure; and it is scarcely more than a century since the principles of mechanics were first applied to the design of bridge structures in such a way as to determine even approximately the amount of stress produced in any member by the imposed load. Naturally the first efforts made toward a truly rational bridge design were in fact simple and crude and only loosely approximate in their results. Probably the first analytic treatment of bridges was given to the design of arches in masonry and then in cast-iron. As the action of forces in structures became better known through the development of mechanical science, the applications of the

latter became less crude and approximate and the approach to the refined accuracy of the present day was begun.

=67. First Cast-iron Arch.=—These older structures, nearly all of them arches or more or less related to the arch, first appeared in cast-iron in the latter part of the eighteenth century, when nothing like an accurate analysis of forces developed by the application of a given load was known. The first cast-iron arch was erected over the Severn in England near Coalbrookdale in the year 1779. This bridge had a span of 100 feet, and the under surface of the arch or soffit at the crown was 45 feet above the points at the abutment from which the arch sprang, or, as civil engineers put it, the arch had a span of 100 feet and a rise or versine of 45 feet. Other cast-iron arches were built in England soon after.

=68. Early Timber Bridges in America.=—Timber bridges have been built since the earliest historic periods and even earlier, but the widest and boldest applications of timber to bridge structures have been made in this country, beginning near the end of the eighteenth century and running to the middle of the nineteenth century, when timber began to be displaced by iron. Timber bridges and those of combined iron and timber are built to some extent even at the present day, but the most extended work of this class is to be found in the period just named.

In 1660 what was called the "Great Bridge" was built across the Charles River near Boston, and was a structure on piles. Other similar structures followed, but the first long-span timber bridge, where genuine bridge trussing or framing was used, appears to have been completed in 1792, when Colonel William P. Riddle constructed the Amoskeag Bridge across the Merrimac River at Manchester, N. H., in six spans of a little over 92 feet from centre to centre of piers. From that time timber bridges, mostly on the combined arch and truss principle, were built, many of them examples of remarkably excellent engineering structures for their day. Among these the most prominent were the Bellows Falls Bridge, in two spans of 184 feet each from centre to centre of piers, over the Connecticut River, built in 1785-92 by Colonel Enoch Hale; the Essex-Merrimac Bridge over the Merrimac River, three miles above Newburyport, Mass., built by Timothy Palmer in 1792, consisting actually of two bridges with Deer Island between them, the principal feature of each being a kind of arched truss of 160 feet span on one side of the island and 113 feet span on the other; the Piscataqua Bridge, seven miles above Portsmouth, N. H., in which a "stupendous arch of 244 feet cord is allowed to be a masterly piece of architecture, planned and built by the ingenious Timothy Palmer of Newburyport, Mass.," in 1794; the so-called "Permanent Bridge" over the Schuylkill River at Philadelphia, built in 1804-06 in two arches of 150 feet and one of 195 feet, all in the clear, after the design of Timothy Palmer; the Waterford Bridge over the Hudson River, built in 1804 by Theodore Burr, in four combined arch and truss spans, one of 154 feet, one of 161 feet, one of 176 feet, and the fourth of 180 feet, all in the clear; the Trenton Bridge, built in 1804-06 over the Delaware River at Trenton, N. J., by Theodore Burr, in five arch spans of the bowstring type, ranging from 161 feet to 203 feet in the clear; a remarkable kind of wooden suspension bridge built by Theodore Burr in 1808 across the Mohawk River at Schenectady, N. Y., in spans ranging in length from 157 feet to 190 feet; the Susquehanna Bridge at Harrisburg, Pa., built by Theodore Burr in 1812-16 in twelve spans of about 210 feet each; the so-called Colossus Bridge, built in 1812 by Lewis Wernwag over the Schuylkill River at Fairmount, Pa., with a clear span of 340 feet 3¾ inches; the New Hope Bridge, built in 1814 over the Delaware River, in six 175 feet combined arch and truss spans, and a considerable number of others built by the same engineer.

Some of these wooden bridges, like those at Easton, Pa., and at Waterford, N. Y., remained in use for over ninety years with only ordinary repairs and with nearly all of the timber in good condition. In such cases the arches and trusses have been housed and covered with boards, so as to make what has been commonly called a covered bridge. The curious timber suspension bridge built by Theodore Burr at Schenectady was used twenty years as originally built, but its excessive deflection under loads made it necessary to build up a pier under the middle of each span so as to support the bridge structure at those points. These bridges were all constructed to carry highway traffic, but timber bridges to carry railroad traffic were subsequently built on similar plans, except that Burr's plan of wooden suspension bridge at Schenectady was never repeated.

[Illustration: MOHAWK BRIDGE AT SCHENECTADY N.Y.

Built by Theodore Burr.

FIG. 1.]

[Illustration: PATENT BRIDGE "COLOSSUS"

Across the River Schuylkill at Philadelphia.

Single Arch 340 feet 3¾ inches.

Built by Lewis Wernwag.

FIG. 2.]

=69. Town Lattice Bridge.=—A later type of timber bridge which was most extensively used in this country was invented by Ithiel Town in January, 1820, which was known as the Town lattice bridge. This timber bridge was among those used for railroad structures. As shown by the plan it was composed of a close timber lattice, heavy plank being used as the lattice members, and they were all joined by wooden pins at their intersections. This type of timber structure was comparatively common not longer ago than twenty-five years, and probably some structures of its kind are still in use. The close latticework with its many pinned intersections made a very safe and strong frame-work, and it enjoyed deserved popularity. It was the forerunner in timber of the modern all-riveted iron and steel lattice truss. It is of sufficient significance to state, in connection with the Town lattice, that its inventor claimed that his trusses could be made of wrought or cast-iron as well as timber. In many cases timber arches were combined with them.

[Illustration: FIG. 3.]

=70. Howe Truss.=—The next distinct advance made in the development of bridge construction in the United States was made by brevet Lieutenant-Colonel Long of the Corps of Engineers, U.S.A., in 1830-39, and by William Howe, who patented the bridge known as the Howe truss, although the structure more lately known under that name is a modification of Howe's original truss. Long's truss was entirely of timber, including the keys, pins, or treenails required, and it was frequently built in combination with the wooden arch. The truss was considerably used, but it was not sufficiently popular to remain in use.

[Illustration: Howe Truss-Bridge.]

[Illustration: FIG. 4.]

The Howe truss was not an all-wooden bridge. The top and bottom horizontal members, known as "chords," the inclined braces between them and the vertical end braces, all connecting the two chords, were of timber, and they were bolted at all intersections; but the vertical braces were of round iron with screw ends. These rods extended through both chords and received nuts at both ends pressing on cast-iron washers through which the rods extended. These wrought-iron round rods were in groups at each panel-point, numbering as many as existing stresses required. The ends of the timber braces abutted against cast-iron joint-boxes. The railroad floor was carried on heavy timber ties running entirely across the bridge and resting upon the lower chord members. It was a structure simple in character, easily framed, and of materials readily secured. It was also easily erected and could quickly be constructed for any reasonable length of span. It possessed so many merits that it became widely adopted and is used in modified form at the present day, particularly on lines where the first cost of construction must be kept as low as possible. The large amount of timber in it and the simple character of its wrought-iron or steel members greatly reduces its first cost.

=71. Pratt Truss.=—In 1844 the two Pratts, Thomas W. and Caleb, patented the truss, largely of timber, which has since been perpetuated in form by probably the largest number of iron and steel spans ever constructed on a single type. The original Pratt trusses had timber upper and lower chords, but the vertical braces were also made of timber instead of iron, while the inclined braces were of round wrought-iron with screw ends, the reverse of the web arrangement in the Howe type. This truss had the great advantage of making the longest braces (of iron) resist tension only, while the shorter vertical braces resist compression. As a partially timber bridge it could not compete with the Howe truss, because it contained materially more iron and consequently was more costly. This structure practically closed the period of development of timber bridges.

=72. Squire Whipple's Work.=—What amounted to a new epoch in the development of bridge construction in this country practically began in 1840 when Squire Whipple built his first bowstring truss with wrought-iron tension and cast-iron compression members. While the Pratts and Howe had begun to employ to some extent the analysis of stresses in the design of their bridge members, the era of exact bridge analysis began with Squire Whipple. He subjected his bridge designs to the exacting requirements of a rational analysis, and to him belongs the honor of placing the design of bridges upon the firm foundation of a systematic mathematical analysis.

=73. Character of Work of Early Builders.=—The names of Palmer, Burr, and Wernwag were connected with an era of admirable engineering works, but, with bridge analysis practically unknown, and with the simplest and crudest materials at their disposal, their resources were largely constituted of an intuitive engineering judgment of high quality and remarkable force in the execution of their designs never excelled in American engineering. They occasionally made failures, it is true, but it is not recorded that they ever

made the same error twice, and the works which they constructed form a series of precedents which have made themselves felt in the entire development of American bridge-building.

CHAPTER VII.

=74. Modern Bridge Theory.=—The evolution of bridge design having reached that point where necessity of accurate analysis began to make itself felt, it is necessary to recognize some of the fundamental theoretical considerations which lie at the base of modern bridge theory, and which involve to a considerable extent that branch of engineering science known as the elasticity or strength of the materials used in engineering construction.

The entire group of modern bridge structures may be divided into simple beams or girders, trusses, arches, suspension bridges, and arched ribs, each class being adapted to carry either highway or railway traffic. That class of structure known as beams or girders is characterized by very few features. There are solid beams like those of timber, with square or rectangular cross-sections, and the so-called flanged girders which are constituted of two horizontal pieces, one at the top and the other at the bottom, connected by a vertical plate running the entire length of the beam. The fundamental theory is identically the same for both and is known as the "common theory of flexure," i.e., the theory of beams carrying loads.

If an ordinary scantling or piece of timber of square or rectangular cross-section, like a plank or a timber joist, so commonly used for floors, be supported at each end, it is a matter of common observation that it will sustain an amount of load depending upon the dimensions of the stick and length of span. When such a bar or piece is loaded certain forces or stresses, as they are called, are brought into action in its interior. The word "stress" is used simply to indicate a force that exists in the interior of any piece of material. It is a force and nothing else. It is treated and analyzed in every way precisely as a force. If the stresses or forces set up by the loading in the interior of the bar become greater than the material can resist, it begins to break, and the breaking of that portion of the timber in which the stresses or forces are greatest constitutes its failure. The load which produces this failure in a beam is called the breaking load of the beam. In engineering practice all beams are so designed or proportioned that the greatest load placed on them shall be only a safe percentage of the breaking load; the safe load usually being found between ■ and ■ of the breaking load. In most buildings the safe or working load, as it is called, is probably about ¼ of the breaking load.

[Illustration: FIG. 5.]

[Illustration: FIG. 6.]

[Illustration: FIG. 7.]

=75. The Stresses in Beams.=—The proper design of beams or girders to carry prescribed loads is based upon the stresses which are developed or brought into action by them. It can easily be observed that if a beam supported at each end be composed of a number of thin planks or boards placed one upon the other, it will carry very little load. Each plank or board acts independently of the others and a very small load will cause a sag, as shown in Fig. 6. If there be taken, on the other hand, a beam made of a single stick of timber of the same width and depth as the number of planks shown in Fig. 6, so as to secure the solid beam shown in Fig. 7, it is a further common observation that this latter beam may carry many times the load which the laminated beam, shown in Fig. 6, sustains. The thin planks or boards readily slide over each other, so that the ends present the serrated form shown in Fig. 6. The preventing of this sliding is the sole cause of the greatly increased stiffness of the solid beam shown in Fig. 7, for there is thus developed along the imaginary horizontal sections in the solid beam of Fig. 7 what are called shearing forces or stresses; and since they exist on horizontal sections or planes running throughout the entire length of the beam, they are called horizontal shears.

At each end of the beam shown in Fig. 7 there will be an upward or supporting force exerted by the abutments on which the ends of the beam rest. Those upward or supporting forces are shown at _R_ and _R′_ and are called reactions, because the abutments, so to speak, react against the ends of the beam when the latter is loaded. These reactions depend for their value on the amount and the location of the loading which the beam carries. Obviously these upward forces or reactions tend to cut or shear off the ends of the beam immediately above them, and if the loads were sufficiently large and the beam kept from bending, the reactions would actually shear off those ends, just as punches or shears in a machine-shop actually shear off the metal when the rivet-hole is punched, or when a plate is cut by shearing into two parts. The beam, however, bends or sags before shearing apart actually takes place.

[Illustration: FIG. 8.]

[Illustration: FIG. 9.]

=76. Vertical and Horizontal Shearing Stresses.=—If it be supposed that the length of the beam is divided into a great number of parts by imaginary vertical lines, like those shown in Fig. 8, then vertical shearing forces will be developed in those vertical planes and sometimes, though not often, they are enough to cause failure. It is not an uncommon thing, on the other hand, in timber to have actual shearing failure take place along a horizontal plane through the centre of the beam. Indeed this is recognized frequently as the principal method of failure in very short spans. When this horizontal shearing failure takes place, the upper and lower parts of the beam slide over each other and act precisely like the group of planks shown in Fig. 6.

If, then, the loaded beam be divided by vertical and horizontal planes into the small rectangular portions shown in Figs. 8 and 9, on each such vertical and horizontal imaginary plane there will be respectively vertical and horizontal shearing forces, which are shown by arrows in Fig. 9. It will be noticed in that figure that in each corner of the rectangle the two shearing forces act either toward or from each other; in no case do the two adjacent shearing forces act around the rectangle in the same direction. This is a condition of shearing stresses peculiar to the bent beam. It can be demonstrated by theory and is confirmed by experiment. There is a further peculiarity about these shearing forces which act in pairs either toward or from the same angle in any rectangle, and it is that the two stresses adjacent to each other have precisely the same value per square inch (or any square unit that may be used) of the surface on which they act. These stresses per square inch vary, however, either along the length of the beam or as the centre line of any normal cross-section is departed from. They are greatest along the centre line or central horizontal plane represented by _AB_, and they are zero at the top and bottom surfaces of the beam.

Inasmuch as the horizontal shear along the plane _A■B■_ is less than that along _AB_ in Fig. 9, a part of the latter has been taken up by the horizontal fibres of the beam lying between the two planes. In other words, the horizontal layer of fibres at _A■B■_ is subjected to a greater stress or force along its length than at _AB_. The same general observation can be made in reference to any horizontal layer of fibres that is farther away from the centre than another. Hence the farther any fibre is from the centre the greater will be the stress or force to which it is subjected in the direction of its length. It results, then, that the horizontal layers of fibres which are farthest from the centre line of the beam, i.e., those at the exterior surfaces, will be subjected to the greatest force or stress, and that is precisely what exists in a loaded beam whatever the material may be.

=77. Law of Variation of Stresses of Tension and Compression.=—Since a horizontal beam supported at each end is deflected or bent downward when loaded, it will take a curved form like that shown in either Fig. 7 or Fig. 10; but this deflection can only take place by the shortening of the top of the beam and the lengthening of its bottom. This shows that the upper part of the beam is compressed throughout its entire length, while the lower part is stretched. In engineering language, it is stated that the upper part of the beam is thus subjected to compression and the lower part to tension. The horizontal layers or fibres receive their tension and compression from the vertical and horizontal shearing forces in the manner already explained. If the conditions of loading of the bent beam should be subjected to mathematical analysis, it would be found that throughout the originally horizontal plane _AB_, Fig. 7, passing through the centre of each section there would be no stress of either tension or compression, although the horizontal shearing stress there would be a maximum. Further, as this central plane is departed from the stress of tension or compression per square inch in any vertical section would be found to increase directly as the distance from it. This is a very simple law, but one of the greatest importance in the design of all beams and girders, whatever may be the form or size of cross-section. It is a law, which applies equally to the solid timber beam and to the flanged steel girder, whether that girder be rolled in the mill or built up of plates and angles or other sections in the shop. It is a fundamental law of what is called the common theory of flexure, and is the very foundation of all beam and girder design. The horizontal plane represented by the line _AB_ in Fig. 8, along which there is neither tension nor compression, is called the “neutral plane,” and its intersection with any normal cross-section of the beam is called the “neutral axis” of that section. Mathematical analysis shows that the neutral plane passes through the centres of gravity of all the normal sections of the beam and, hence, that the neutral axis passes through the passes through the centre of gravity of the section to which it belongs.

=78. Fundamental Formulæ of Theory of Beams.=—The fundamental formulæ of the theory of loaded beams may be quite simply written. Fig. 10 exhibits in a much exaggerated manner a bent beam supporting any system of loads _W■_, _W■_, _W■_, etc., while Fig. 11 shows a normal cross-section of the same beam. In Fig. 10 _AB_ is the neutral line, and in Fig. 11 _CD_ is the neutral axis passing through the centre of gravity, _c.g._, of the section.

[Illustration: FIG. 10.]

[Illustration: FIG. 11.]

If _a_ is the amount of force or stress on a square inch (or other square unit), i.e., the intensity of stress, at the distance of unity from the neutral axis _CD_ of the section, then, by the fundamental law already stated, the amount acting on another square inch at any other distance _z_ from the neutral axis will be _az_. This quantity is called the "intensity of stress" (tension or compression) at the distance _z_ from the neutral axis. Evidently it has its greatest values in the extreme fibres of the section, i.e., _ad_ and _ad_■. At the neutral axis _az_ becomes equal to zero. _FG_ in Fig. 11 represents the same line as _FG_ in Fig. 10. If the line _FH_ in Fig. 11 be laid down equal to _ad_ and at right angles to _FG_, and if _O_ represent the centre of gravity, _c.g._, of the section, then let the straight line _LH_ be drawn. Any line drawn parallel to _FH_ from _FG_ to _LH_ will represent the intensity of stress in the corresponding part of the beam's cross-section. Obviously, as these lines are drawn in opposite directions from _FG_, those above _O_ will indicate stress of one kind, and those below that point stress of another kind, i.e., if that above be tension, that below will be compression. It can be demonstrated by a simple process that the total tension on one side of the neutral axis is just equal to the total compression on the other side, and from that condition it follows that the neutral axis must pass through the centre of gravity or centroid of the section.

Returning to the left-hand portion of Fig. 11, let _dA_ represent a very small portion of the cross-section; then will _az. dA_ be the amount of stress acting on it. The moment of this stress or force about the neutral axis will be

azdA·z = az²·dA.

If this expression be applied to every small portion of the entire section, the aggregate or total sum of the small moments so found will be the moment of all the stresses in the section about the neutral axis. That moment will have the value

_M_ = ∫_az²·dA_ = _a_ ∫_z²·dA_ = _aI_. (1)

In equation (1) the symbol ∫ means that the sum of all the small quantities to the right of it is taken, and _I_ stands for that sum which, in the science of mechanics, is called the moment of inertia of the cross-section about its neutral axis. The value of the quantity _I_ may easily be computed for all forms of section. Numerical values belonging to all the usual forms employed in engineering practice are found in extended tables in the handbooks of the large iron and steel companies of the country, so that its use ordinarily involves no computations of its value.

Equation (1) may readily be changed into two other forms for convenient practical use. In Fig. 10 _mn_ is supposed to be a very short portion of the centre line of the beam represented by _dl_. Before the beam is bent the section _FG_ is supposed to have the position _MN_ parallel to _PQ_. Also let _u_ be the small amount of stretching or compression (shortening) of a unit's length of fibre at unit's distance from the centre line _AB_ of the beam, then will _udl_ and _uzdl_ be the short lines parallel to _GN_ in the triangle _GmN_ shown in the figure. The point _C_ is the centre of curvature of the line _mn_, and _Cn = Cm_ is the radius. The two triangles _Cnm_ and _mNG_ are therefore similar, hence

udl _mn_ _dl_ I ------- = ---- = ----- ∴ u = ---. (2) I ρ ρ ρ

If the quantity called the coefficient or modulus of elasticity be represented by _E_, then, by the fundamental law of the theory of elasticity in solid bodies,

_a = Eu_. (3)

As has already been shown, the greatest stresses (intensities) in the section are +_ad_ (tension) and -_ad_■ (compression). If _K_ represent that greatest intensity of stress, then

_K_ _K = ad_, and _a_ = ----. (4) _d_

If the value of _a_ from equation (4) be substituted in equation (1),

_KI_ _M_ = -----. (5) _d_

=79. Practical Applications.=—Equation (5) is a formula constantly used in engineering practice. All quantities in the second member are known in any given case. _K_ is prescribed in the specifications, and is known as the "working resistance" in the design of beams and girders. For rolled steel beams in buildings it is frequently taken at 16,000 pounds, i.e., 16,000 pounds per square inch, about one fourth the breaking strength of the steel. In railroad-bridge work it may be found between 10,000 and 12,000

pounds, or approximately one fifth of the breaking strength of the steel. The quantities _I_ and _d_ depend upon the form and dimensions of the cross-section, and are either known or may be determined. The quotient _I ÷ d_ is now known as the "section modulus," and its numerical values for all forms of rolled beams can be found in published tables. The use of equation (5) is therefore in the highest degree convenient and practicable.

=80. Deflection.=—It is frequently necessary, both in the design of beams and framed bridges, to ascertain how much the given loading will cause the beam or truss to sag, or, in engineering language, to deflect below the position occupied when unloaded. The deflection is determined by the sagging in the vertical plane of the neutral line below its position when the structure carries no load. In Fig. 10 the curved line _AB_ is the neutral line of the beam when supporting loads. If the loads should be removed, the line _AB_ would return to a horizontal position. The line drawn horizontally through _A_ and indicated by _x_ is the position of the centre line of the beam before being bent. The vertical distance _w_ below this horizontal line shows the amount by which the point at the end of the line _x_ is dropped in consequence of the flexure of the beam. The vertical distance _w_ is therefore called the deflection. Evidently the deflection varies with the amount of loading and with the distance from the end of the beam. The curved line _AB_ in one special case only is a circle. The general character of that curve is determined by the loading and the length of span.

In order that the deflection may be properly considered it is necessary that the relation between _x_ and _w_ shall be established for all conditions of loading and length of span. If the value of _u_ from equation (2) be placed in equation (3), there will result

$$E\,a = \frac{}{\rho}. \quad (6)$$

If the value of _a_ from equation (6) be substituted in the last member of equation (1), there will at once result

$$EI\,M = \frac{}{\rho}. \quad (7)$$

It is established by a very simple process in differential calculus that

$$I\,\frac{d^2w}{} = \frac{}{\rho\,dx^2}. \quad (8)$$

Hence, substituting from equation (8) in equation (7),

$$\frac{d^2w}{dx^2}\,M = EI\,\frac{}{}. \quad (9)$$

Equation (9) may be used by means of some very simple operations in integral calculus to determine the value of _w_ in terms of _x_ and the loads on the beam when the value of the bending moment _M_ is known, and the procedures for determining that quantity will presently be given.

Using the processes of the calculus, the two following equations will immediately be found:

$$\frac{dw}{dx} = \frac{1}{EI}\int M dx; \quad (10)$$

$$w = \frac{1}{EI}\int\int M dx^2 \quad (11)$$

As already explained, numerical values for both _E_ and _I_ may be taken at once from tables already prepared for all materials and for all shapes of beams ordinarily employed in structural work, so that equation (11) enables the deflection or sag of the bent beam to be computed in any case. The expression _dw/dx_ is the tangent of the angle made by the neutral line of a bent beam with a horizontal line at any given point, and it is a quantity that it is sometimes necessary to determine. _dw_ and _dx_ are indefinitely short vertical and horizontal lines respectively, as shown immediately to the left of _B_ in Fig. 10.

Equation (11) is not used in structural work nearly as much as equation (5), but both of them are of practical value and involve only simple operations in their use.

=81. Bending Moments and Shears with Single Load.=—The second members of equations (5) and (9) exhibit values of the moments of the internal forces or stresses in any normal cross-section of a bent beam about the neutral axis of the section, while the values of _M_ must be expressed in terms of the external forces or loading. Inasmuch as the latter moment develops just the internal moment, it is obvious that the two must be equal. In order to write the value of the external moment in terms of any loading, it is probably the simplest procedure to consider a beam carrying a single load. In Fig. 12, _AB_ is such a beam, and _W_ is a load which may be placed anywhere in the span, whose length is _l_. The distances of the load from the abutments are represented by x_1 and x_2. The reactions or supporting forces exerted under the ends of the beam at the abutments are shown by _R_ and

_R′_. The reactions, determined by the simple law of the lever, are

_x■ x■_ _R = W_ ---- and _R■ = W_ ---- (12) _l l_

The greatest bending moment in the beam will occur at the point of application of the load, and its value will be

_x■x■_ _M■ = Rx■ = W_ ------- = -_R■x■_. (13) _l_

[Illustration:

_Wx■x■_ _M■ = Rx■ = -R■x■_ = ------- _l_

FIG. 12.]

The bending moments at the end of the beam are obviously zero, and the second and fourth members of equation (13) show that the moment increases directly as the distance from either end. Hence in the lower portion of Fig. 12, at _D_, immediately under the load _W_, the line _DC_ is laid off at any convenient scale to represent the moment _M_■. The straight lines _AC_ and _CB_ are then drawn. Any vertical intercept, as _FH_ or _KL_, between _AB_ and either _AC_ or _CB_ will represent the bending moment at the corresponding point in the beam. The simple triangular diagram _ACB_ therefore represents the complete condition of bending of the beam under the single load _W_ placed at any point in the span.

The beam _AB_ is supposed for the moment to have no weight. Consequently the only force acting upon the portion of the beam _AO_ is the reaction _R_, and, similarly, _R■_ is the only force acting upon the portion _OB_. Obviously so far as the simple action of these two forces or reactions is concerned, the tendency of each is to cause vertical slices of the beam, so to speak, to slide over each other. In other words, in engineering language, the portion _AO_ of the beam is subjected to the shear _S = R_, while _OB_ is subjected to the shear _S■ = -R■_. The cross-sectional area of the beam must be sufficient to resist the shear _S_ or _S■_. The upper part of Fig. 13 shaded with broken vertical lines indicates this condition of shear. It is evident from this simple case that the total vertical shears at the ends of any beam will be the reactions or supporting forces exerted at those ends, and that each will remain constant for the adjoining portion of the beam.

The third member of equation (13) shows that the greatest bending moment _M_■ in the beam varies as the product _x_■_x_■ of the segments of the span. That product will have its greatest value when _x_■ = _x_■. Hence _a simple beam loaded by a single weight will be subjected to the greatest possible bending moment when the weight is placed at the middle of the span, at which point also that moment will be found_.

=82. Bending Moments and Shears with any System of Loads.=—The general case of a simple beam loaded with any system of weights whatever may be represented in Fig. 13, in which the beam of Fig. 12 is supposed to carry three loads, _w_■, _w_■, _w_■. The spacing of the loads is as shown. The reactions or supporting forces _R■_ are determined precisely as in Fig. 12, each reaction in this case being the resultant of three loads instead of one. Applying the law of the lever as before, the reaction _R_ will have the value

_d d + c d + c + b_ _R = W■--- + W■------- + W■----------_. (14) _l l l_

A similar value may be written for _R■_, but it is probably simpler, after having found one reaction, to write

_R′ = W■ + W■ + W■ - R_. (15)

As the beam is supposed to have no weight, no load will act upon the beam between the given weights. The bending moments at the points of application of the three weights or loads will be

_M■_ = _Ra_, } _M■_ = _R_(_a + b_) - _W■b_, } (16) _M■_ = _R_(_a + b + c_) - _W■_(_b + c_) - W■c_.}

After substituting the value of _R_ from equation (14) in equations (16) the values of the latter are at once known.

[Illustration: FIG. 13.]

The bending produced by each weight will also be represented precisely like that in Fig. 12. The triangle _ANB_ represents the bending produced by _W_■; _AOB_ the bending produced by _W_■; and _APB_ the bending produced by _W_■. The resultant bending effect produced by the three loads or weights acting simultaneously is simply the summation of the three effects each due to a single load. Hence _DC_ is erected vertically through the point of application of _W_■, so as to equal _DN_ added to the two

vertical intercepts between _AB_ and _AP_, and _AB_ and _AO_. Similarly, _HF_ is equal to _HO_ added to the intercepts between _AB_ and _AP_, and _AB_ and _BN_. Finally, _KL_ is equal to _PL_ added to the other two intercepts, one between _AB_ and _BN_, and the other between _AB_ and _BO_. Straight lines then are drawn through _A_, _C_, _F_, _K_, and _B_. Any vertical intercept between _AB_ and _ACFKB_ will represent the bending moment in the beam at the corresponding point. Obviously any number of loads of any magnitude, or a uniform load, may be treated in precisely the same way.

An important practical rule can readily be deduced from the equations (16), each one of which may be regarded as a general equation of moments. If the system of three, or any other number of loads, be moved a small distance Δ_x_, while they all remain separated by the same distances as before, the bending moment _M_ will be changed by the amount shown in equation (16_a_):

ΔM = RΔx - W■Δx - W■Δx - etc. (16_a_)

If the notation of the differential calculus be used by writing the letter _d_ instead of Δ, and if both members of equation (16_a_) be then divided by _dx_, equation (16_b_) will result:

_ΔM dM_ --- = ---- = _R - W■ - W■_ - etc. = shear. (16_b_) _Δx dx_

The second member of this equation shows the sum of all the external forces acting on one portion of the beam, that portion being limited by the section about which the moment _M_ acts. That sum of all the external forces, as given by the second member of equation (16_b_), is evidently the total transverse shear at the section considered. Equation (16_b_) then shows, in the language of the differential calculus, that the first derivative of _M_ in respect to _x_ is equal to the total transverse shear. It is further established in the differential calculus that whenever a function, such as _M_, the bending moment, is a maximum or a minimum, the first derivative is equal to zero. The application of this principle to equation (16_b_) shows that the bending moment in any beam or truss has its greatest value wherever the shear is zero. Hence, in order to determine at what section the bending moment has its greatest value in any loaded beam carrying a given system of loads, it is only necessary to sum up all the forces or loads, including the reaction _R_, on that beam from one end to the point where that sum or shear is zero; at this latter point the greatest moment sought will be found. This is a very simple method of determining the section at which the greatest moment in the beam exists.

The preceding formulæ and diagrams may be extended to include any number of loads, and they are constantly used in engineering practice, not only for beams and girders in buildings, but also for bridges carrying railroad trains. Whatever may be the number of loads, the expressions for the bending moments at the various points of application of those loads are to be written precisely as indicated in equations (16). When the number of loads becomes great the number of terms in the equations correspondingly increase, but in reality they are just as simple as those for a smaller number of loads.

The diagram for the vertical shear in this beam is the lower part of Fig. 13. As in the case of Fig. 12 the shear at _A_ is the reaction _R_, as it is _R■_ at the other end of the beam. The shear in the portion _AD_ of the beam has the value _R_, but in passing the point _D_ to the right the weight _W■_ represented by _OT_ must be subtracted from _R_, so that the shear over the section _b_ of the span is _R_ - _W■_ or _QV_ in the diagram. Similarly, in passing the point _H_ toward the right, both _W■_ and _W■_ must be subtracted from _R_, giving the negative shear (the previous shear being taken positive) _VW_. The negative shear _VW_ remains constant throughout the distance _c_, but is increased by _W■_ at the point _L_, so that throughout the distance _d_ the shear _S■_ = _-R■_. These shear values are all shown in the lower portion of Fig. 13 by the vertical shaded lines. Obviously it is a matter of indifference whether the shear above the straight line _GJ_ is made positive or negative; it is only necessary to recognize that the signs are different.

In the case of heavy beams, either built or rolled, as in railroad structures, it is of the greatest importance to determine both the bending moments and the shears, as represented in the preceding equations and diagrams, and to provide sufficient metal to resist them.

The case of Fig. 13 is perfectly general for moments and shears, and the methods developed are applicable to any amount or any system of loading whatever.

=83. Bending Moments and Shears with Uniform Loads.=—Fig. 14 represents what is really a special case of Fig. 13, in which the loading is uniform for each unit of length of the beam throughout the whole span _l_. Inasmuch as the load is uniformly distributed, it is evident that the reaction at each end of the beam will be one half the total load, or

_wl_ _R = R_■ = ----. (17) 2

[Illustration: FIG. 14.]

The general expression for the bending moment at any point _G_ in the span, and located at the distance _x_ from the end _A_, will take the form

_x w_ _M_ = _Rx_ - _wx_.--- = --- _x_(l-_x_). (18) 2 2

This equation, giving the value of _M_, is the equation of a parabola with the vertex over the middle of the span. The bending moment at the latter point will be found by placing _x = l/2_ in equation (18), which will give

$$M = \frac{wl^2}{8}. \quad (19)$$

Hence, in Fig. 14, if the vertical line _DC_ be erected at _D_, so as to represent the value of _M_ in equation (19) to a convenient scale, the parabola _ACB_ may be at once drawn. Any vertical intercept, as _GF_ between _AB_ and the curve _AFCB_, will represent by the same scale the bending moment in the beam at the point indicated by the intercept. Equation (19), giving the greatest external bending moment in a simple beam due to a uniform load, is constantly employed in structural work, and shows that that moment is equal to the total load multiplied by one eighth of the span.

It has already been shown, in connection with Fig. 12, that when a single centre weight rests on a beam the centre bending moment is equal to that weight multiplied by one fourth the span. If the total uniform load in the one case is equal to the single load in the other, these equations show that the single centre load will produce just double the bending moment due to the same load uniformly distributed over the span. Wherever it is feasible, therefore, the load should be distributed rather than concentrated at the centre of the span.

That portion of Fig. 14 shaded with vertical lines shows the shear existing in the beam. Evidently the shear at each end is equal to the reaction, or one half the total load on the span. The expression for the shear at any point, as _G_, distant _x_ from _A_ will be

$$S = R - wx = w\left(\frac{l}{2} - x\right). \quad (20)$$

If _x = l/2_ in equation (20), _S_ becomes equal to zero. In other words, there is no shear at the centre of the span of a beam uniformly loaded. Hence, if at each end of the span a vertical line _AK_ or _BL_ be laid off downward, and if straight lines _KD_ and _DL_ be drawn, any vertical intercept, as _GH_, between these lines and _AB_ will represent the shear at the corresponding point. Equation (20) also shows that the shear _S_ at any point is equal to the load resting on the beam between the centre _D_ and that point. Although this case of uniform loading is a special one it finds wide application in practical operations.

=84. Greatest Shear for Uniform Moving Load.=—The preceding loads have been treated as if they were occupying fixed positions on the beams considered. This is not always the case. Many of the most important problems in connection with the loading of beams and bridges arise under the supposition that the load is movable, like that of a passing railroad train. One of the simplest of these problems, although of much importance, consists in finding the location of a uniform moving load, like that of a train of cars, which will produce the greatest shear at a given point of a simple beam, such as that represented in Fig. 15, in which a moving load is supposed to pass continuously over the span from the left-hand end _A_. It is required to determine what position of this uniform load will produce the greatest shear at the section _C_.

[Illustration: FIG. 15.]

Let the moving load extend from _A_ to any point _D_ to the right of _C_. The two reactions _R_ and _R■_ may be found by the methods already indicated. Let _W_ represent the uniform load resting on the portion _CD_ of the span. The shear _S′_ existing at _C_ will be

_S■ = R■ - W_. (21)

Let _R■_ be that part of _R■_ which is due to _W_, and _R■_ that part due to the load on _AC_. Evidently _R■_ is less than _W_; then

_S■ = R■ + R■ - W_. (22)

Since the negative quantity _W_ is greater than the positive quantity _R■_, _S′_ will have its greatest value when both _W_ and _R■_ are zero. Hence the greatest shear at the point _C_ will exist when

_S■ = R■_. (23)

Obviously the loading must extend at least from _A_ to _C_ in order that _R■_ may have its maximum value. Hence _the greatest shear at any section will exist when the uniform load extends from the end of the span to that section, whatever may be the density of the load_.

If the segment of the span covered by the moving load is greater than one half the span, the maximum shear is called the _main shear_; but if that segment is less than one half the span, the maximum shear is called the _counter-shear_. The reason for these two names will be apparent later in the discussion of bridge-trusses.

This rule for determining the maximum shear at any section of a beam is equally applicable to bridge-trusses under certain conditions, and has an important bearing upon the determination of the greatest stresses in some of the members of bridge-frames, although it has less importance now than it had in the earlier days of bridge-building.

=85. Bending Moments and Shears for Cantilever Beams.=—The case of a loaded overhanging beam or cantilever bracket, as shown in Fig. 16, is sometimes found. In that figure a single weight _W_ is supposed to be applied at the end, while a uniform load _w_ per unit of length extends over its length _l_. The bending moment at any point _C_ distant _x_ from the end will obviously be

$$M = Wx + \frac{wx^2}{2}. \quad (24)$$

[Illustration: FIG. 16.]

The greatest value of the bending moment will be found by placing _x_ equal to _l_ in equation (24), and it will have the value

$$M_{\blacksquare} = Wl + \frac{wl^2}{2}. \quad (25)$$

The shear at any point and at the end _A_ respectively will be

$$S = W + wx \text{ and } S_{\blacksquare} = W + wl. \quad (26)$$

The shear due to _W_ is equal to itself and is constant throughout the whole length of the beam.

The second term of the second member of equation (24) is the equation of a parabola with its vertex at _B_, Fig. 16. Hence if _AF_ be laid off equal to $(wl^2)/2$, and if the parabola _FHB_ be drawn, any vertical intercept, as _HK_, between that curve and _AB_ will represent the bending moment at the corresponding point. On the other hand, the first term of the second member of equation (24) shows that the bending moment due to _W_ varies directly as the distance from _B_. Hence if _AG_ be laid off vertically downward from _A_ equal to _Wl_ to any convenient scale, then any intercept, as _KL_, between _AB_ and _BG_ will represent the bending moment due to _W_ at the corresponding point of the beam.

=86. Greatest Bending Moment with any System of Loading.=—One of the most important positions of loading to be established either for simple beams or for bridge-trusses is that at which any given system of loading whatever is to be placed on any span so as to produce the maximum bending moment at any prescribed point in that span. In order to make the case perfectly general a system of arbitrary loads, like that shown in Fig. 17, is assumed and the system is supposed to be a moving one.

[Illustration: FIG. 17.]

The separate loads are placed at fixed distances apart, indicated by the letters _a_, _b_, _c_, _d_, etc., _W_■ being supposed to be at the head of the train, while _W_ is the last load having a variable distance _x_ between it and the end of the span. In Fig. 17 this system of moving loads or train is supposed to pass over the span _l_ from right to left. The problem is to determine the position of the loading, so that the bending moment at the section _C_ of the beam or truss will be a maximum, the section _C_ being at the distance _l■_ from the left-hand end of the span. The complete analysis of this problem is comparatively simple and may readily be found, but it is not necessary for the accomplishment of the present purpose to give it here. In order to exhibit the formula which expresses the desired condition, let _W_■■ be that weight which is really placed at _C_, but which is assumed to be an indefinitely short distance to the left of that point, for a reason which will presently be explained. The equation of condition or criterion sought will then be the following:

_l■ W■ + W■ + ... + W■■_ ----- = ----------. (27) _l W■ + W■ + W■ + ... + W■_

If the loads are so placed as to fulfil the condition expressed in equation (27), the bending moment at section _C_ will be a maximum. If the variation in the train weights is very great, it is possible that there may be more than one position of the train which will satisfy that equation. It is necessary, therefore, frequently to try different positions of the loading by that criterion and then ascertain which of the resulting maximum moments is the greatest. It is not usually necessary to make more than one or two such trials. The application of the equation is therefore simple and involves but little labor.

It will usually happen that _W_■■ in equation (27) is not to be taken as the whole of that weight, but only so much of it as may be necessary to satisfy the equation. This is simply assuming that any weight, _W_, may be considered as made up of two separate weights placed indefinitely near to each other, which is permissible.

After having found the position of loading which satisfies equation (27), the resulting maximum bending moment will take the following form:

_l■_ _M■_ = ----- [_W■a_ + (_W■+ W■_)_b_ + ... + (_W■ + W■ + ... + W■_)_x_] _l_

- _W■a_ - (_W■ + W■_)_b_ - ... - (_W■ + W■ + ... + W■■■■■■_)(?). (28)

In this equation _x_ corresponds to the position of loading for maximum bending, while the sign (?) represents the distance between the concentrations _W_■■■■■■ and _W_■■. This equation has a very formidable appearance, but its composition is simple and it is constantly used in making computations for the design of railroad bridges. The loads _W_■, _W_■, _W_■, etc., represent the actual weights on the driving-axles and other axles of locomotives, tenders, and cars, and the spacings _a_, _b_, _c_, etc., are the actual spacings found between those axles. In other words, these quantities are the actual weights and dimensions of the different portions of moving railroad trains.

The computations indicated by equation (28) are not made anew in every instance. Concentrated weights of typical locomotives, tenders, and cars are prescribed by different railroad companies for their different classes of trains, ranging from the heaviest freight traffic to the lightest passenger train. A tabulation is then made from equation (28) for each such typical train, and it is used as frequently as is necessary to design a bridge to carry the prescribed traffic. The tabulations thus made are never changed for a given or prescribed loading.

=87. Applications to Rolled Beams.=—It is to be remembered that these last observations do not limit the use of equations (27) and (28) to railroad-bridge trusses only; they are equally applicable to solid and rolled beams and are frequently used in connection with their design. Great quantities of these beams and various rolled steel shapes are used in the construction of large modern city buildings, as well as in railroad and highway bridge structures. The steel frames of the great office buildings, so many of which are seen in New York and Chicago as well as in other cities, which carry the entire weight of the building, are formed wholly of these steel shapes. The so-called handbooks published by steel-producing companies exhibit the various shapes rolled in each mill. These books also give in tabular statements many numerical values of the moment of inertia, the section modulus, and other elements of all these sections, so that the formulæ which have been established in the preceding pages may be applied in practical work with great convenience and little labor. Tables are also given showing the sizes of rolled beams required to sustain the loads named in them. Such tables are formed for practical use, so that, knowing the distance apart of the beams, their span, and the load per square foot which they carry, the required size of beam may be selected without even computation. Such labor-saving tables are quite common at the present time, and they reduce greatly the labor of numerical computations.

CHAPTER VIII.

=88. The Truss Element or Triangle of Bracing.=—A number of the preceding formulæ find their applications to bridge-trusses, as well as to beams; hence it is necessary to give attention at least to some simple forms of those trusses.

[Illustration: FIG. 18.]

[Illustration: FIG. 18_a_.]

The skeleton of every bridge-truss properly designed to carry its load is an assemblage of triangles. In other words, the truss element, i.e., the simplest possible truss, is the triangular frame, such as is shown in skeleton in Figs. 18 and 18_a_. These simple triangular frames are sometimes called the King-post Truss. The action of such a triangular frame in carrying a vertical load is

extremely simple. In Fig. 18 let the weight _W_ be suspended from the apex _C_ of the triangle. The line _CF_ represents that weight, and if the latter be resolved into its two components parallel to the two upper members of the triangular frame, the two component forces _CG_ and _CD_ will result. If from _D_ and _G_ the horizontal lines _DH_ and _GO_ be drawn, those two lines will represent the horizontal components of the forces or stresses in the two bars _CA_ and _CB_. The force _HD_ will act to the left at the point _A_, and the force _CG_ will act to the right at _B_, and as these two forces are equal and opposite to each other, equilibrium will result. Either of the horizontal forces will represent the magnitude of the tension in _AB_. Both _AC_ and _CB_ will be in compression, the former being compressed by the force _CD_, and the latter by the force _CG_. The manner of drawing a parallelogram of forces makes the triangle _COG_ similar to _CNB_, and _CHD_ similar to _CNA_; hence _HW_ divided by _CH_ will be equal to _AN_ divided by _NB_. But _HW_ is the vertical component of the stress in _CB_, while _CH_ is the vertical component of the stress in _AC_, the latter being represented by the reaction _R_ and the former by the reaction _R′_. It is seen, therefore, that the weight _W_ is carried by the frame to the two abutment supports _A_ and _B_, precisely as if it were a solid beam. In other words, the important principle is established that when weights rest upon a simple truss supported at each end they will produce reactions at the ends in accordance with the principle of the lever, precisely as in the case of a solid beam. In engineering parlance it is stated that the weight _W_ is divided according to the principle of the lever, and that each portion travels to its proper abutment through the members of the triangular frame. If the two inclined members of the triangular frame are equally inclined to a vertical, the case of Fig. 18_a_ results, in which one half of the weight goes to each abutment.

The triangular frame, with equally inclined sides, shown in Fig. 18_a_, is evidently the simplest form of roof-truss, constituting two equally inclined members with a horizontal tie.

=89. Simple Trusses.=—The simplest forms of trussing used for bridge purposes are those shown in Figs. 19, 20, and 21. There are many other forms which are exhibited in complete treatises on bridge structures, but these three are as simple as any, and they have been far more used than any other types. The horizontal members _af_ and _AB_ are called the “chords,” the former being the upper chord and the latter the lower chord. The vertical and inclined members connecting the two chords are called the web members or braces. When a bridge is loaded, either by its own weight only, or by its own weight added to that of a moving train of cars, the upper chord will evidently be in compression, while the lower chord is in tension. A portion, which may be called a half, of the web members will be in tension and the other portion, or half, will be in compression.

The function of the upper and lower chords is to take up or resist the horizontal tension and compression which correspond to the direct stresses of tension and compression existing in the longitudinal fibres of a loaded solid or flanged beam. The metal designed to take these so-called direct stresses is concentrated in the chords of trusses, whereas it is distributed throughout the entire section of a beam, whether that beam be solid or flanged. The function of the web members of a truss is to resist the transverse or vertical shear which is represented by the algebraic sum of the reactions and loads. The total section of a solid beam resists these vertical shears, while the web only of a flanged beam is estimated to perform that duty. The horizontal shears, which have already been recognized as existing along the horizontal planes in a bent beam, are resisted by the inclined web members of a truss, the horizontal stress components being the horizontal shears, whereas the vertical shears are resisted by the vertical web members of a truss. If the web members are all inclined, as shown in Fig. 21, each web member resists both horizontal and vertical shear. It is thus seen that the members of a truss perform precisely the same duties as the various portions of either solid or flanged beams. Inasmuch as the chords of bridge-trusses resist the direct or horizontal stresses of tension and compression produced by the bending in the truss, it is obvious that the greatest chord stresses will be found at the centre of the span, and that they will be the smallest at the ends of the span. In the web members, on the contrary, since the vertical shear is the greatest at the ends of the span and equal to the reactions at those points, decreasing towards the centre precisely as in solid beams, the greatest web stresses will be found at the ends of the span and the least near the centre. It is obvious that the areas of cross-sections of either chords or web members must be proportioned to the stresses which they carry. Hence the distribution of stresses just described tends to a uniform distribution of the truss weights over the span.

=90. The Pratt Truss Type.=—In the discussion of these three simple types of trusses, the simplest possible loading of a perfectly uniform train will be assumed. The portions into which the trusses are divided by the vertical or inclined bracing are called panels. In Fig. 19, for instance, the points 1, 2, 3, 4, 5, and 6 of the lower chord and _a_, _b_, _c_, _d_, _e_, and _f_ of the upper chord are called panel-points. The distance between each consecutive two of these points is called a panel length. The uniform train-load which is to be assumed will be represented by the weight _W_ at each panel-point. This is called the “moving load” or “live load.” The own weight of the structure is called the “dead load” or the “fixed load.” The dead load per upper-chord panel will be taken as _W■_, and _W_■ for the lower chord. The loads to be used will, therefore, be as follows:

Panel moving load = _W_; Upper-chord panel dead load = _W■_; Lower " " " " = _W_■.

There will also be used the length of panel and depth of truss as follows:

Panel length = _p_; Depth of truss = _d_.

In these simple trusses with horizontal upper and lower chords the stress in any inclined web members is equal to the shear multiplied by the secant of the inclination of the members to a vertical line. Also, at each panel-point every inclined web member, in passing from the end to the centre of the span, adds to either chord stress at that point an amount represented by the horizontal component of the stress which it carries; or, what is the same thing, an amount equal to the shear at the panel in question multiplied by the tangent of its angle of inclination to a vertical line.

It has already been shown in discussing solid beams that the greatest shear at any section will be found when the uniform moving load covers one of the segments of the span. This principle holds equally true for trusses carrying uniform panel-loads like those under consideration. In determining the stresses in these trusses, therefore, the inclined web members will take their greatest stresses when the moving train or load extends from the farthest end of the span up to the foot of the member in question. In this connection it is to be observed also that any two web members meeting in the chord which does not carry the moving load take their greatest stresses for the same position of the latter. The so-called "counter web members" take no stresses from the dead load.

Inasmuch as every load placed upon a truss will produce compression in the upper chord and tension in the lower, the greatest chord stresses will obviously exist when the moving load covers the entire span, and that condition of loading is to be used for the stresses in the following cases.

Bearing these general observations in mind, the ordinary simple method of truss analysis yields the tabulated statement of stresses given below for the three types selected for consideration. The first case to be treated is that of Fig. 19, which represents the Pratt truss type. The moving load is supposed to pass across the bridge from right to left. The plus sign indicates tension and the minus sign compression.

[Illustration: FIG. 19.]

Stress in c■ = + (^{1}/■ + ^{2}/■) _W_ sec _a_ = ^{3}/■ _W_ sec _a_. _Stress in T■_ = + (^{1}/■ + ^{2}/■ + ^{3}/■) _W_ sec _a_ = ■/■ _W_ sec _a_; " " _T■_ = + [(^{1}/■ + ^{2}/■ + ^{3}/■ + ■/■) _W_ + _W■_ + _W■_] sec _a_ = (^{1}■/■ _W_ + _W■_ + _W■_) sec _a_; " " _T■_ = + [(^{1}/■ + ^{2}/■ + ^{3}/■ + ■/■ + ■/■) _W_ + _2w■_ + _2w■_] sec _a_ = (^{1}■/■ W + 2w■ + 2w■) sec _a_; " " _T■_ = + (_W_ + _W■_).

Stress in P■ = -(■/■ _W_ + _W■_); " " _P■_ = -(^{1}■/■ _W_ + 2_W■_ + _W■_); " " _P■_ = -3(_W_ + _W■_ + _W■_) sec _a_.

Stress in L■ =_Stress in L■_ = + 3(_W_ + _W■_ + _W■_) tan _a_; " " _L■_ = " " _L■_ + 2(_W_ + _W■_ + _W■_)tan _a_ + + 5(_W_ + _W■_ + _W■_) tan _a_; " " _L■_ = " " _L■_ + (_W_ + _W■_ + _W■_) tan _a_ + 6(_W_ + _W■_ + _W■_) tan _a_.

Stress in U■ = _-Stress in L■_ = -5(_W_ + _W■_ + _W■_) tan α; " " _U■_ = - " " _L■_ = -6(_W_ + _W■_ + _W■_) tan α; " " _U■_ = " " _U■_ = -6(_W_ + _W■_ + _W■_) tan α.

It is easy to check any of the chord stresses by the method of moments. As an example, let moments first be taken about the panel-point 5 in the lower chord, and then about the panel-point _c_ in the upper chord. The following expressions for the chord members _U■_ and _L■_ will be found, and it will be noticed that they are identical with the stresses for the same members given in the preceding tabulation, the counter-members, shown in broken lines, being omitted from consideration as they are not needed.

_R.2p_ - (_W + W■ + W■_)_p_ _Stress in U■_ = ---------- _d_

_p_ = 5(_W + W■ + W■_) ---- = 5(_W + W■ + W■_) tan α. (29) _d_

_R.3p_ - 2(_W + W■ + W■_) . 1½_p_ _Stress in L■_ = ---------- _d_

= 6(_W + W■ + W■_) tan α. (30)

[Illustration: FIG. 20.]

=91. The Howe Truss Type.=—The truss shown in Fig. 20 is the skeleton of the Howe truss, to which reference has already been made. The inclined web members are all in compression, while the vertical web members are all in tension. In the Howe truss all compression members are composed of timber. It has the disadvantage of subjecting the longest web members to compression. It thus makes the truss, if built all in iron or steel, heavier and more expensive than the trusses of the Pratt type. As in the preceding case, the moving train or load is supposed to pass across the bridge from _B_ to _A_. Also, as before, the + sign indicates tension and the - sign compression. The greatest stresses, given in the tabulated statement below, can be computed or checked by the method of moments in this case, precisely as in the preceding.

Stress in c■ = -(1/■ + 2/■) _W_ sec _a_ = -3/■ _W_ sec _a_.

Stress in P■ = -(1/■ + 2/■ + 3/■) _W_ sec _a_ = -■/■ _W_ sec _a_; " " P■_ = -(_1■/■ W + W■ + W■_) sec _a_; " " P■_ = -(_1■/■ W + 2W■ + 2W■_) sec _a_; " " P■_ = -3(_W + W■ + W■_) sec _a_.

Stress in T■ = + (_1■/■ W + W■_) sec _a_; " " T■_ = + (_1■/■ W + W■ + 2W■_) sec _a_; " " T■_ = + (_3W + 2W■ + 3W■_) sec _a_.

Stress in L■ = + 3(_W + W■ +W■_) tan _a_; " " L■_ = + 3(_W + W■ + W■_) tan _a_+2(_W + W■ + W■_) tan _a_ = + 5(_W + W■ + W■_) tan _a_; " " L■_ = + 5(_W + W■ + W■_) tan _a_+(_W + W■ + W■_) tan _a_ = + 6(_W + W■ + W■_) tan _a_; " " L■_ = _Stress in L■._

Stress in U■ = _- Stress in L■_ " " U■_ = _- " " L■_; " " U■_ = _- " " L■_.

It will be noticed in the cases of Figs. 19 and 20 that upper and lower chord panels in the same lozenge or oblique panel have identically the same stresses, but with opposite signs. For instance, in Fig. 20 the stress in _U■_ is equal in amount to that in _L■_; and the same observation can be made in reference to the stresses in _U■_ and _L■_ of Fig. 19. This must necessarily always be the case in trusses having vertical web members.

In making computations for these forms of trusses it is very essential to observe where the first counter-member, as _c■_, must be used. These counter-members may be omitted if the proper main web members near the centre of the span are designed to take both tension and compression.

=92. The Simple Triangular Truss.=—The truss shown in Fig. 21, in which all the web members have equal inclination to a vertical line, is sometimes called the Warren Truss, although that term has also been applied specially to this type of truss so proportioned as to make the depth just equal to the panel length. As before, the moving train is supposed to pass over the bridge from _B_ toward _A_, while the + sign represents tension and the - sign compression. The greatest stresses are the following.

[Illustration: FIG. 21.]

{ -(_■/■W + ½W■_) sec _a_, or _Stress in P■_ = { +(_■/■W - ½W′_) sec _a_; " " P■_ = { -(_1■/■W + 1½W′ + W■_) sec _a_, or { +(_3/■ W - 1½W■ - W■_) sec _a_;

" " P■_ = -(_1■/■ W + 2½W■ + 2W■_) sec _a_; " " P■_ = -(_3W + 3½ W■ + 3W■_) sec _a_.

{ +(_1■/■W + ½W■ + W■_) sec _a_, or _Stress in T■_ = { -(_3/■W - ½W■ - W■_) sec _a_;

" " T■_ = +(_1■/■W + 1½W′ + 2W■_) sec _a_; " " T■_ = +(_3W + 2½W■ + 3W■_) sec _a_.

Stress in L■ = + 3(_W + W■ + W■_) tan _a + ½W′_ tan _a_; " " L■_ = _Stress in L■_ + (_5W + 5W■ + 5W■_) tan _a_ = + 8(_W + W■ + W■_) tan _a + ½W■_ tan _a_; " " L■_ = _Stress in L■_ + 3(_W + W■ + W■_) tan _a_ = + 11 (_W + W■ + W■_) tan _a + ½W■_ tan _a_; " " L■_ = _Stress in L■_ + (_W + W■ + W■_) tan _a_ = + 12 (_W + W■ + W■_) tan _a + ½W■_ tan _a_.

Stress in U■ = -6(_W + W■ + W■_) tan _a_; " " U■_ = -6(_W + W■ + W■_)tan _a_ - 4(_W + W■ + W■_) tan _a_ = -10(_W + W■ + W■_) tan _a_;

" " U■_ = -10(_W+ W■+ W■_) tan _a_ - 2(_W + W■ + W■_) tan _a_ = -12(_W + W■ + W■_) tan _a_.

The chord stresses may be checked or found by the method of moments, precisely as in the case of Fig. 19. If, for instance, it is desired to determine the stresses in the upper chord member _U■_, moments must be taken about the lower-chord panel-point 5, and about the upper-chord panel-point _d_ for the lower-chord stress in _L■_. Taking moments about those points, results given in

equations (31) and (32) will at once follow, which it will be observed are identical with the values previously found for the same members.

(_3W + 3½ W′ + 3W■_)._2p_ - 2_W′p_ - (_W + W■_)_p_ _Stress in U■_ = - ---------- _d_

= -10(_W + W′ + W■_) tan _a_. (31)

(_3W + 3½ W′ + 3W■_)._3½ p_ - 3(_W + W■_)._1½p - 3W′.2p_ _Stress in L■_ = + ---------- _d_

= + 12(_W + W■ + W′_) tan _a_ + ½_W′_ tan _a_. (32)

=93. Through- and Deck-Bridges.=—These simple trusses have all been taken as belonging to the "through" type, i.e., the moving load passes along their lower chords. It is quite common to have the moving load pass along the upper chords, in which cases the bridges are said to be "deck" structures. The general methods of computation are precisely the same whether the trusses be deck or through. It is only necessary carefully to observe that the application of the methods of analysis depends upon the position of each panel-load as it passes across the structure.

[Illustration: Fig. 22.]

=94. Multiple Systems of Triangulation.=—Figs. 19, 20, and 21 exhibit what are called single systems of triangulation or single systems of bracing, but in each of those types the system of web members may be double or triple; in other words, they may be manifold. There have been many bridges built in which two or more systems of bracing are employed. Fig. 22 represents a truss with a double system of triangulation, known at one time as the Whipple truss. Fig. 23, again, exhibits a quadruple system of triangulation with all inclined web members. The method of computation for such manifold systems is precisely the same as for a single system, each system in the compound truss being treated as carrying those loads only which rest at its panel-points. This procedure is not quite accurate. The complete consideration of an exact method of computation would take the treatment into a region of rather complicated analysis beyond the purposes of these lectures, but its outlines will be set forth on a later page. The exact method of treatment of two or more web systems involves the elastic properties of the material of which the trusses are composed. In the best modern bridge practice engineers prefer to design trusses of all lengths with single web systems, although the panels are frequently subdivided to avoid stringers and floor-beams of too great weight.

[Illustration: Fig. 23.]

=95. Influence of Mill and Shop Capacity on Length of Span.=—In the early years of iron and steel bridge-building the sizes of individual members were limited by the shop capacity for handling and manufacturing, and by the relatively small dimensions of bars of various shapes, and of plates which could be produced by rolling-mills. As both mill and shop processes have advanced and their capacities increased, corresponding progress has been made in bridge design. Civil engineers have availed themselves of those advances, so that at the present time single system trusses with depths as great as 85 feet or more and spans of over 550 feet are not considered specially remarkable.

=96. Trusses with Broken or Inclined Chords.=—As the lengths of spans have increased certain substantial advantages have been gained in design by no longer making the upper chords horizontal in the case of long through-spans, or indeed in the cases of through-spans of moderate length. The greatest bending moments and the greatest chord stresses have been shown to exist at the centre of the span, while the greatest web stresses are found near the ends. Trusses may be lightened in view of those considerations by making their depths less at the ends than at the centre. This not only decreases the sectional areas of the heaviest web members near the ends of the truss, but also shortens them. It adds somewhat to the sectional area of the end upper-chord members, but the resultant effect is a decrease in total weight of material and increased stability against wind pressure by the decreased height and less exposure near the ends. It has therefore come to be the ruling practice at the present time to make through-trusses with inclined upper chords for practically all spans from about 200 feet upward. A skeleton diagram of such a truss is given in Fig. 24.

[Illustration: Fig. 24.]

=97. Position of any Moving Load for Greatest Web Stress.=—In the preceding treatment of bridge-trusses with parallel and horizontal chords a moving or live load has been taken as a series of uniform weights concentrated at the panel-points. This simple procedure was formerly generally used, and at the present time it is occasionally employed, but it is now almost universal practice to assume for railroad bridges a moving load consisting of a series of concentrations, which represent both in amount and

distribution the weights on the axles of an actual railroad train. If a bridge is supposed to be traversed by such a train, it becomes necessary to determine a method for ascertaining the positions of the train causing the greatest stresses in the various members of the bridge-truss. The mathematical demonstration of the formulæ determining those positions of loading need not be given here, but it can be found in almost any standard work on bridges.

In order to show concisely the results of such a demonstration let it be desired to find the position of a moving load which will give the greatest stress to any web member, as _S_ in Fig. 24. Let the point of intersection of _GK_ and _DC_ be found in the point _O_, then let _CK_ be extended, and on its extension let the perpendicular _h_ be dropped from _O_. The distance of the point _O_ from _A_, the end of the span, is _i_, while _m_ is the distance _AD_. Using the same notation which has been employed in the discussion of beams, together with that shown in Fig. 24, equation (33) expresses the condition to be fulfilled by the train-loads in order that _S_ shall have its greatest stress. The first parenthesis in the second member of that equation represents the load between the panel _p_ and the left end of the span, while the second parenthesis represents the load in panel _p_ itself.

_l_ _W■ + W■ + ... + W■_ = - ----(_W■ + W■_ + etc.) _i_

_l_(_m + i_) + (_W■ + W■_ + etc.) ---------- (33) _pi_.

It will be noticed in equation (33) that the quantity _m_ shows in what panel the inclined web member whose greatest stress is desired is located, and it is important to observe that panel carefully. If, for instance, the vertical member _KD_ were in question, the point _O_ would be located at the intersection of the panel _NK_ and the lower chord of the bridge. In other words, the point _O_ must be at the intersection of the two chord members belonging to the same panel in which the web member is located.

=98. Application of Criterions for both Chord and Web Stresses.=—The criterion, equation (33), belongs to web members only. If it is desired to find the position of moving load which will give the greatest chord stresses in any panel, equation (27), already established for beams, is to be used precisely as it stands, the quantity _l′_ representing the distance from one end of the span to the panel-point about which moments are taken.

If the desired positions of the moving load for greatest stresses have been found by equations (27) and (33), those stresses themselves are readily found by taking moments about panel-points for chord members and about the intersection-points _O_, Fig. 24, for web members. These operations are simple in character and are performed with great facility. Tabulations and diagrams are made for given systems of loading by which these computations are much shortened and which enable the numerical work of any special case to be performed quickly and with little liability to error. These tabulations and diagrams and other shortening processes may be found set forth in detail in many publications and works on bridge structures. They constitute a part of the office outfit of civil engineers engaged in structural work.

The criterion, equation (27), for the greatest bending moments in a bridge is applicable to any truss whatever, whether the chords are parallel or inclined, but it is not so with equation (33). If the chords of the trusses are parallel, the quantity _i_ in equation (33) becomes infinitely great, and the equation takes the following form:

_l_ _W■ + W■ + ... + W■_ = ---- (_W■ + W■_ + etc.) (34) _p_

Ordinarily the span _l_ divided by the panel length _p_ is equal to the number of panels in the span. Hence equation (34) shows, in the case of parallel or horizontal chords, that when the moving load is placed for the greatest web stress in any panel, the total load on the bridge is equal to the load in that panel multiplied by the total number of panels.

=99. Influence Lines.=—A graphical method, known as that of “influence lines,” is used for determining the greatest shears and bending moments caused by a train of concentrated weights passing along a beam or bridge-truss. Obviously it must express in essence that which has already been shown by the formulæ which determine positions of moving loads for the greatest shears and bending moments. In reality it is the application of graphical methods which have become so popular to the determination of the greatest stresses in beams and bridges.

=100. Influence Lines for Moments both for Beams and Trusses.=—It is convenient to construct these influence lines for an arbitrary load which may be considered a unit load; the effect of any other load will then be in proportion to its magnitude. The results determined from influence lines drawn for a load which may be considered a unit can, therefore, be made available for other loads by multiplying the former by the ratio between any desired load and that for which the influence lines are found.

[Illustration: FIG. 25.—Bending Moment in a Simple Beam.]

_AB_ in Fig. 25 represents a beam simply supported at each end, so that any load _g_ resting upon it will be divided between the points of support, according to the law of the lever. Let it be desired to determine the bending moment at the section _X_ produced by the load _g_ in all of its positions as it passes across the span from _A_ to _B_. Two expressions for the bending moment must be written, one for the load _g_ at any point in _AX_, and the other for the load at any point in _BX_. The expression for the first bending moment is

_z_ _M = g_ ----(_l-x_), (_a_) _l_

and that for the latter

_l-z_ _M′ = g_ ---- _x_. (_b_) _l_

As shown in the figure, _z_ and _x_, the latter locating the section at which the bending moments are to be found, are measured to the right from _A_. Equation (_a_) shows that if the quantity _g_(l-_x_) be laid off, by any convenient scale, as _BK_ at right angles to _AB_, _XC_ will represent the moment _M_ by the same scale when _x = z_ or when _z_ has any value between 0 and _x_. Similarly will _AD_ be laid off at right angles to _AB_ by the same scale as before, to represent _gx_. Then when _x = z_ the expression for _M′_ will have the same value _XC_ as before. Hence if the lines _AC_ and _CB_ be drawn as parts of _AK_ and _DB_, any vertical intercept between _AB_ and _ACB_ will represent the bending at _X_ produced by the load _g_ when placed at the point from which the intercept is drawn. The lines _AC_ and _CB_ are the influence lines for the bending moments produced by the load _g_ in its passage across the span _AB_. It is to be observed that the influence lines are continuous only when the positions of the moving load are consecutive. In case those positions are not consecutive the influence lines are polygonal in form.

If there are a number of loads _g_ resting on the span at the same time, the total bending moments produced at _X_ will be found by taking the sum of all the vertical intercepts between _AB_ and _ACB_, drawn at the various points where those loads rest. The influence lines drawn for a single load, therefore, may be at once used for any number of loads.

The load _g_ is considered as a unit load. If the vertical intercepts representing the bending moments by the scale used are themselves represented by _y_, and if _W_ represent any load whatever, the general expression for the bending moment at _X_, produced by any system of loads, will be

_l_ ---- Σ_Wy._ (_c_) _g_

If this expression be written as a series, the general value of the bending moment will be the following:

_l_ _M_ = --- (_W■y■ + W■y■ + W■y■_ + etc.). (_d_) _g_

The effect of a moving train upon the bending moment at any given section is thus easily made apparent by means of influence lines. It is obvious that there will be as many influence lines to be drawn as there are sections to be considered. In the case of a truss-bridge there will be such a section at every panel-point.

A slight modification of the preceding results is to be made when the loads are applied to the beam or truss at panel-points only.

In Fig. 25 let 1, 2, 3, 4, 5, 6, and 7 be panel-points at which loads are applied, and let the load _g_ be located at the distance _z′_ to the right of panel-point 5, also let the panel length be _p_. The reactions at 5 and 6 will then be

_p-z′_ _z′_ _R■ = g_ -------- and _R■ = g_ ------. _p_ _p_

The reactions at _A_ will then be

_l-z_ _R = g_ ------. _l_

Hence the moment at any section _X_ in the panel in question will be

[_l-x z′_] _M = Rx-R■_{_z_′-(_z-x_)} = _g_[---- _z_-(_z-z′ + p-x_)---]. (_e_) [_l p_]

Remembering that _z-z′_ is a constant quantity, it is at once clear that the preceding expression is the equation of a straight line, with _M_ and _z_ or _z′_ the variables. If _z′ = 0_, equation (_e_) becomes identical with equation (_a_), while if _z′ = p_, it becomes identical with equation (_b_). Hence the influence line for the panel in which the load is placed, as 5-6, is the straight line _KL_. It is manifest that when the load _g_ is in any other panel than that in which the section _X_ is located, the effect of the two

reactions at the extremities of that panel will be precisely the same at the section as the weight itself acting along its own line of action. Hence the two portions _AK_ and _BL_ of the influence line are to be constructed as if the load were applied directly to the beam or truss, and in the manner already shown. The complete influence line will then be _AKLB_, and it shows that the existence of the panel slightly reduces the bending at any section within its limits. The panel 5-6, as treated, is that of a beam in which the bending moment will, in general, vary from point to point. If _AB_ were a truss, however, _X_ would always be taken at a panel-point, and no intercept between panel-points, as 5 and 6, would be considered.

=101. Influence Lines for Shears both for Beams and Trusses.=—The influence lines for shears in a simple beam, supported at each end, can be drawn in the manner shown in Fig. 25_a_. In that figure _AB_ represents a non-continuous beam with span _l_ supported from _A_. The reaction at _A_ will be

_l-z_ _R_ = ----- _g_. _l_

[Illustration: FIG. 25_a_.—Shear in a Simple Beam.]

Let _X_ be the section at which the shear for various positions of _g_ is to be found. When _g_ is placed at any point between _A_ and _X_ the shear _S_ at the latter point will be

_z_ _S_ = _R_ = _g_ = - _g_ ----; (_f_) _l_

but when the load is placed between _B_ and _X_ the shear becomes

_z_ _S_′ = _R_ = _g-g_ ----. (_h_) _l_

Obviously these two values of the shear are equations of two parallel straight lines, that represented by equation (_f_) passing through _A_, and that represented by equation (_h_) passing through _B_, the constant vertical distance between them being _g_. Hence let _BF_ be laid off negatively downward and _AG_ positively upward, each being equal to _g_ by any convenient scale. The ordinates drawn from the various positions 1, 2, 3 ... 6 of _g_ on _AB_ to _AD_ and _BC_ will be the shears at _X_ produced by the load _g_ at any point of the span, and determined by equations (_f_) and (_h_). The influence line, therefore, for the section _X_ will be the broken line _ADCB_. When _g_ is at _X_ the sign of the shear changes, since the latter passes through a zero value.

If a train of weights _W■_, _W■_, _W■_, etc., passes across the span, the total shear at _X_ will be found by taking the sum of the vertical intercepts between _AB_ and _ADCB_, drawn at the positions occupied by the various single weights of the train. If those single weights are expressed in terms of the unit load _g_, the shear _S_ will have the value

1 _S_ = ---- Σ _Wy_; _g_

_y_ being the general value of the intercept between _AB_ and the influence line. The latter shows that the greatest negative shear at _X_ will exist when the greatest possible amount of loading is placed on _AX_ only, while the greatest positive shear at the same section will exist when _BX_ only is loaded. If _BX_ is the smaller segment of span, the latter shear is called the “counter-shear,” and the former the “main shear.”

If the loads are applied at panel-points of the span only, the treatment is the same in general character as that employed for bending moments. In Fig. 25_a_ let 4 and 5 be the panel-points between which the load _g_ is found, and let the panel length be _p_. Also, let _z′_ be the distance of the weight _g_ from panel-point 4. The reactions at _A_ and 4 will then be

_l - z p - z′_ _R_ = ------_g_ and _R■_ = ---------- _g_. _l p_

The shear at the section _X_ for any position of the weight _g_ will then be

(_z′ z_) _S_ = _R - R■_ = _g_(--- - ---). (_k_) (_p l_)

As this is the equation of a straight line, with _S_ and _z_ or _z′_ for the coordinates, the influence line for the panel in which the section _X_ is located will be the straight line represented by _KL_ in Fig. 25_a_.

If _z′_ is placed equal to 0 and _p_ successively, then will equation (_k_) become identical with equations (_f_) and (_h_) in succession. The shears at points 4 and 5 will therefore take the same values as if the loads were applied directly to the beam. For the reasons stated in connection with the consideration of bending moments, loads in other panels than that containing the section

for which the influence line is drawn will have the same effect on that section as if they were applied directly to the beam or truss. Hence _AKLB_ is the complete influence line for this case.

It is evident that there must be as many influence lines drawn as there are sections to be discussed. Also, if _g_ is taken as some convenient unit, i.e., 1000 or 10,000 pounds, it is clear that the labors of computation will be much reduced.

=102. Application of Influence-line Method to Trusses.=—In considering both the bending moments and shears when the loads are applied at panel-points, it has been assumed, as would be the case in an ordinary beam, that the bending moments as well as the shears may vary in the panel; but this latter condition does not hold in a bridge-truss. Neither bending moment nor shear varies in any one panel. Yet the influence lines for moments and shears are to be drawn precisely as shown in Figs. 25 and 25_a_. The section _X_ will always be found at a panel-point, and no intercept drawn within the limits of the panel adjacent to that section carrying the load _g_ is to be used. This method will be illustrated by the aid of Fig. 25_b_.

The employment of influence lines may be illustrated by determining the moment and shear in a single section of the truss shown in Fig. 24, which is reproduced in Fig. 25_c_, when carrying the moving load exhibited in Fig. 25_b_, although its use may be much extended beyond this simple procedure.

The moving load shown in Fig. 25_b_ is that of a railroad train consisting of a uniform train-load of 4000 pounds per linear foot drawn by two locomotives with the wheel concentrations shown; it is a train-load frequently used in the design of the heaviest class of railroad structures. If the criterion of equation (27) be applied to this moving load, passing along the truss shown in Fig. 25_c_, from left to right, it will be found that the greatest bending moment is produced at the section _Q_ when the second driving-axle of the second locomotive is placed at the truss section in question, as shown in Fig. 25_c_.

The unit load to be used in connection with the influence lines will be taken at 10,000 pounds. Remembering that the panel lengths are each 30 feet, it will be seen that the panel-point _Q_ is 150 feet from _A_. Hence the product _gx_ will be 1,500,000 foot-pounds. Similarly the product _g_(l - _x_) will be 900,000 foot-pounds. Laying off the first of these quantities, as _AD_, at a scale of 1,000,000 foot-pounds per linear inch, and the second quantity, as _BK_, by the same scale, the influence line _ACB_ can at once be completed. Vertical lines are next to be drawn through the positions of the various weights, including one through the centre of the uniform train-load 110 feet in length resting on the truss. The vertical line through the centre of the uniform train-load is shown at _O_. By carefully scaling the vertical intercepts between _AB_ and _ACB_, and remembering that each of the loads on the truss must be divided by 10,000, the following tabulated statement will be obtained, the sum of the intercepts for each set of equal weights being added into one item, and all the items of intercepts being multiplied by 1,000,000:

.195 × 110 × .4 × 1,000,000 = 8,580,000 foot-pounds. 1.78 × 2.6 × ” = 4,628,000 ” ” 2.14 × 4 × ” = 8,560,000 ” ” .485 × 2 × ” = 970,000 ” ” 1.525 × 2.6 × ” = 3,965,000 ” ” .9 × 4 × ” = 3,600,000 ” ” .12 × 2 × ” = 240,000 ” ” ---------- 2■30,543,000 ” ” ---------- Moment for one truss = 15,271,500 ” ”

The lever-arm of _ef_, i.e., the normal distance from _Q_ to _ef_, is 39.7 feet. Hence the stress in _ef_ is

15,271,500 ---------- = 384,700 pounds. 39.7

All the chord stresses can obviously be found in the same manner.

In order to place the same moving load so as to produce the greatest shear at the same section _Q_, the criterion of equation (33) must be employed. The dimensions of the truss shown in connection with Fig. 29 give the following data to be used in that equation: _i_ = 210 feet, _m_ = 60 feet, and _p_ = 30 feet.

_l_(_m + i_) _l_ Hence ---------- = $10^{2}/■$, --- = $1^{1}/■$. _pi i_

[Illustration: FIG. 25_b_.]

[Illustration: FIG. 25_c_.]

[Illustration: FIG. 25_d_.]

Introducing these quantities into equation (33), and remembering that the train moves on to the bridge from _A_, it would be found that the second axle of the first locomotive must be placed at the section _Q_, as shown in Fig. 25_d_, which exhibits the lower-chord panel-points numbered from 1 to 7. The conventional unit load _g_ will be taken in this case at 20,000 pounds. It is

represented as _AG_ and _BF_ (Fig. 25_d_), laid off at a scale of 10,000 pounds per inch. _K_ is immediately under panel-point 5 and _L_ is immediately above panel-point 6, hence the broken line _AKLB_ is the influence line desired. The vertical lines are then drawn from each train concentration in its proper position, all as shown, including the vertical line through the centre of the 54 feet of uniform train-load on the left. The summation of all the vertical intercepts between _AB_ and the influence line _AKL_, having regard to the scale and to the ratio between the various loads and the unit load _g_, will give the following tabular statement:

.22 × 54 × .2 × 10,000 = 23,760 pounds. 2.2 × 1.3 × " = 28,600 " 3.02 × 2 × " = 60,400 " .9 × 1 × " = 9,000 " 4.06 × 1.3 × " = 53,780 " 4.53 × 2 × " = 90,060 " .5 × 1 × " = 5,000 " -------- 2■ 270,600 " -------- Shear for one truss = 135,300 "

These simple operations illustrate the main principles of the method of influence lines from which numerous and useful extensions may be made.

CHAPTER IX.

=103. Lateral Wind Pressure on Trusses.=—The duties of a bridge structure are not confined entirely to the supporting of vertical loads. There are some horizontal or lateral loads of considerable magnitude which must be resisted; these are the wind loads resulting from wind pressure against both structure and moving train. In order to determine the magnitudes of these loads it is assumed in the first place that the direction of the wind is practically or exactly at right angles to the planes of the trusses and the sides of the cars. This assumption is essentially correct. There is probably nothing else so variable as both the direction and pressure of the wind. These variations are not so apparent in the exposure of our bodies to the wind, for the reason that we cannot readily appreciate even considerable changes either in direction or pressure. As a matter of fact suitable measuring apparatus shows that there is nothing steady or continued in connection with the wind unless it be its incessant variability. Its direction may be either horizontal or inclined, or even vertical, while within a few seconds its pressure may vary between wide limits. Under such circumstances the wind is as likely to blow directly against both bridge and train as in any other direction, and inasmuch as such a condition would subject the structure to its most severe duty against lateral forces, it is only safe and proper that the assumption should be made. The open work of bridge-trusses enables the wind to exert practically its full pressure against both trusses of a single-track bridge, or against even three trusses if they are used for a double-track structure. Hence it is customary to take the exposed surface of bridge-trusses as the total projected area on a plane throughout the bridge axis of both trusses if there are two, or of three trusses if there are three. Inasmuch as the floor of a bridge from its lowest point to the top of the rails or other highest point of the floor is practically closed against the passage of the wind, all that surface between the lowest point and the top of the rail or highest floor-member is considered area on which wind pressure may act.

Many experimental observations show that on large surfaces, greater perhaps than 400 or 500 square feet in area, the pressure of the wind seldom exceeds 20 or 25 pounds per square foot, while it may reach 80 or 90 pounds, or possibly more on small surfaces of from 2 to 40 or 50 square feet in area. This distinction between small and large exposed areas in the treatment of wind pressures is fundamental and should never be neglected.

This whole subject of wind pressures has not yet been brought into a completely definite or well-defined condition through lack of sufficient experimental observations, but in order to be at least reasonably safe civil engineers frequently, and perhaps usually, assume a wind pressure acting simultaneously on both bridge and train at 30 pounds per square foot of exposed surface and 50 pounds per square foot of the total exposed surface of a bridge structure which carries no moving load. This distinction arises chiefly from the fact that a wind pressure of 30 pounds per square foot on the side of many railroad trains, particularly light ones, will overturn them, and it would be useless to use a larger pressure for a loaded structure. There have been wind pressures in this country so great as to blow unloaded bridges off their piers; indeed in one case a locomotive was overturned which must have resisted a wind pressure on its exposed surface of not less than 90 pounds and possibly more than 100 pounds per square foot.

The consideration of wind pressure is of the greatest importance in connection with the high trusses of long spans, as well as in long suspension and cantilever bridges, and in the design of high viaducts, all of which structures receive lateral wind pressures of great magnitude.

Some engineers, instead of deducing the lateral wind loads from the area of the projected truss surfaces, specify a certain amount for each linear foot of span, as in "The General Specifications for Steel Railroad Bridges and Viaducts" by Mr. Theodore Cooper it is prescribed that a lateral force of 150 pounds for each foot of span shall be taken along the upper chords of through-bridges and the lower chords of deck-bridges for all spans up to 300 feet in length; and that for the same spans a lateral force of 450 pounds for

each foot of span shall be taken for the lower chords of through-spans and the upper chords of deck-spans, 300 pounds of this to be treated as a moving load and as acting on a train of cars at a line 8■/■■ feet above the base of rail.

When the span exceeds 300 feet in length each of the above amounts of load per linear foot is to be increased by 10 pounds for each additional 30 feet of span.

Special wind-loadings and conditions under which they are to be used are also prescribed for viaducts.

These wind loads are resisted in the bridges on which they act by a truss formed between each two upper chords for the upper portion of the bridge, and between each two lower chords for the lower portion of the structure.

[Illustration: FIG. 26.]

=104. Upper and Lower Lateral Bracing.=—Fig. 26 shows what are called the upper and lower lateral bracing for such trusses as are shown in the preceding figures. The wind is supposed to act in the direction shown by the arrow. _DERA_ and _KLBC_ are the two portals at the ends of the structure, braced so as to resist the lateral wind pressures. It will be observed that the systems of bracing between the chords make an ordinary truss, but in a horizontal plane, except in the case of inclined chords like that of Fig. 24. In the latter case the lateral trusses are obviously not in horizontal planes, but they may be considered in computations precisely as if they were. These lateral trusses are then treated with their horizontal panel wind loads just as the vertical trusses are treated for their corresponding vertical loads, and the resulting stresses are employed in designing web and chord members precisely as in vertical trusses. The wind stresses in the chords, in some cases, are to be added to those due to vertical loading, and in some cases subtracted. In other words, the resultant stresses are recognized and the chord members are so designed as properly to resist them. At the present time it is the tendency in the best structural work to make all the web members of these lateral trusses of such section that they can resist both tension and compression, as this contributes to the general stiffness of the structure. On account of the great variability of the wind pressures and the liability of the blows of greatest intensity to vary suddenly, some engineers regard all the wind load on structure or train as a moving load and make their computations accordingly. It is an excellent practice and is probably at least as close an approximation to actual wind effects as the assumption of a uniform wind pressure on a structure.

Both the lateral and transverse wind bracing of railroad bridges have other essential duties to perform than the resistance of lateral wind pressures. Rapidly moving railroad trains produce a swaying effect on a bridge, in consequence of unavoidable unevenness of tracks, lack of balance of locomotive driving-wheels, and other similar influences. These must be resisted wholly by the lateral and transverse bracing, and these results constitute an important part of the duties of that bracing. These peculiar demands, in connection with the lateral stability of bridges, make it the more desirable that the lateral and transverse bracing should be as stiff as practicable.

=105. Bridge Plans and Shopwork.=—After the computations for a bridge design are completed in a civil engineer's office they are placed in the drawing-room, where the most detailed and exact plans of every piece which enters the bridge are made. The numerical computations connected with this part of bridge construction are of a laborious nature and must be made with absolute accuracy, otherwise it would be quite impossible to put the bridge together in the field. The various quantities of bars, plates, angles, and other shapes required are then ordered from the rolling-mill by means of these plans or drawings. On receipt of the material at the shop the shopwork of manufacture is begun, and it involves a great variety of operations. The bridge-shop is filled with tools and engines of the heaviest description. Punches, lathes, planers, riveters, forges, boring and other machines of the largest dimensions are all brought to bear in the manufacture of the completed bridge.

=106. Erection of Bridges.=—When the shop operations are completed the bridge members are shipped to the site where the bridge is to be erected or put in place for final use. A timber staging, frequently of the heaviest timbers for large spans, called false works, is first erected in a temporary but very substantial manner. The top of this false work, or timber staging, is of such height that it will receive the steelwork of the bridge at exactly the right elevation. The bridge members are then brought onto the staging and each put in place and joined with pins and rivets. If the shopwork has not been done with mathematical accuracy, the bridge will not go together. On the accuracy of the shopwork, therefore, depends the possibility of properly fitting and joining the structure in its final position. The operations of the shop are so nicely disposed and so accurately performed that it is not an exaggeration to state that the serious misfit of a bridge member in American engineering practice at the present time is practically impossible. This leads to rapid erection so that the steelwork of a pin-connected railroad bridge 500 feet long can be put in place on the timber staging, or false works, and made safe in less than four days, although such a feat would have been considered impossible twenty years ago.

[Illustration: FIG. 27.]

=107. Statically Determinate Trusses.=—The bridge structures which have been treated require but the simplest analysis, based only on statical equations of equilibrium of forces acting in one plane, i.e., the plane of the truss. It is known from the science of mechanics that the number of those equations is at most but three for any system of forces or loads, viz., two equations of forces and one of moments. This may be simply illustrated by the system of forces _F■_, _F■_, etc., in Fig. 27. Let each force be resolved into its vertical and horizontal components _V_ and _H_. Also let _l■_, _l■_, etc. (not shown in the figure), be the normals or lever-arms dropped from any point _A_ on the lines of action of the forces _F■_, _F■_, etc., so that the moments of the forces about that point will be _F■l■_, _F■l■_, etc. The conditions of purely statical equilibrium are expressed by the three general equations

_H■ + H■_ + etc. = _F■_ cos _a■_ + _F■_ cos _a■_ + etc. = 0; (35) _V■ + V■_ + etc. = _F■_ sin _a■_ + _F■_ sin _a■_ + etc. = 0; (36) _Fl = F■l■ + F■l■_ + etc. = 0. (37)

If all the forces except three are known, obviously those three can be found by the three preceding equations; but if more than three are unknown, those three equations are not sufficient to find them. Other equations must be available or the unknown forces cannot be found. In modern methods of stress determinations those other needed equations express known elastic relations or values, such as deflections or the work performed in stressing the different members of structures under loads. A few fundamental equations of these methods will be given.

In Figs. 19, 20, and 21 let the truss be cut or divided by the imaginary sections _QS_. Each section cuts but three members, and as the loads and reactions are known, the stresses in the cut members will yield but three unknown forces, which may be found by the three equations of equilibrium (35), (36), (37). If more than three members are cut, however, as in the section _TV_ of Figs. 22 and 23, making more than three unknown equations to be found, other equations than the three of statical equilibrium must be available. Hence the general principle that _if it is possible to cut not more than three members by a section through the truss, it is statically determinate_, but _if it is not possible to cut less than four or more, the stresses are statically indeterminate_.

At each joint in the truss the stresses in the members meeting there constitute, with the external forces or loads acting at the same point, a system in equilibrium represented by the two equations (35) and (36). If there are _m_ such joints in the entire structure, there will be 2_m_ such equations by which the same number of unknown quantities may be found. Since equilibrium exists at every joint in the truss, the entire truss will be in equilibrium, and that is equivalent to the equilibrium of all the external forces acting on it. This latter condition is expressed by the three equations (35), (36), and (37), and they are essentially included in the number 2_m_. Hence there will remain but 2_m_ - 3 equations available for the determination of unknown stresses or external forces.

If, therefore, all the external forces (loads and reactions) are known, the 2_m_ - 3 equations of static equilibrium can be applied to the determination of stresses in the bars of the truss or other structure. It follows, therefore, that the greatest number of bars that a statically determinate truss can have is

_n_ = 2_m_ - 3. (38)

In Fig. 19 there are twelve joints and twenty-one members, omitting counter web members and the verticals _ab_ and _fl_, which are, statically speaking, either superfluous or not really bars of the truss. Hence

_m_ = 12 and 2_m_ - 3 = 21. (39)

Again, in Fig. 21 there are fifteen joints. Hence

_m_ = 15, 2_m_ - 3 = 27,

and there are twenty-seven bars or members of the truss. The number of joints and bars in actual, statically determinate trusses, therefore, confirm the results.

=108. Continuous Beams and Trusses—Theorem of Three Moments.=—These considerations find direct application to what are known as "continuous beams," i.e., beams (or trusses) which reach continuously over two or more spans, as shown in Fig. 28.

[Illustration: FIG. 28.]

The beam shown is continuous over three spans, but a beam or truss may be continuous over any number of spans. In general the ends of the beam or girder may be fixed or held at the ends _A_ and _D_, so that bending moments _M_ and _M■_ at the same points may have value. The bending moments at the other points of support are represented by _M■_, _M■_, etc. The points of support may or may not be at the same elevation, but they are usually assumed to be so in engineering practice. Finally, it is ordinarily assumed that the continuous structure is straight before being loaded, and that in that condition it simply touches the points of support. Whether the preceding assumptions are made or not, a perfectly general equation can be written expressing the relation between the bending moments over each set of three consecutive points of support, as _M_, _M■_, and _M■_, or _M■_, M■, and M■. Such an equation expresses what is called the "Theorem of Three Moments." It is not necessary to give the most general form of this theorem, as that which is ordinarily used embodies the simplifying assumptions already described. This simplified form of the "Theorem of Three Moments" applied to the case of Fig. 28 will yield the following two equations:

1 ■ _Ml■ + 2M■_(_l■ + l■_) + _M■l■_ + ---- ∑ _W_(_l■² - z²_)_z_ _l■_

1 ■ + ----- ∑ _W_(_l■² - z²__)z_ = 0. (40) _l■_

1 ■ _M■l■ + 2M■_(_l■ + l■_) + _M■l■_ + ------ ∑ _W_(_l■² - z²_) _l■_ 1 ■ + ---- ∑ _W_(_l■² - z²_)_z_ = 0. (41) _l■_

The figure over the sign of summation shows the span to which the summation belongs. If there is but one weight or load _W_ in each span, the sign of summation is to be omitted. In an ordinary bridge structure or beam the ends are simply supported and _M = M■ = 0_. In any case if the number of supports be _n_, there will be _n_ - 2 equations like the preceding.

If the end moments _M_ and _M■_ are not zero, they will be determinable by the local conditions in each instance. In any event, therefore, they will be known, and there will be but _n_ - 2 unknown moments to be found by the same number of equations. When the moments are known the reactions follow from simple formulæ.

=109. Application to Draw- or Swing-bridges.=—In general the reactions or supporting forces of the beams and trusses of ordinary civil-engineering practice are vertical, and all their points of application are known. Hence there are but two equations of equilibrium, equations (36) and (37), for external forces. These two equations for the external forces and the _n_ - 2 equations derived from the theorem of three moments are therefore always sufficient to determine the _n_ reactions. After the reactions are known all the stresses in the bars or members of the trusses can at once be found. The preceding equations and methods as described are constantly employed in the design and construction of swing- or drawbridges.

=110. Special Method for Deflection of Trusses.=—The method of finding the elastic deflections produced by the bending of solid beams has already been shown, but it is frequently necessary to determine the elastic deflections of bridge-trusses or other jointed or so-called articulate frames or structures. It is not practicable to use the same formulæ for the latter class of structures as for the former. The elastic deflection of a bridge- or roof-truss depends upon the stretching or compressions of its various members in consequence of the tensile or compressive forces to which they are subjected. Any method by which the deflection is found, therefore, must involve these elastic changes of length. There are a number of methods which give the desired expressions, but probably the simplest as well as the most elegant procedure is that which reaches the desired expression through the consideration of the work performed in the truss members in producing their elastic lengthenings and shortenings.

The general features of this method can readily be shown by reference to Fig. 29. It may be supposed that it is desired to find the deflection of any point, as _J_, of the lower chord produced both by the dead and live load which it carries. It is known from what has preceded that every member of the upper chord will be shortened and that every member of the lower chord will be lengthened; and also that generally the vertical web members will be shortened and the inclined web members lengthened. If there can be obtained an expression giving that part of the deflection of _J_ which is due to the change of length of any one member of the truss independently of the others, then that expression may be applied to every other member in the entire truss, and by taking the sum of all those effects the desired deflection will at once result. While this expression will be found for some one particular truss member, it will be of such a general form that it may be used for any truss member whatever; it will be written for the upper-chord member _BC_ in Fig. 29.

[Illustration: FIG. 29.]

The general problem is to determine the deflection of the point _J_ when the bridge carries both dead and moving load over the entire span, as shown in Fig. 29. The general plan of procedure is first to find the stresses due to this combined load in every member of the truss, so that the corresponding lengthening or shortening is at once shown. The effect of this lengthening and

shortening for any single member _BC_ in producing deflection at _J_ is then determined; the sum of all such effects for every member of the truss is next taken, and that sum is the deflection sought. In this case the vertical deflection will be found, because that is the deflection generally desired in connection with bridge structures, but precisely the same method and essentially the same formulæ are used to find the deflection in any direction whatever. The following notation will be employed:

Let _w_ = deflection in inches at any panel-point or joint of the truss;

" _P_ = any arbitrary load or weight supposed to be hung at the point where the deflection is desired and acting as if gradually applied. This may be taken as unity;

" _Z_ = stress produced in any member of truss by _P_;

" _S_ = stress produced in any member of truss by the combined dead and moving loads;

Let _l_ = length in inches of any member of the truss in which _Z_ or _S_ is found;

" _A_ = area of cross-section of same member in square inches;

" _E_ = coefficient of elasticity.

_S_ or _Z_ may be either tension or compression, and the formulæ will be so expressed that tension will be made positive and compression negative.

The change of length of the chord member _BC_ produced by a stress gradually increasing from zero to _S_ is

_S_ ----_l_. _AE_

If it be supposed that _BC_ is a spring of such stiffness that it will be compressed by the gradual application of _Z_ exactly as much as the shortening of the actual member by the stress _S_, the deflection of the point 4 with the weight _P_ hung from it, and due to that compression alone, will be precisely the same as that due to the actual shortening of _BC_ by the combined dead and moving loads.

It is known by one of the elementary principles of mechanics that, since _P_ acts along the direction of the vertical deflection _w_, the work performed by the weight _P_ over that deflection is equal to the work performed by _Z_ over the change of length _l_. Hence

_l l Sl_ --- _Pw_ = --- _Z_ ----, or 2 2 _AE_

_Z Sl_ _w_ = --- ----. (42) _P AE_

The quantity _Z÷P_ is the stress produced in the member by a unit load applied at the joint or point where the deflection is desired. Again, _S÷A_ is the stress per unit of area, i.e., intensity of stress, in the member considered by the actual dead and moving loads. For brevity let these be written

_Z S_ --- = _z_ and --- = _s_; _P A_

then

zsl _w_ = ------. (43) _E_

If the influence of every member of the truss is similarly expressed, the value of the total deflection produced by the dead and moving loads will be

zsl _w_ = ∑ ------. (44) _E_

The sign of summation ∑ indicates that the summation is to extend over all the web and chord members of the truss.

=111. Application of Method for Deflection to Triangular Frame.=—Before applying those equations to the case of Fig. 29 it is best to consider a simpler case, i.e., that of the triangular frame shown in Fig. 18. The reactions are

_l■ l■_ _R_ = --- _W_ and _R■_ = --- _W_. (45) _l l_

The stresses in the various members are:

_l■_ In _CB_, _S_ = ---- _W_ sec α. _l_

_l■_ " _CA_, _S_ = ---- _W_ sec β. _l_

_l■ l■_ " _AB_, _S_ = --- _W_ tan β = --- _W_ tan α. _l l_

Also: _CB = h_ sec α; area of section = _A■_. _CA = h_ sec β; " " " = _A■_. _AB = l_; " " " = _A■_.

In this instance it is simplest to take _P = W_. Equation (44) then gives

(_l■² h_ sec³ α _l■² h_ sec³ _β_ _w_ = (----- ---------- + ----- ---------- (_l² A■ l² A■_

_l■² l_ tan² _β_) _W_ + ---- ----------) ------. (46) _l² A■_) _E_

Let it be supposed that

_l_ = 25 feet = 300 inches; _h_ = 8 feet 4 inches = 100 inches; _l■_ = 16 feet 8 inches = 200 inches and _l■_ = 100 inches; tan β = 1; sec β = 1.414; sec α = 2.24; _W_ = 10,000 pounds.

If the bars are all supposed to be of yellow-pine timber, there may be taken

_E_ = 1,000,000 pounds; _A■_ = 10″ × 12″ = 120 square inches; _A■_ = 10″ × 10″ = 100 square inches; _A■_ = 10″ × 12″ = 120 square inches.

The insertion of these quantities in equation (46) gives the deflection

_w_ = .01042 + .01253 + .01111 = 0.034. (47)

Equation (47) is so written as to show the portion of the deflection due to each member of the frame.

In applying either equation (43) or equation (44) care must be taken to give each stress and its corresponding strain (lengthening or shortening) the proper sign. As the formulæ have been written and used, a tensile stress and its resulting stretch must each be written positive, while a compressive stress must be written negative. This holds true for both the stresses _Z_ and _S_ (or _z_ and _s_). The magnitude of the assumed load _P_ is a matter of indifference, since the stress _Z_ will always be proportional to it and the ratio _P ÷ Z_ will therefore be constant. _P_ is frequently taken as unity; or, as in the case just given, it may have any value that the conditions of the problem make most convenient.

=112. Application of Method for Deflection to Truss.=—In making application of the deflection formulæ to any steel railroad truss similar to that shown in Fig. 29, it will first be necessary to determine the stresses in all its members due to the dead and moving loads, since the deflection under the moving load is sought. These loads will be considered uniform, and that is sufficiently accurate for any railroad bridge. The moving train-load will be taken as covering the entire span, assumed, for a single-track railroad, 240 feet in length between centres of end pins. There are eight panels of 30 feet each, and the depth of truss at centre is 40 feet. Other truss dimensions are as shown in Fig. 29. The dead loads, or own weight, are taken at 400 pounds per linear foot of span for the rails and other pieces that constitute the track; at 400 pounds per linear foot for the steel floor-beams and stringers, and 1600 pounds per linear foot for the weight of trusses and bracing. The moving train-load will be taken at 4000 pounds per linear foot. This will make the panel-loads for each truss as follows:

Lower-chord dead load, 30 × 800 = 24,000 pounds per panel. Lower-chord moving load, 30 × 2000 = 60,000 " " " ------ Total load on lower chord = 84,000 " " " Upper-chord dead load, 30 × 400 = 12,000 " " "

The structure is a "through" bridge, hence all moving loads rest on the lower chord.

[Illustration: FIG. 30.]

The stresses in the truss members due to the combined uniform dead and moving load are best found by the graphical method. One diagram only is needed to determine all the stresses, and it is shown in Fig. 30. This diagram is drawn accurately to scale, and the stresses measured from it are shown in the table on page 136.

The stresses in all the truss members due to the unit load hung at _J_ are readily found by the single diagram shown in Fig. 31, also carefully drawn to scale. These stresses measured from the diagram are given in the table as indicated by the column _z_; they are also represented in equation (44) by the letter _z_. The quantity _s_ in equation (44) is the intensity of the stress (pounds per square inch of cross-section of member) produced by the combined dead and moving loads in each member. As shown, these stresses are least in the web members near the centre of the span, and greatest in the chord members. The lengths in inches of the truss members are shown in the proper column of the table. It will be observed that all counter web members are omitted, as they are not needed for the uniform load. The coefficient of elasticity (_E_) is taken at 28,000,000 pounds. The quantities represented by the second member of equation (44) are computed from these data, and they appear in the last column of the table, the sum of which gives the desired deflection in inches. The elements of the table show how much of the deflection is due to the chords and to the web members, and they show that disregarding the latter would lead to a considerable error.

+-------+----------+---------+--------+-----+---------+ | | _S_ | _s_ | _z_ | _l_ | _w_ | +-------+----------+---------+--------+-----+---------+ | _L■_ | +373,300 | +12,000 | +.555 | 360 | +.08563 | | _L■_ | +373,300 | +12,000 | +.555 | 360 | +.08563 | | _L■_ | +480,000 | +12,000 | +.833 | 360 | +.1284 | | _L■_ | +540,000 | +12,000 | +1.125 | 360 | +.1736 | | _P■_ | -502,300 | -9,000 | -.748 | 472 | +.1132 | | _U■_ | -501,000 | -9,500 | -.870 | 376 | +.1108 | | _U■_ | -544,800 | -10,000 | -1.135 | 363 | +.1472 | | _U■_ | -576,000 | -10,000 | -1.50 | 360 | +.1928 | | _T■_ | +84,000 | +9,000 | 0 | 324 | -- | | _T■_ | +143,500 | +10,000 | +.3738| 472 | +.0629 | | _P■_ | -12,000 | -1,000 | -.250 | 432 | +.00386 | | _T■_ | +93,720 | +7,400 | +.456 | 562 | +.0677 | | _P■_ | +12,000 | +1,000 | -.35 | 480 | -.0060 | | _T■_ | +60,000 | +4,800 | +.625 | 600 | +.0643 | | _P■_ | -12,000 | -1,000 | 0 | 480 | -- | +-------+----------+---------+--------+-----+---------+

Deflection for ½ truss members = 1.2300 inches. Deflection at _J_ = 2 × 1.2300 = 2.4600 inches.

[Illustration: FIG. 31.]

As the deflection is usually desired in inches, the lengths of members must be taken in the same unit.

=113. Method of Least Work.=—The so-called theorem or principle of "Least Work" is closely related to the subject of elastic deflections just considered in its availability for furnishing equations of condition in addition to those of a purely statical character in cases where indetermination would result without them. This principle of least work is expressed in the simple statement that when any structure supports external loading the work performed in producing elastic deformation of all the members will be the least possible. Although this principle may not be susceptible of a complete and general demonstration, it may be shown to hold true in many cases if not all. The hypothesis is most reasonable and furnishes elegant solutions in many useful problems.

The application of this principle requires the determination of expressions for the work performed in the elastic lengthening and shortening of pieces subjected either to tension or compression, and for the work performed in the elastic bending of beams carrying loads at right angles to their axes. Both of these expressions can be very simply found.

Let it be supposed that a piece of material whose length is _L_ and the area of whose cross-section is _A_ is either stretched or compressed by the weight or load _S_ applied so as to increase gradually from zero to its full value. The elastic change of length will be _SL/AE_, _E_ being the coefficient of elasticity. The average force acting will be ½_S_, hence the work performed in producing the strain will be

1 _S^2L_ --- -----. (48) 2 _AE_

It will generally be best, although not necessary, to take _L_ in inches. The expression (48) applies either to tension or compression precisely as it stands.

To obtain the expression for the work performed by the stresses in a beam bent by loads acting at right angles to its axis, a differential length (_dL_) of the beam is considered at any normal section in which the bending moment is _M_, the total length being _L_. Let _I_ be the moment of inertia of the normal section, _A_, about an axis passing through the centre of gravity of the latter, and let _k_ be the intensity of stress (usually the stress per square inch) at any point distant _d_ from the axis about which _I_ is taken. The elastic change produced in the indefinitely short length _dL_ when the intensity _k_ exists is (_k/E_)_dL_. If _dA_ is an indefinitely small portion of the normal section, the average force or stress, either of tension or compression, acting through the small elastic change of length just given, can be written by the aid of equation (5) as

_Md_ ½_k.dA_ = ----- ._dA._ (49) 2_I_

Hence the work performed in any normal section of the member, for which _M_ remains unchanged, will be, since ∫_k.dA.d_ = _M_,

∫ _M M²_ ∫ ------ _kd.dA.dL_ = ----- _dL._ (50) 2_IE_ 2_IE_

The work performed throughout the entire piece will then be

∫ _M²_ ∫ ------ _dL._ (51) 2_IE_

Each of the expressions (48) and (51) belongs to a single piece or member of the structure. The total work performed in all the pieces subjected either to direct stress or to bending, and which, according to the principle of least work, must be a minimum, is found by taking the summation of the two preceding expressions:

1 ■ _S²L_ 1 ■ ∫ _M²_ _e_ = ----■ ------ + ----- ■ ∫ ----- _dL_ = minimum. (52) 2_E_ _A_ 2_E_ _I_

In making an application of equation (52) it is to be remembered that _S_ is the direct stress of tension or compression in any member, and that _M_ is the general value of the bending moment in any bent member expressed in terms of the length _L_.

=114. Application of Method of Least Work to General Problem.=—The problem which generally presents itself in the use of equation (52) is the finding of an equation which expresses the condition that the work expended in producing elastic deformation shall be a minimum, some particular stress in the structure or some external load or force being the variable. If _t_ represent that variable, then the desired equation of condition will be found simply by placing the first differential coefficient of _e_ in equation (52) equal to zero:

_de_ 1 (■ _S dS_ ■ ∫ _M dM_) ----- = ----(■ --- --- _dL_ + ■ ∫ ---- --- _dL_) = 0. (53) _dt_ _E_(_A dt_ _I dt_)

The solution of equation (53) will give a value of _t_ which will make the work performed as expressed in equation (52) a minimum. This method is not a difficult one to employ in such cases as those of drawbridges and stiffened suspension bridges. In the latter case particularly it is of great practical value.

=115. Application of Method of Least Work to Trussed Beam.=—The method of least work may be illustrated by the application of the preceding equations to the simple truss shown in Fig. 32. The pieces _BC_ and _GD_ are supposed to be of yellow-pine timber, the former 10 inches by 14 inches (vertical) in section and the latter 8 inches by 10 inches, while each of the pieces _BD_ and _DC_ are two 1■-inch round steel bars. The coefficient of elasticity _E_ will be taken at 1,000,000 pounds for the timber and 28,000,000 for the steel. The length of _BC_ is 360 inches; _GD_ 96 inches; _BD_ = 96 × 2.13 = 204.5 inches.

tan α = 1.875 and sec α = 2.13.

The weight _W_ resting at _G_ is 20,000 pounds. A part of this weight is carried by _BC_ as a simple timber beam, while the remainder of the load will be carried on the triangular frame _BCD_ acting as a truss, the elastic deflection of the latter throwing a part of the load on _BC_ acting as a beam. According to the principle of least work the division of the load will be such as to make the work performed in straining the different members of the system a minimum.

That part of _W_ which rests on _BC_ as a simple beam may be represented by _W■_, while _W■_ represents the remaining portion carried by the triangular frame. As _G_ is at the centre of the span, the beam reaction at either _B_ or _C_ is ½_W■_. Hence the general value of the bending moment in either half of the beam at any distance _x_ from either _B_ or _C_ is

_M_ = ½_W■x._ Hence _M²dL_ = ¼_W■²x²dx_.

As there is but one member acting as a beam, whose moment of inertia _I_ is constant, the second term of the second member of equation (52) becomes, by the aid of the preceding equation,

1 1 ¹/■ 1 _W■²l³_ ----- ∫ _M²dL_ = ---- ∫ _¼W■²x²dx_ = ---- --------. (54) 2_EI_ ∫ _EI_ ∫■ _EI_ 96

[Illustration: FIG. 32.]

The numerical elements of the expression for the work done in the members of the triangular frame are:

Member. Stress. Length. Area of Section.

_BC_ ½_W■_ tan _α_ 360 inches = _I_ 140 square inches _DC_ ½_W■_ sec _α_ 204.5 ” 4.14 ” ” _DG_ _W■_ 96 ” 80 ” ”

10 × 14³ 27440 _I_ = -------- = ------- = 2286.7. 12 12

The substitution of those quantities in the first term of the second member of equation (52) will give

1 ■ _S²L_ 1 (_W■²_ tan² _α_.360 _W■²_.96) -----■ ----- = ---------- (---------- + ----------) 2_E A_ 2,000,000 (4 × 140 80)

2 _W■²_ sec² _α_ .204.5 + ---------- ---------- = .000,003,73 _W■²_. 56,000,000 4 × 4.14

The substitution of numerical quantities in equation (54) gives

1 _W■²|³_ ---- -------- = .000,213_W■²_. _EI_ 96

Or, since _W - W■ = W■_,

_e_ = .000,003,73_W■²_ + .000,213(_W - W■)²_. (55)

Hence

_de_ ---- = .000,007,46_W■_ - .000,426(_W - W■_) = 0. (56) _dW■_

The solution of this equation gives

_W■_ = .893_W_ = 19,660 pounds.

_W■_ = 340 ”

It is interesting to observe that the first term of the second member of equation (56) is the deflection of the point of application of _W■_ as a point in the frame, while the second term is the deflection of the point of application of _W■_ considered as a point of the beam. In other words, the condition resulting from the application of the principle of least work is equivalent to making the elastic deflections by _W■_ and _W■_ equal. Indeed equation (53) expresses the equivalence of deflections whenever the features of the problem are such as to involve concurrent deflections of two different parts of the structure.

=116. Removal of Indetermination by Methods of Least Work and Deflection.=—The indetermination existing in connection with the computations for such trusses as those shown in Fig. 22 and Fig. 23 can be removed by finding equations of condition by the aid of the method of least work or of deflections. It is evident that the component systems of bracing of which such trusses are composed must all deflect equally. Hence expressions may be found for the deflections of those component trusses, each under its own load. Since these deflections must be equal, equations of condition at once result. A sufficient number of such equations, taken with those required by statical equilibrium, can be found to solve completely the problem. Such methods, however, are laborious, and the ordinary assumption of each system carrying wholly the loads resting at its panel-points is sufficiently near for all ordinary purposes.

The method of least work can be very conveniently used for the solution of a great number of simple problems, like that which requires the determination of the four reactions under the four legs of a table, carrying a single weight or a number of weights, and many others of the same character.

CHAPTER X.

=117. The Arched Rib, of both Steel and Masonry.=—During the past ten or fifteen years the type of bridge structure called the arched rib has come into much use, and its merits insure for it a wider application in the future. It partakes somewhat of the nature of both truss and arch; or it may be considered a curved beam or girder. The ordinary beam or truss when placed in a horizontal position and loaded vertically yields only vertical reactions. Under the same conditions, however, the arched rib will produce both vertical and horizontal reactions, and the latter must either be resisted by abutments of sufficient mass, or by a tie-rod, usually horizontal, connecting the springing points of the rib.

The arched rib may be built solid, as was done in the early days of bridge-building in this country when engineers like Palmer, Burr, and Wernwag introduced timber arches in combination with their wooden trusses, or as a curved plate girder, one of the most prominent examples of which is the Washington Bridge across the Harlem River in the city of New York; or, again, as a braced frame or curved truss, like the 800 feet arched rib carrying the roadway traffic and trolley cars across the Niagara gorge, or like those used in such great railroad train-sheds as the Grand Central Station, New York, the Pennsylvania stations at Jersey City and Philadelphia, and the Philadelphia and Reading station in Philadelphia. Those are all admirable examples of steel arched ribs, and

they are built to sustain not only vertical loads but, in the case of station roofs, the normal or horizontal wind pressures.

Within a few years, less than ten, another type of arched rib has been brought into use and promises to be one of the most beautiful as well as the most substantial applications of this type of structure; that is, the arched rib of combined steel and concrete. Many examples of this type of structure already exist both in this country and in Europe, probably the most prominent of which in this country is that at Topeka, Kansas, across the Kansas River.

[Illustration: =FIG. 33.=]

[Illustration: =FIG. 34.=]

[Illustration: =FIG. 35.=]

The characteristic feature of this type of structure, so far as the stresses developed in it are concerned, is the thrust throughout its length, more or less nearly parallel to its axis, which is combined with the bending moments and shears similar to those found in ordinary bridge-trusses. This thrust is the arch characteristic and differentiates it in a measure from the ordinary bridge-truss, while the bending moments and shears to which it is subjected differentiate it, on the other hand, from the pure arch type or a series of blocks in which thrust only exists. The thrust, bending moments, and shears in arched ribs are all affected by certain principal features of design. Those features are either fixedness of the ends of the ribs or the presence of pin-joints at those ends or at the crown. Fig. 33 represents an arched rib with its ends _D_ and _F_ supposed to be rigidly fixed in masonry or by other effective means.

=118. Arched Rib with Ends Fixed.=—The railroad steel arched bridge at St. Louis, built by Captain Eads between 1868 and 1874, is a structure of this character. The three spans (two each 537 feet 3 inches and one 552 feet 6 inches in length from centre to centre of piers) consist of ribs the main members of which are composed of chrome steel. It was a structure of unprecedented span when it was built, and constituted one of the boldest pieces of engineering in its day. The chords of the ribs are tubes made of steel staves, and their ends are rigidly anchored to the masonry piers on which they rest. It is exceedingly difficult, indeed impossible, to fix rigidly the ends of such a structure, and observations in this particular instance have shown that the extremities of the ribs are not truly fixed, for the piers themselves yield a little, giving elastic motion under some conditions of loading.

=119. Arched Rib with Ends Jointed.=—The rib shown in Fig. 34 is different from the preceding in that pin-joints are supplied at each end, so that the rib may experience elastic distortion or strain by small rotations about the pins at _A_ and _B_. In the computations for such a design it is assumed that the ends of the rib may freely change their inclination at those points. As a matter of fact the friction is so great, even if no corrosion exists, as to prevent motion, but the presence of the pins makes no bending moment possible at the end joints, and the failure to move freely probably produces no serious effect upon the stresses in the ribs. The presence of these pin-joints simplifies the computations of stresses and renders them better defined, so that there is less doubt as to the actual condition of stress under a given load than in the type shown in Fig. 33 with ends fixed more or less stiffly. In Fig. 34, if the horizontal force _H_ exerted by the ends of the rib against the points of support is known, the remaining stresses in the structure can readily be computed; but neither in Fig. 34 nor in Fig. 33 are statical equations sufficient for the determination of stresses. Equations of condition, depending upon the elastic properties of the material, are required before solutions of the problems arising can be made.

=120. Arched Rib with Crown and Ends Jointed.=—The rib shown in Fig. 35 possesses one characteristic radically different from any found in the ribs of Figs. 33 and 34, in that it is three-jointed, one pin-joint being at the crown and one at each end. So far as the conditions of stress are concerned, this is the simplest rib of all. Since there is a pin-joint at the crown as well as at the ends, the bending moments must be zero at each of those three points whatever may be the condition of loading. The point of application of the force or thrust at the crown, therefore, is always known, as well as the points of application at the ends of the joints. As will presently be seen, this condition makes equations of statical equilibrium sufficient for the determination of all stresses in the rib, and no equations depending upon the elastic properties of the material are required. The stresses in this class of ribs, therefore, are more easily determined than in the other two, and they are better defined. These qualities have insured for it a somewhat more popular position than either of the other two classes. The ribs of the great train-sheds of the Pennsylvania and Reading railroads in Jersey City and in Philadelphia belong to this class, while those of the Grand Central Station at New York City belong to the class shown in Fig. 34, as does the arched rib across the Niagara gorge, to which reference has already been made.

=121. Relative Stiffness of Arch Ribs.=—Obviously the three-hinged ribs are less stiff than the two-hinged ribs or those with fixed ends. This is a matter of less consequence for station roofs than for structures carrying railroad loads. The joints of the two-hinged rib being at the ends of the structure, there is but little difference in stiffness between that class of ribs and those with ends fixed. Indeed the difference is so slight, and the uncertainty as to the degree of fixedness of the fixed ends of the rib is so great, that the latter type of rib possesses no real advantage over that with hinged ends.

=122. General Conditions of Analysis of Arched Ribs.=—In each of the three types of arched ribs shown in Figs. 33, 34, and 35 it is supposed that all external forces act in the vertical planes which contain the centre lines of the various members of the rib. There are, therefore, the three conditions of statical equilibrium expressed by the three equations (35), (36), and (37). In practically all cases, except those of arched ribs employed in roof construction, all the external loads are vertical. In such cases the equations of statical equilibrium of the entire structure may be reduced to two only, viz., equations (36) and (37). These features of the problems connected with the design of arched ribs will always make necessary, except in the case of the three-hinged rib (Fig. 35), equations of condition depending upon the elastic properties of the structure.

The rib represented by Fig. 33 is supposed to have its ends so fixed that the inclinations of the centre line at _F_ and _D_ will never change whatever may be the loading or the variation of temperature. This requires the application at each of those points of a couple whose moment varies in value, but which is always equal and opposite to the bending moment at the same point produced by the loads imposed on the rib. It is also to be observed that the loads resting upon the rib are not divided between the points of support _F_ and _D_ in accordance with the law of the lever, since the conditions of fixedness at the ends are equivalent to continuity. There are then to be found, as acting external to the rib, the two vertical reactions and the two moments at _F_ and _D_, as well as the horizontal thrust exerted at the ends of the structure, which is sometimes resisted by the tie-rod, making five unknown quantities. Inasmuch as all external loading is supposed to be vertical, equations (36) and (37) are the only statical equations available, and three others, depending upon the elastic properties of the structure, must be supplied in order to obtain the total of five equations of condition to determine the five unknown quantities. Inasmuch as the end inclinations remain unchanged, the total extension or compression of the material at any given constant distance from the axis of the rib taken between the two end sections _F_ and _D_ must be equal to zero. Similarly, whatever may be the amount or condition of loading, the vertical and horizontal deflections of either of the ends _F_ or _D_ in relation to the other must be zero, since no relative motion between these two points can take place. It is not necessary in these lectures to give the demonstration of the equations which express the three preceding elastic conditions, but if _M_ is the general value of the bending moment for any point of the rib, and if _x_ and _y_ are the horizontal and vertical coordinates of the centre line of the rib, taking the central point of the section at either _F_ or _D_ as an origin, those equations, taken in the order in which the elastic conditions have been named, will be the following, in which _n_ represents a short length of rib within which the bending moment _M_ is supposed to remain unchanged.

F F F ■ ■ ■ ■ _nM_ = 0; ■ _nMx_ = 0; ■ _nMy_ = 0. (57) D D D

The second and third of these equations express the condition that the vertical and horizontal deflections respectively of the two ends in reference to each other shall be zero. The conditions expressed by equation (57) are constantly used in engineering practice to determine the bending moments and stresses which exist in the arched rib with fixed ends. The graphical method is ordinarily used for that purpose, as its employment is a comparatively simple procedure for a rib whose curvature is any whatever.

If the rib has hinged joints at the ends, as in Fig. 34, obviously there can be no bending moment at either of those two points, and hence the two equations of condition which were required in connection with Fig. 33 to determine them will not be needed. There is, therefore, no restriction as to the angle of inclination of the centre line of the rib at those two points. Again, it is obvious that either end _A_ or _B_ may have vertical movement, i.e., deflection in reference to the other, without affecting the condition of stress in any member of the rib; but it is equally obvious that neither _A_ nor _B_ can be moved horizontally, i.e., deflected in reference to the other, without producing bending in the rib and developing stresses in the various members. The unknown quantities in this case are, therefore, only the horizontal thrust _H_ exerted at the two springing points _A_ and _B_, and the two vertical reactions, making a total of three unknown quantities, equations for two of which will be given by equations (36) and (37). The other equation required is the third expression in equation (57), expressing the condition that the horizontal deflection of either of the points _A_ or _B_ in respect to the other is zero, since the span _AB_ is supposed to remain unchanged. By the application of the graphical method to this case, as to the preceding, the employment of equations (36), (37), and (58) will afford an easy and quick determination of the three unknown quantities, whatever may be the curvature of the rib.

A ■ ■ _nMy_ = 0. (58) B

If the reactions and horizontal thrust _H_ are found, stresses in every member may readily be computed and the complete design made.

If the arch is three-hinged, as in Fig. 35, the condition that the bending moment must be zero at the crown _C_ under all conditions of loading gives a third statical equation independent of the elastic properties of the structure which, in connection with equations (36) and (37), give three equations of condition sufficient to determine the two vertical reactions and the horizontal thrust _H_. In this case, as has already been stated, no elastic equations of condition are required.

The determination of the end reactions, bending moments, and horizontal thrust _H_, in these various cases, is all that is necessary in order to compute with ease and immediately the stresses in every member of the rib. These computations are obviously the final numerical work required for the complete design of the structure. These procedures are always followed, and in precisely the manner indicated, in the design of arched ribs by civil engineers, whether the rib be articulated, i.e., with open bracing, or with a solid plate web, like those of the Washington Bridge across the Harlem River.

CHAPTER XI.

=123. Beams of Combined Steel and Concrete.=[2]—A reference has already been made to a class of beams and arches recently come into use and now quite widely employed, composed of steel and concrete, the former being completely surrounded by and imbedded in the latter. These composite beams are very extensively used in the floors of fire-proof buildings as well as for other purposes. Arches of combined concrete and steel were probably first built in Germany and but a comparatively few years ago. During the past ten years they have been largely introduced into this country, and many such structures have not only been designed but built. The most prominent design of arches of combined concrete and steel are those of the proposed memorial bridge across the Potomac River at Washington, for which a first prize was awarded as the result of a national competition in the early part of 1900. So far as the bending or flexure of these composite beams and arches is concerned, the theory is identically the same for both, the formulæ for each of which are given below. In order to express these formulæ the following notation will be needed:

[2] For a complete and detailed statement of this whole subject, including design work, reference should be made to the author's "Elasticity and Resistance of Materials."

[Illustration: MEMORIAL BRIDGE ACROSS THE POTOMAC

AT WASHINGTON D.C.

WM. H. BURR, Civil Engineer.

E. P. CASEY, Associated Architect.

PLAN NO. 2.

Plan Awarded First Prize in National Competition.

River spans 192 feet clear. Total length of structure 3615 feet.]

[Illustration:

WM. H. BURR, Civil Engineer.

E. P. CASEY, Associated Architect.

PLAN NO. 1.

The Towers of this Plan were Recommended by Board of Award to be Substituted for Those in Plan No. 2.

River spans 283 feet clear. Total length of structure 3437 feet.]

_P_ is the thrust along the arch determined by the methods explained in the consideration of arched ribs.

_I_ is the distance of the line of the thrust _P_ from the axis of the arched rib.

_E■_ and _E■_ are coefficients of elasticity for the two materials.

_A■_ and _A■_ are areas of normal section of the two materials.

_I■_ and _I■_ are moments of inertia of _A■_ and _A■_ about the neutral axes of the composite beam or arch sections.

_k■_ and _k■_ are intensities of bending stress in the extreme fibres of the two materials.

_h■_ and _h■_ are total depths of the two materials.

_d■_ and _d■_ are distances from the neutral axes to farthest fibres of the two materials; distances to other extreme fibres would be (_h■-d■_) and (_h■-d■_).

_W■_ and _W■_ are loads, either distributed or concentrated, carried by the two portions.

_W = W■ + W■_ is total load on the beam or arch.

_q■ = W■/W_ and _q■ = W■/W_; ∴ _q■ + q■_ = 1; _e = E■/E■_.

The application of the theory of flexure to the case of a beam or arch of two different materials, steel and concrete in this case, will give the following results:

_M = Pl_; hence _M■ = q■Pl_ and _M■ = q■Pl_. (59)

_W■ E■I■_ _q■_ = --- = ---------- (60) _W E■I■ + E■I■_

_W■ E■I■_ _q■_ = --- = ---------- (61) _W E■I■ + E■I■_

_p Md_ _k■_ = ---------- + --------- (62) _A■ + eA■ I■ + eI■_

(_P Md_) _k■_ = _e_(---------- + ----------) (63) (_A■ + eA■ I■ + eI■_)

These formulæ exhibit some of the main features of the analysis which must be used in designing either beams or arches of combined steel and concrete. In the use of these equations care must be taken to give the proper sign to the bending moment _M_. They obviously apply to the combination of any two materials, although at the present time the only two used in such composite structures are steel and concrete. If the subscript 1 belongs to the concrete portion, and the subscript 2 to the steel portion, there may be taken _E■_ = 1,500,000 to 3,000,000 and _E■_ = 30,000,000. Hence _e_ = 20 to 10.

The purpose of introducing the steel into the concrete is to make available in the composite structure the high tensile resistance of that metal. A very small steel cross-section is sufficient to satisfactorily accomplish that purpose. The percentage of the total composite section represented by the steel will vary somewhat with the dimensions of the structure and the mode of using the material; it will usually range from 0.75 per cent to 1.5 per cent of the total section. The large mass of concrete in which the steel should be completely imbedded serves not only to afford a large portion of the compressive resistance required in both arches and beams, but also to preserve the steel effectively from corrosion. Many experiments have shown that it requires but a small per cent of steel section to give great tensile resistance to the composite mass.

CHAPTER XII.

=124. The Masonry Arch.=—The masonry arch is so old that its origin is lost in antiquity, but its complete theory has been developed with that of other bridge structures only within the latest period. It is only possible here to give some of the main features of that theory and a few of the fundamental ideas on which it is based. It is customary among engineers to regard the masonry arch as an assemblage of blocks finely cut to accurate dimensions, so that the assumption of either a uniform or uniformly varying pressure in the surface of contact between any two may be at least sufficiently near the truth for all practical purposes. Although care is taken to make joints between ring-stones or voussoirs completely cemented or filled with a rich cement mortar, it is usually the implicit assumption that such joints do not resist tension. As a matter of fact many arch joints are capable of resisting considerable tension, but, in consequence of settlement or shrinkage, cracks in them that may be almost or quite imperceptible frequently prevent complete continuity. It is, therefore, considered judicious to determine the stability of the ordinary masonry arch on the assumption that the joints do not resist tension.

In these observations it is not intended to convey the impression that no analysts treat the ordinary arch as a continuous elastic masonry mass, like the composite arches of steel and concrete. Although much may be said in favor of such treatment for all arches, it is believed that prolonged experience with arch structures makes it advisable to neglect any small capacity of resistance to tension which an ordinary cut-stone masonry joint may possess, in the interests of reasonable security.

The ring-stones or voussoirs of an arch are usually cut to form circular or elliptic curves, or to lines which do not differ sensibly from those curves. The arch-ring may make a complete semicircle, as in the old Roman arches, or a segment of a semicircle; or the stones may be arranged to make a pointed arch, like the Gothic; or, again, a complete semiellipse may be formed, or possibly a segment of that curve. When a complete semiellipse or complete semicircle is formed, the arches are said to be full-centred, and in those cases they spring from a horizontal joint at each end. On the other hand, segmental arches spring from inclined joints at each end called skew-backs.

=125. Old and New Theories of the Arch.=—In the older theories of the arch, considered as a series of blocks simply abutting against each other, the resultant loading on each block was assumed to be vertical. In the modern theories, on the other hand, the resultant loading on any block is taken precisely as it is, either vertical or inclined, as the case may be. Many arches are loaded with earth over their arch-rings. This earth loading produces a horizontal pressure against each of the stones, as well as a vertical loading due to its own weight. In such cases it is necessary to recognize this horizontal or lateral pressure of the earth, as it is called, as a part of the arch loading.

It is known from the theory of earth pressure that the amount of that pressure per square foot or any other square unit may vary between rather wide limits, the upper of which is called the abutting power of earth, and the latter the conjugate pressure due to its own weight only. If _w_ is the weight per cubic unit of earth and _x_ the depth considered, and if ϕ be the angle of repose of the earth, the abutting power per square unit will have the value:

$$1 + \sin \phi \quad _p_ = _wx_ \text{ ---------. (64)} \quad 1 - \sin \phi$$

while the horizontal or conjugate pressure due to the weight of earth only will be:

$$1 - \sin \phi \quad _p■_ = _wx_ \text{ ---------. (65)} \quad 1 + \sin \phi$$

The use of these formulæ will be illustrated by actual arch computations.

[Illustration: FIG. 36.]

[Illustration: FIG. 37.]

Fig. 36 is supposed to show a set of ring-stones for an arch of any curvature whatever. The joints _LM_ and _ON_ represent the skew-backs or springing joints, while _R_ and _R■_ represent the supporting forces or reactions with centres of action at _a■_ and _a■_. The ring is divided into blocks or pieces by the joints at _a_, _b_, _c_, _d_, and _e_, the resultant loading or force on each block being given by the lines with arrow-heads and numbered 1, 2, 3, 4, 5, 6, and 7. Fig. 37 represents a force polygon constructed in the ordinary manner by laying off carefully to scale the two reactions _R_ and _R■_, together with the loads or forces numbered 1 to 7, inclusive. By constructing the so-called polygonal frame in the ring-stones of Fig. 36 in the usual manner with its lines or sides parallel to the radiating lines in Fig. 37, as shown by the broken lines, the points _a_, _b_, _c_, etc., are found where the resultant forces cut each joint. The line drawn through those points thus determined is called the line of resistance of the arch. Obviously, if that line of resistance be determined, the complete stability or instability of the arch, as the case may be, will be established. Furthermore, the complete determination of the force polygon in Fig. 37, and the corresponding polygonal frame drawn in the arch-ring, constitute all the computations involved in the design of an arch.

The thrust _T■_ at the crown, shown both in Fig. 36 and Fig. 37, is frequently horizontal, although not necessarily so; its value is shown by Fig. 37. In the older arch theories a principle was enunciated called the "principle of least resistance." The thrust _T■_ is a fundamental and so-called passive force. That is, its magnitude depends not only upon its position, but also largely upon the magnitude of the active forces which represent the loading on the arch-ring. Under the principle of least resistance it was laid down as a fundamental proposition, in making arch computations, that this passive force _T■_ must be the least possible consistent with the stability of the structure. While this provisional proposition answered its purpose well enough, there are other clearer methods of procedure which are thoroughly rational and involve the employment of no extraneous considerations other than those attached to the determination of statical equilibrium.

A scrutiny of the conditions existing in Fig. 36 will show that if the external forces or loadings on the individual blocks of the ring are given, four quantities are to be determined, viz., the two reactions _R_ and _R■_ and their lines of action. Inasmuch as no elastic features of the structure are to be considered, there are available for the determination of these four quantities the three equations of equilibrium, equations (35), (36), and (37), which are not sufficient for the purpose. If one line of action, such as that of _R_, be located by assuming its point of application _a■_, the three equations just named will be sufficient for the determination of the remaining three equations; and that is precisely the method employed. It is tentative, but perfectly practicable. If, instead of assuming one of the points of application of the reactions, we assume both of those points and construct a trial polygonal frame, it will be necessary to use but two of the three equations of statical equilibrium. For that purpose there are employed equations (35) and (36), but in a graphical manner, which will presently be illustrated.

=126. Stress Conditions in the Arch-ring.=—Before proceeding to the construction of an actual line of resistance, a little consideration must be given to the stress conditions in the arch-ring. As the joints are considered capable of resisting no tension, the dimensions of the arch-ring must be finally so proportioned that pressure only will exist in each and every joint. If each centre of pressure, as _a_, _b_, etc., in Fig. 36, is found in the middle third of the joint, it is known from a very simple demonstration in mechanics that no tension will ever exist in that joint, although the pressure may be zero at one extremity and a maximum at the other. This is the condition usually imposed in designing an arch-ring to carry given dead or live loads. It is usually specified that "the line of resistance of the ring must lie in the middle third." It must be borne in mind, however, that the stability of the ring is perfectly consistent with the location of the line of resistance outside of the limits of the middle third, provided it is not so far outside as to induce crushing of the ring-stones. Whenever that crushing begins the arch is in serious danger and complete failure is likely to result.

=127. Applications to an Actual Arch.=—These principles will be applied to the arch-ring shown in Fig. 38, in which the clear span _TU_ is 90 feet. The radius _CO_ of the soffit (as the under surface of the arch is called) is 50 feet, the ring being circular and segmental. The uniform thickness of the ring shown at the various joints is assumed at 4 feet as a trial value. The loading above the ring to the level of the line _E■O_ is assumed to be dry earth weighing, when well rammed in place, 100 pounds per cubic foot. The depth of this earth filling at the crown _n_ of the arch is taken at 4 feet. The ring-stones are assumed to be of granite or best quality of limestone, weighing 160 pounds per cubic foot. The thickness or width of arch-ring of one foot is assumed, as each foot in width is like every other foot, and the loads are taken for that width of ring. The rectangle _EJJ■E■_ is supposed to represent a moving load covering one half of the span and averaging 500 pounds per linear foot; in other words, averaging 500 pounds per square foot of upper surface projected in the line _E■O_. The total length of the arch-ring, measured on the soffit, is about 113 feet, and it is divided into ten equal portions for the purpose of convenient computation. The radial joints so located are as shown at _de_, _fg_, _hk_. From the points where these joints cut the extrados (as the upper surface of the arch-ring is called) vertical broken lines are erected, as shown in Fig. 38.

[Illustration: FIG. 38.]

The horizontal line drawn to the left from _f_ gives the vertical projection of that part of the extrados between _d_ and _f_, and the horizontal earth pressure on _df_ will be precisely the same in amount as that on the vertical projection of _df_, as just found. In the same manner the horizontal earth pressure on that part of the extrados between any two adjacent joints may be found. The mid-depths of these vertical projections below the line _E′O_ are to be carefully measured by scale and then used for the values of _x_ in equations (64) and (65), which now become equations (66) and (67), as the angle of repose ϕ is taken to correspond to a slope of earth surface of 1 vertical on 1½ horizontal.

$$p = 3.51wx. \quad (66)$$

$$p■ = 0.285wx. \quad (67)$$

The horizontal earth pressures thus found are as follows:

_h■_ = { 101,500 pounds; _h■_ = { 30,625 pounds; { 8,700 " { 2,625 "

_h■_ = { 59,500 " _h■_ = { 9,800 " { 5,100 " { 840 "

These quantities _h■_, etc., are found by multiplying the two intensities _p_ and _p′_ by the vertical projections of the surface on which they act. The larger values are found by equation (66) and represent the abutting power of the earth, while the smaller values are found by equation (67), and represent the horizontal or conjugate pressure of the earth due to its own weight only. The actual

horizontal earth pressure against the arch-ring may lie anywhere between these limits.

The weights of the moving load, earth, and ring-stones between each pair of vertical lines and radial joints shown in Fig. 38 are next to be determined, and they are as follows:

_W■_ = 27,300 pounds; _W■_ = 12,300 pounds; _W■_ = 27,900 " _W■_ = 15,550 " _W■_ = 24,500 " _W■_ = 19,500 " _W■_ = 21,300 " _W■_ = 19,400 " _W■_ = 18,300 " _W■■_ = 24,300 "

The centres of gravity of these various vertical forces are shown in Fig. 38 at the points _W■_, _W■_, etc. The triangles of forces shown in that figure and composed, each one, of a vertical and horizontal force as described, are laid down in actual position on the arch-ring, as shown. All data are thus secured for completing the force polygon and polygonal frame or line of resistance. It will be assumed that the reactions _R_ and _R′_ cut the springing joints at _c_ and _a_, respectively, one third of the width of the joint from the soffit, and it will further be assumed that _b_, the mid-point of the joint at the crown, is also in the line of resistance. The assumption of the location of these three points is made for the reason, as is well known, that with a given system of forces a polygonal frame may be found which will pass through any three points in the ring.

[Illustration: FIG. 39.]

The force polygon _B_, 1, 2, 3, ..., 10, _A_, Fig. 39, is then drawn with the loadings on each ring segment found as already explained. The horizontal forces are taken as represented by the smaller values of _h■_, _h■_, _h■_, _h■_. Other force polygons with larger values of these horizontal forces were tried and not found satisfactory. Having constructed the force polygon and assumed the trial pole _P■_, the radial lines are drawn from it as shown in Fig. 39. The polygonal frame shown in broken lines in Fig. 38 results from this trial pole. The frame practically passes through _b_ and _c_, but leaves the ring, passing outside of it, above the joint _VU_. The point _q_ in this frame is vertically above _a_. The "three-point" method of finding the frame that will pass through _a_, _b_, and _c_ was then employed. The line _A6_, Fig. 39, was drawn; then _P′D_ was drawn parallel to _qb_, Fig. 38 (not shown); after which _PD_ was drawn parallel to _ab_, until it intercepted the horizontal line _PQ_, the line _P■Q_ having previously been drawn parallel to _qc_ (not shown). The final pole _P_ was thus found. The polygonal frame shown in full lines in the arch-ring was then drawn with sides parallel to the lines radiating from _P_, all in accordance with the usual methods for such graphic analysis. That polygonal frame lies within the middle third of the arch-ring, although at three points it touches the limit of the middle third. The arch, therefore, is stable.

This construction shows that, with the actual loading of the ring, a line of resistance can be found lying within the middle third; its stability under the conditions assumed is, therefore, demonstrated. It does not follow that the line of resistance as determined must necessarily exist, since there may be others located still more favorably for stability. This indetermination results from the fact already observed that the equations of statical equilibrium are not sufficient in number to determine the four unknown quantities (the two horizontal and the two vertical reactions); but the process of demonstrating the stability of the arch-ring is simple and sufficient for all ordinary purposes. The line of resistance found, if not the true one, is so near to it that no sensible waste of material is involved in employing it. This indetermination has prompted some engineers and other analysts to consider all arch-rings as elastic, thus obtaining other equations of condition. While such a procedure may be permissible, it is scarcely necessary, and perhaps not advisable, in view of the fact that many joints of cut-stone arches become slightly open by very small cracks, resulting possibly from unequal settlement, quite harmless in themselves, having practically no effect upon the stability of the structure.

=128. Intensities of Pressure in the Arch-ring.=—It still remains to ascertain whether the actual pressures of masonry in the arch-ring are too high or not. The greatest single force shown in the force polygon in Fig. 39 is the reaction _R_, having a value by scale of 122,000 pounds, under the left end of the arch, and it is supposed to act at the limit of the middle third of the joint. Hence the average pressure on that joint will be

$$\frac{122{,}000 \times 2}{4} = 61{,}000 \text{ pounds per square foot.}$$

This value may be taken as satisfactory for granite or the best quality of limestone.

Again, it is necessary in bridges, as in some other structures, to determine whether there is any liability of stones to slip on each other. In order that motion shall take place the resultant forces acting on the surface of a stone joint must have an inclination to that surface less than a value which is not well determined and which depends upon the condition of the surface of the stone; it certainly must be less than 70°. The inclination of every resultant force in Fig. 38 to the surface on which it acts is considerably greater than that value and, hence, the stability of friction is certainly secured.

=129. Permissible Working Pressures.=—The working values of pressures permissible on cut-stone and brick or other masonry must be inferred from the results of the actual tests of such classes of masonry in connection with the results of experience with structures in which the actual pressures existing are known. It is safe to state that with such classes of material as are used in the best grade of engineering structures these pressures will generally be found not to exceed the following limits:

Concrete, 20,000 to 40,000 pounds per square foot.

Cement rubble, same values.

Hard-burned brick, cement mortar joints, 30,000 to 50,000 pounds per square foot.

Limestone ashlar, 40,000 to 60,000 pounds per square foot.

Granite ashlar, 50,000 to 70,000 pounds per square foot.

The masonry arch is at the same time the most graceful and the most substantial and durable of all bridge structures, and it is deservedly coming to be more and more used in modern bridge practice. One of the greatest railroad corporations in the United States has, for a number of years, been substituting, wherever practicable, masonry arches for the iron and steel structures replaced. The high degree of excellence already developed in this country in the manufacture of the best grades of hydraulic cement at reasonable prices, and the abundance of cut stone, has brought this type of structure within the limits of a sound economy where cost but a few years ago would have excluded it. It is obviously limited in use to spans that are not very great but yet considerably longer than any hitherto constructed.

[Illustration]

[Illustration: FIG. 40.—Elevation of Luxemburg Bridge and Sections of Main Span.]

=130. Largest Arch Spans.=—The longest arch span yet built has been but recently completed in Germany at the city of Luxemburg. This bridge has a span of 275.5 feet and a rise of 101.8 feet. It is rather peculiarly built in two parallel parts separated 19.5 feet in the clear, the space between being spanned by slabs or beams of combined concrete and steel. The arch-ring is 4.75 feet thick at the crown and 7.18 feet thick at a point 53.14 feet vertically below the crown where it joins the spandrel masonry. The roadway is about 52.5 feet wide and 144.5 feet above the water in the Petrusse River, which it spans.

[Illustration: Cabin John Bridge, near Washington, D. C.]

The longest arch in this country is known as the Cabin John Bridge of 220 feet span and 57.5 feet rise. It is a segmental arch and is located a short distance from the city of Washington, carrying the aqueduct for the water-supply of that city. These lengths of span may be exceeded in good ordinary masonry construction, but the high degree of strength and comparative lightness which characterize the combination of steel and concrete will enable bridges to be built in considerably greater spans than any yet contemplated in cut-stone masonry.

CHAPTER XIII.

=131. Cantilever and Stiffened Suspension Bridges.=—There are two other types of bridges of later development which have, in recent years, become prominent by remarkable examples of both completed structure and design; they are known as the cantilever and stiffened suspension bridges. Both are adapted to long spans, although the latter may be applied to much longer spans than the former. A cantilever structure, with a main span of 1800 feet between centres of piers, is now in process of construction across the St. Lawrence River at Quebec, while the well-known Forth Bridge across the Firth of Forth in Scotland has a main span of 1710 feet. The longest stiffened suspension bridge yet constructed is the New York and Brooklyn Bridge, with a river span of about 1595.5 feet between centres of towers, but the stiffened suspension system has been shown by actual design to be applicable to spans of more than 3200 feet, with material now commercially produced.

[Illustration: FIG. 41.]

[Illustration: FIG. 42.—Monongahela Bridge—Pittsburgh, Carnegie & Western Railroad (Wabash), at Pittsburgh.]

=132. Cantilever Bridges.=—Figs. 41 and 42 exhibit in skeleton outline two prominent cantilever designs for structures in this country. That shown in Fig. 41 was intended for a bridge across the Hudson River between Sixtieth and Seventieth streets, New

York City. The main central opening has a span of 1800 feet, and a length of 2000 feet between centres of towers. Fig. 42 shows the Monongahela River cantilever bridge,[3] now being built at Pittsburgh, Penn. Both figures exhibit the prominent features of the cantilever system. The main parts are the towers, at each end of the centre span, which are 534.5 feet high in the North River Bridge and 135 feet high in the Monongahela River structure, and the central main or river span with its simple non-continuous truss hung from the ends of the cantilever brackets or arms which flank it on both sides. These cantilever arms are simply projecting trusses continuous with the shore- or anchor-arms. They rest on the piers at either end of the main span, as a lever rests on its fulcrum. This arrangement requires the shore extremities or the anchor-arms to be anchored down by a heavy weight formed by the masonry piers at those points. Recapitulating and starting from the two shore ends of the structure, there are the anchor-spans, continuous at the towers, with the cantilever arms projecting outward toward the centre of the main opening and supporting at their ends the suspended truss, which is a simple, non-continuous one. It is thus evident that the cantilever bridge is a structure composed of continuous trusses with points of contraflexure permanently fixed at the ends of the suspended span. The greatest bending moments are at the towers, and the great depth at that point is given for the purpose of affording adequate resistance to those moments by the members of the structure. The following statement shows some elements of the more prominent cantilever bridges of this country and of the Forth Bridge:

[3] This bridge was designed by and is being constructed under the direction of Messrs. Boller and Hodge, Consulting Engineers, New York City.

Length of Cantilever Name. Opening, Centre to Total Length. Centre of Towers.

Pittsburgh 812 feet. 1504 feet. Red Rock (Colo.) 660 " 990 " Memphis (Tenn.) 790.48 " 2378.2 " Forth 1710 " 5330 "

The arrangement of web members of cantilever structures is designed to be such as will transfer the loads from the points of application to the points of support in the shortest and most direct paths. Both Figs. 41 and 42 show these general results accomplished by an advantageous arrangement of web members.

It is interesting to note that the first cantilever bridge designed and built in this country was constructed in 1871. This structure was designed and erected by the late C. Shaler Smith, a prominent civil engineer of his day.

=133. Stiffened Suspension Bridges.=—The stiffened suspension bridge is a structure radically different in its main features and its mode of transferring load to points of support from any heretofore considered, except arched ribs. When a load is supported by a beam or truss, the stresses, either in the web members of the truss or in the solid web of the beams, travel up and down those members in zigzag directions with a relatively large amount of metal required for that kind of transference. That metal is represented by the weight of the web members of the truss and of the solid web of the beam. Again, there are two sets of truss members—the chords or flanges, one of which sustains tension and the other an equal amount of compression. The greater part of this metal must be so placed and used that the working intensities of stress are comparatively small. This is particularly the case in compression members of both chords and webs which constitute the greater portion of the weight of the truss. All compression members are known as long columns which sustain not only direct compression but bending, and the amount of stress or load which they carry per square inch is relatively small, decreasing as the length increases. For all these reasons the amount of metal required for both beams and trusses is comparatively large. In suspension bridges, however, the conditions requiring the employment of a relatively large amount of metal with relatively small unit stresses are absent. The main members of a suspension bridge are the cables and the stiffening trusses, the latter being light in reference to the length of span. The cables are subjected to tension only, which is the most economical of all methods of using metal. A member in tension tends to straighten itself, so that it is never subjected to bending by the load which it carries. The opposite condition exists with compression members. Again, grades of steel possessing the highest ultimate resistance may be used in the manufacture of cables. It is well known that wire is the strongest form in which either wrought-iron or steel can be manufactured. While the ultimate tensile resistance of ordinary structural steel will seldom rise above 70,000 pounds per square inch, steel wire, suitable to be used in suspension-bridge cables, may be depended upon, at the present time, to give an ultimate resistance of at least 180,000 pounds per square inch. The elastic limit of ordinary structural steel is but little above half its ultimate resistance, while the elastic limit of the steel used in suspension-bridge cables is probably not less than three fourths of its ultimate resistance. It is seen, therefore, that the high resistance of steel wire makes the steel cable of the suspension bridge a remarkably economical application of metal to structural purposes.

The latest example of stiffened suspension-bridge is the new East River Bridge reaching across the East River from Broadway in Brooklyn to Delancey Street, New York City, now being built, with a main span of 1600 feet between centres of towers. The entire

length of the metal structure is 7200 feet, and the elevation of the centres of cable at the tops of the towers is 333 feet above mean high water.

Fig. 43 shows a view of this bridge. Its three principal divisions are the cables, the stiffening trusses, and the towers. The latter afford suitable points of support for the cables, which not only extend over the river span, but are carried back to points on the land where they are securely attached to a heavy mass of anchorage masonry. These anchorages must be sufficiently heavy to prevent any load which may come upon the bridge from moving them by the pull of the cables. It is usual to make these masses so great that they are capable of resisting from two to two and a half times the pull of the cables.

[Illustration: FIG. 43.—New East River Bridge.]

=134. The Stiffening Truss.=—The function of the stiffening trusses is peculiar and imperatively essential to the proper action of the whole system. If they are absent and a weight should be placed upon the cable at any point, a deep sag at that point would result. If a moving load should attempt to pass along a roadway supported by a cable only, the latter would be greatly distorted, and it would be impossible to use such a structure for ordinary traffic. Some means must then be employed by which the cable shall maintain essentially the same shape and position, whatever may be the amount of loading. It can be readily shown that if any perfectly flexible suspension-bridge cable carries a load of uniform intensity over the span from one tower to the other, the curve of the cable will be a parabola, with its vertex at the lowest point. Furthermore, it can also be shown that if any portion of the span be subjected to a uniform load, the corresponding portion of the cable will also assume a parabolic curve. It is assumed in all ordinary suspension-bridge design that the total weight of the structure, including the cables and the suspension-rods which connect the stiffening trusses to the cable, is uniformly distributed over the span, and that assumption is essentially correct. So far as the weight of the structure is concerned, therefore, the curve of the cable will always be parabolic. It only remains, therefore, to devise such stiffening trusses as will cause any moving load passing on or over the bridge to be carried uniformly to the cables throughout the entire span. This condition means that if any moving load whatever covers any portion of the span, the corresponding pull of the suspension-rods on the cables must be uniform from one tower to the other, and that result can be practically accomplished by the proper design of stiffening trusses; it is the complete function of those trusses to perform just that duty.

=135. Location and Arrangement of Stiffening Trusses.=—It has been, and is at the present time to a considerable extent, an open question as to the best location and arrangement of the stiffening trusses. The more common method in structures built is that illustrated by the New York and Brooklyn and the new East River bridges. Those stiffening trusses are uniform in depth, extending from one tower to the other, or into the land spans, and connected with the cables by suspension-rods running from the latter down to the lower chords of the trusses. It is obvious that the floor along which the moving load is carried must have considerable transverse stiffness, and hence it may appear advisable to place the stiffening trusses so that the floor may be carried by them. On the other hand, some civil engineers maintain that it is a better distribution of stiffening metal to place it where the cables themselves may form members of the stiffening trusses, with a view to greater economy of material.

Figs. 44, 45, and 46 illustrate some of the principal proposed methods of constructing stiffening trusses in direct connection with the cables. The structure shown in Fig. 44 illustrates the skeleton design of the Point Bridge at Pittsburgh. The curved member is a parabolic cable composed of eye-bars. This parabolic cable carries the entire weight of the structure and moving load when uniformly distributed. If a single weight rests at the centre, the two straight members of the upper chord may be assumed to carry it. If a single weight rests at any other point of the span, it will be distributed by the bracing between the straight and curved members of the stiffening truss. Obviously the most unbalanced loading will occur when one half of the span is covered with moving load. In that case the bowstring stiffening truss in either half of Fig. 44 will make the required distribution and prevent the parabolic tension member from changing its form.

[Illustration: FIG. 44.]

[Illustration: FIG. 45.]

[Illustration: FIG. 46.]

The type of bracing shown in Fig. 45 possesses some advantages of a peculiar nature. Each curved lower chord of the stiffening truss corresponds to the position of the perfectly flexible cable with the moving load covering that half of the span which belongs to the greatest sag of the cable. The two parabolic cables thus cross each other in a symmetrical manner at the centre of the span. If the moving load covers the entire span, the line of resistance or centre line of imaginary cable will be the parabola, shown by the

broken line midway along each crescent stiffening truss. The diagonal bracing placed between the cables is so distributed and applied as to maintain the positions of cables under all conditions of loading.

The mode of constructing the stiffening truss between two cables, shown in Fig. 46, is that adopted by Mr. G. Lindenthal in his design for a proposed stiffened suspension bridge across the Hudson River with a span of about 3000 feet. The two cables are parabolic in curvature and may be either concentric or parallel. This system of stiffening bracing possesses some advantages of uniformity and is well placed to secure efficient results. The same system has been used in suspension bridges of short span by Mr. Lindenthal at both St. Louis and Pittsburgh. The stiffening bracing produces practically a continuous stiffening truss from one tower to the other, whereas the systems shown in Figs. 44 and 45 involve practically a joint at the centre of the span.

In all these three types of vertical stiffness the floor is designed to meet only the exigencies of local loading, being connected with the stiffening truss above by suspension bars or rods, preferably of stiff section.

When stiffening trusses are placed along the line of the floor, as in the case of the two East River bridges, to which reference has already been made, those trusses need not necessarily be of uniform depth, and they may be continuous from tower to tower or jointed at the centre, like those of the New York and Brooklyn suspension bridge. This centre joint detracts a little from the stiffness of the structure, but in a proper design this is not serious.

=136. Division of Load between Cables and Stiffening Truss.=—In a case where continuous stiffening trusses are employed it is obvious that they may carry some portion of the moving load as ordinary trusses. The portion so carried will be that which is required to make the deflection of the stiffening truss equal to that of the cable added to the stretch of the suspension-rods. In the old theory of the stiffening truss constructed along the floor of the bridge this effect was ignored, and the computations for the stresses in those trusses were made by the aid of equations of statical equilibrium only. That assumption, that the cable carried the entire load, was necessary to remove the ambiguity which would otherwise exist. In modern suspension-bridge design those trusses may be assumed continuous from tower to tower with their ends anchored at the towers, or they may be designed to be carried continuously through portions of the land spans and held at their extremities by struts reaching down to anchorages, so that those ends may never rise nor fall, but move horizontally if required. If there are no pin-joints in the trusses at the centre and ends of the main span, equations of statical equilibrium are not sufficient to enable the reactions under the trusses and the horizontal component of cable tension to be found.

One of the best methods of procedure for such cases is that of least work, in which the horizontal component of cable tension is so found that the total work performed in the elastic deflection of the stiffening trusses, suspension-rods, cables, and towers is a minimum. After having found this horizontal component of the cable tension and the reactions under the stiffening trusses, the stresses in all the members of the entire structure can be at once determined. It is obvious that the stiffening truss and the cables must deflect together. It is equally evident that the deeper the stiffening trusses are the more load will be required to deflect them to any given amount, and hence that the deeper they are the more load they will carry independently of the cable. It is desirable to throw as much of the duty of carrying loads upon the cables as possible. It therefore follows that the stiffening trusses should be made as shallow as the proper discharge of their stiffening duties will permit.

=137. Stresses in Cables and Moments and Shears in Trusses.=—The necessary limits of this discussion will not permit even the simplest analyses to be given. It is evident, however, that the greatest cable stresses will exist at the tops of the towers, and that if the horizontal component of cable tension be found by any proper method, the stress at any other point will be equal to that horizontal component multiplied by the secant of cable inclination to a horizontal line, it being supposed that the suspenders are found in a vertical plane.

If the stiffening trusses are jointed at the centre of the main span, as well as at the ends, the simple equations of statical equilibrium are sufficient in number to make all computations, for the reason that the centre pin-joint gives the additional condition that, whatever may be the amount or distribution of loading, the centre moment must be zero. If _l_ is the length of main or centre span and _p_ the moving load per linear foot of span, and if the stiffening trusses run from tower to tower, the following equations will give their greatest moments and shears both by the old and new theory of the stiffening truss.

_p_ = load per lin. ft., _l_ = length of span in ft., Old theory. New theory.

Max. moment _M_ = 0.01856_pl_² _M_ = 0.01652_pl_²}no centre Max. shear _S_ = ■_pl_ _S_ = ■_pl_ } hinge. With centre hinge _M_ = 0.01883_pl_² and _S_ = ■_pl_

The details of the theory of stiffening trusses for suspension bridges have been well developed during the past few years and are fully exhibited in modern engineering literature. The long spans requiring stiffened suspension bridges are usually found over navigable streams, and hence those bridges must be placed at comparatively high elevations. This is illustrated by the clear height of 135 feet required under the East River suspension-bridge structures already completed and in progress. Furthermore, the heights of towers above the lowest points of the cables usually run from one eighth to one twelfth of the span. These features expose the entire structure to comparatively high wind pressures, which must be carefully provided against. This is done by the requisite lateral bracing between the stiffening trusses and by what is called the cradling of the cables. The latter expression simply means that the cables as they are built are swung out of a vertical plane and toward the axis of the structure, being held in that position by suitable details. The cables on opposite sides of the bridge are thus moved in toward each other so as to produce increased stability against lateral movement. Occasionally horizontal cables are stretched between the towers in parabolic curves in order to resist horizontal pressures, just as the main cables carry vertical loads. This matter of stability against lateral wind pressures requires and receives the same degree of careful consideration in design as that accorded to the effects of vertical loading. The same general observation applies also to the design of the towers.

=138. Thermal Stresses and Moments in Stiffened Suspension Bridges.=—All material used in engineering structures expands and contracts with rising and falling temperatures to such an extent that the resulting motions must be provided for in structures of considerable magnitude. In ordinary truss-bridges one end is supported upon rollers, so that as the span changes its length the truss ends move the required amount upon the rollers. In the case of stiffened suspension bridges, however, the ends of the cables at the anchorages are rigidly fixed, so that any adjustment required by change of temperature must be consistent with the change of length of cable between the anchorages. The backstays, which are those portions of the cables extending from the anchorages to the tops of the towers, expand and contract precisely as do the portions of the cable between the tops of the towers. As the cables lengthen, therefore, the sag or rise at the centre of the main span will be due to the change in the entire length of cable from anchorage to anchorage. In order to meet this condition it is usual to support the cables at the tops of the towers on seats called saddles which rest upon rollers, so as to afford any motion that may be required. Designs have been made in which the cables are fixed to the tops of steel towers. In such cases changes of temperature would subject the towers to considerable bending which would be provided for in the design.

The rise and fall at the centres of long spans of stiffened suspension bridges is considerable; indeed, for a variation of 120° Fahr. the centre of the New York and Brooklyn Bridge changes its elevation by 4.6 feet if the saddles are free to move, as intended. In the case of a stiffened suspension bridge designed to cross the North River at New York City with a main span of 3200 feet a variation of 120° Fahr. in temperature would produce a change of elevation of the centre of the span of 6.36 feet. Such thermal motions in the structure obviously will produce stresses of considerable magnitude in various parts of the stiffening trusses, all of which are invariably recognized and provided for in good design.

=139. Formation of the Cables.=—At the present time suspension-bridge cables are made by grouping together in one cylindrical mass a large number of so-called strands or individual small cables, each composed of a large number of parallel wires about one sixth of an inch in diameter. The four cables of the New York and Brooklyn Bridge are each composed of 19 strands, each of the latter containing 332 parallel wires, making a total of 6308 wires, the cables themselves being 15½ inches in diameter. The wire is No. 7 gauge, i.e., 0.18 inch in diameter. In the new East River Bridge each of the four cables is 18¼ inches in diameter and contains 37 strands, each strand being composed of 208 wires all laid parallel to each other, or a total of 7696 wires. The size of the wire is No. 6 (Roebling) gauge, i.e., 0.192 inch in diameter. These strands are formed by laying wire by wire, each in its proper place. The strands are then bound together into a single cable, around which is tightly wound a sheathing or casing of smaller wire, 0.134 inch in diameter for the New York and Brooklyn Bridge. The tightness of this binding wire insures the unity of the whole cable, each wire having been placed in its original position so as to take a tension equal to that of each of the other wires. The suspension-rods are usually of wire cables and are attached by suitable details to the lower chords of the stiffening truss, also by specially designed clamps to the cable. The stiffening trusses are usually built with all riveted joints, so as to secure the greatest possible stiffness from end to end. The stiffened suspension bridge has been shown by experience, as well as by theory, to be well adapted to carry railroad traffic over long spans.

=140. Economical Limits of Spans.=—In the past, suspension bridges have, in a number of cases, been built for comparatively short spans, but it is well recognized among engineers that their economical use must be found for spans of comparatively great length. While definite lower limits cannot now be assigned to such spans, it is probable that with present materials of construction and with available shop and mill capacities the ordinary truss-bridge may be economically used up to spans approximately 700 to

800 feet, and that above that limit the cantilever system is economically applicable to lengths of span not yet determined but probably between 1600 and 2000 feet. The special field of economical employment of the long-span stiffened suspension bridge will be found at the upper limit of the cantilever system. So far as present investigations indicate, the stiffened suspension type of structure may be employed to advantage from about 1800 feet up to the maximum practicable length of span not yet assignable, but perhaps in the vicinity of 4000 feet. Obviously such limits are approximate only and may be pushed upward by further improvements in the production of material and in the enlargement of both shop and mill capacity.

PART III.

WATER-WORKS FOR CITIES AND TOWNS.

CHAPTER XIV.

=141. Introductory.=—A preceding lecture in this course has shown to what an advanced state the public supply of water to large cities was developed in ancient times. The old Romans, Greeks, Egyptians, and other ancient peoples evidently possessed an adequate appreciation of the value of efficient systems of public water-supply. Very curiously that appreciation diminished so greatly as almost to disappear during the middle ages. The demoralization of public spirit and the decrease of national power which followed the fall of Rome induced, in their turn, among other things, a neglect of the works of the great water system of Rome, entailing their partial destruction. The same retrogression in civilization seemed to affect other ancient nations as well, until probably the lowest state of the use of public waters and the construction of public water systems was reached somewhere between A.D. 1000 and A.D. 1300 or 1400. Without reasonable doubt the terrible epidemics or plagues of the middle ages can be charged to the absence of suitable water-supplies and affiliated consequences. During that middle period of the absence of scientific knowledge and any apparent desire to acquire it, sanitary works and consequently sanitary conditions of life were absolutely neglected. No progress whatever was made toward reaching those conditions so imperative in large centres of population for the well-being of the community. Grossly polluted waters were constantly used for public and private supplies, and no efforts whatever were made among the masses toward the suitable disposition of refuse matters or, in a word, to attain to sanitary conditions of living.

A few important works were completed, particularly in Spain, but nothing indicative of general relief from the depths of ignorance and sanitary demoralization to which the greater portion of the civilized world had sunk at that time. The city of Paris took all its water from the Seine, except that which was supplied by a small aqueduct built in 1183. So small was the supply, aside from the water obtained from the river, that in 1550 it is estimated that the former amounted to about one quart only per head of population per day. The situation in London was equally bad, for it was only in the first half of the thirteenth century that spring-water was brought to the city by means of lead pipes and masonry conduits. Public water-works began to be constructed in Germany on a small scale in the early part of the fifteenth century. Obviously no pumps were available in those early days of water-supply, so that the small systems which have been mentioned were of the gravity class; that is, the water flowed naturally in open or closed channels from its sources to the points of consumption. Pumps of a simple and crude type first began to be used at a point on the old London Bridge in 1582, and in Hanover in 1527. Subsequently to those dates other pumps were set up on London Bridge, and installations of the same class of machinery were made in Paris in 1608, usually operated by water-power in some simple manner, as by the force of the water-currents. In 1624 the Paris supply received a reinforcement of 200,000 gallons per day by the completion of the aqueduct Arcueil. The New River Company was incorporated in 1619 for the partial supply of the city of London, and it began to lay its pipes at that time. As its name indicates, it took its supply from New River, and the inception of its business is believed to mark the first application of the principle of supplying each house with water. This company is still in existence and furnishes a considerable portion of the present London supply.

=142. First Steam-pumps.=—The application of steam to the creation or development of power by Watt, near the end of the eighteenth century, stimulated greatly the construction of water-works, as it offered a very convenient and economical system of pumping. It seems probable that the first steam-pumps were used in London in 1761. Twenty years later a steam-pump was erected in Paris, while another was installed in 1783. The second steam-pump in London was probably constructed in 1787. In all these earlier instances of the use of steam-pumps river supplies were naturally used.

=143. Water-supply of Paris and London.=—After the early employment of steam pumping-machinery demonstrated its great efficiency for public water-supplies, the extension of the latter became more rapid, and since 1800 the supplies of the two great

cities of London and Paris have been greatly increased. As late as 1890 the Paris supply amounted to about 65 gallons per head of population, one fourth of which was used as potable, being drawn from springs, while three fourths, drawn from rivers, was used for street-cleaning or other public purposes. This supply, however, was found inadequate and was re-enforced in 1892 by an addition of 30,000,000 gallons per day of potable water brought to the city by an aqueduct 63 miles long. Another addition of about 15,000,000 gallons has been provided more recently.

Rather curiously the water-supply of London is afforded by eight private companies, one of which is the old New River Company already mentioned. These companies, with one exception, draw their supply mainly from the rivers Thames and Lea, all such water being filtered. The remaining company draws its water from deep wells driven into the chalk. The total population supplied amounts to about 5,500,000, the rate of supply being thus less than 45 gallons per head per day.

=144. Early Water-pipes.=—Inasmuch as the use of cast-iron for pipes was only begun about the year 1800, other materials were used prior to that date. As is well known, the pipes used in ancient water-works were either of lead or earthenware. In the eighteenth century wooden pipes made of logs with their centres bored out were used, sometimes 6 or 7 inches in diameter. As many lines of these log pipes were used as needed to conduct a single line of supply. In the earlier portion of the nineteenth century such log pipes, usually of pine or spruce, were used by the old Manhattan Company for the supply of New York City. A section of such a wooden pipe, with a bore of about 2½ inches is preserved in the museum of the Department of Civil-Engineering of Columbia University. Large quantities of such pipes were formerly used.

=145. Earliest Water-supplies in the United States.=—The earliest system of public water-supply in this country was completed for the city of Boston in 1652. This was a gravity system. It is believed that the first pumping-machinery for such a supply was set up for the town of Bethlehem, Pa., and put in operation in 1754. Subsequently water-supplies were completed for Providence, R. I., 1772, and for Morristown, N. J., in 1791; the latter has maintained a continuous existence since that date. The first use of steam pumping-machinery in this country was in Philadelphia in 1800. This machinery, curiously enough, was largely of wood, including some portions of the boiler; it was necessarily very crude and would perform with 100 pounds of coal only about one twenty-fifth or one thirtieth of what may be expected from first-class pumping-machinery at the present time. Other cities and towns soon began to follow the lead of these earlier municipalities in the construction of public water-supplies, but the principal development in this class of public works has taken place since about 1850.

It is estimated that the total population supplied in 1880 was about 12,000,000, which rose to about 23,000,000 in 1890, and it is probably not less than 50,000,000 at the present time.

=146. Quality and Uses of Public Water-supply.=—Advances in the public supplies in this country have been made rather in the line of quantity than quality. Insufficient attention has been given both to the quality of the original supply and to the character of the reservoirs in which it is gathered until within possibly the past decade. A few cities like Boston have scrutinized with care both the quality of the water and the character of the bottom and banks of reservoirs, and have spared neither means nor expense to acquire a high degree of excellence in their potable water. The same observations can be applied to a few other large cities, but to a few only. The realization of the dependence of public health upon the character of water-supply, however, has been rapidly extending, and it will doubtless be but a short time before the care exercised in collecting and preparing water for public use will be as great in this country as in Europe, where few large cities omit the filtration of public waters.

The distribution of water supplied for public use is not limited to domestic purposes, although that class of consumption controls public health so far as it is affected by the consumption of water. The applications of water to such public purposes as street-cleaning and the extinguishing of fires are of the greatest importance and must receive most careful consideration. Again, the so-called system of water-carriage in the disposal of domestic and manufacturing wastes, constituting the field of sewage-disposal, depends wholly upon the efficiency of the water-supply.

=147. Amount of Public Water-supply.=—The first question confronting an engineer in the design of public water-supply is the amount which should be provided, usually stated on the basis of an estimated quantity per head of population. This is not in all cases completely rational, but it is by far the best basis available. If the water-supply is designed for a small city or town previously supplied by wells or other individual sources, the first year's consumption will be low per head of population for the reason that many people will retain their own sources instead of taking a share of the public supply. As time elapses that portion of population decreases quite rapidly in numbers, and in a comparatively few years practically the whole population will use the public supply. In communities, therefore, where public systems have long existed and it is desired either to add to the old supply or to install new

ones, the only safe basis of estimate is the entire population.

=148. Increase of Daily Consumption and the Division of that Consumption.=—The amount of water required per head of population might naturally be assumed identical with the past consumption, but that would frequently be incorrect. It is one of the most prominent features of the history of public water-supplies in this country that the consumption per head of population has increased with great rapidity from the early years of the installation of the different systems, for reasons both legitimate and illegitimate. The daily average consumption of water from the Cochituate Works of the Boston supply increased from 42 gallons per head of population in 1850 to 107 gallons in 1893, and in the Mystic Works of the same supply the increase was from 27 gallons in 1865 to 89 gallons in 1894. Again, the daily average consumption in Chicago rose from 43 gallons per head per day in 1860 to 147 gallons in 1893, while in Philadelphia during the same period the increase was from 36 gallons per head per day to 150 gallons. In Cambridge, Mass., the increase in daily average consumption per head of population was from 44 gallons in 1870 to 70 gallons in 1894. These instances are sufficient to show that, under existing conditions, the daily consumption was increased at a rapid rate in the cities named, and they have been selected as fairly representative of the whole field. Civil engineers have made extended studies in connection with this question in a great number of cities, for it bears upon one of the most important lines of public works. It is absolutely essential to the health and business prosperity of every city that the water-supply should be abundant, safe, and adapted to the industrial and commercial pursuits of its population. It is imperative, therefore, that the division of the daily supply should be carefully analyzed. For this purpose the water-supply of a city may be, and frequently is, divided into four parts:

(1) That used for domestic purposes; (2) That used for commercial and industrial purposes; (3) That used for public purposes; (4) That part of the supply which is wasted.

1. That portion of the supply consumed for domestic purposes includes not only the water used in private residences, but in those branches of consumption which may be considered of a household character found in hotels, clubs, stores, markets, laundries, and stables, or for any other residential service. As might be expected, this branch of consumption varies largely from one city to another. The results of one of the most interesting and suggestive studies ever made in connection with this subject are given by Mr. Dexter Brackett, M. Am. Soc. C. E., in the Transactions of the American Society of Civil Engineers for 1895. In Boston the purely domestic consumption varied in different houses and apartments from 59 gallons per head per day in costly apartments down to 16.6 gallons per head per day in the poorest class of apartment. In Brookline, one of the finest suburbs of Boston, the quantity was 44.3 gallons per day. In some other cities of Massachusetts, as Newton, Fall River, and Worcester, this class of consumption varied from 6.6 gallons to 26.5 gallons per day, the latter quantity being found at Newton in some of the best residences, and the former at houses also in Newton having but one faucet each. In Yonkers, N. Y., where the system was metered, the amount was 21.4 gallons per head of population per day, while in portions of London, England, it varied from 18.6 to 25.5 gallons per head per day. The average of these figures gives a result of 18.2 gallons per head per day, which, in round numbers, may be put at 20 gallons.

2. It is obvious that the rate of consumption for commercial and industrial purposes in any city must vary far more than that for domestic purposes, for the reason that some cities may be essentially residential in character while others may be essentially manufacturing. At the same time, it is to be remembered that many manufacturing establishments may have their own water-supply. The city of Fall River, Mass., is eminently a manufacturing city, yet Mr. Brackett found that the manufacturing demand on the public water-supply amounted to 2 gallons only per inhabitant per day, as the manufacturers draw the most of their supply from the river, but that where the manufacturers depend upon the public supply for all their water the amount rises to a value between 20 and 30 gallons per inhabitant. In Boston in 1892 the water consumed for all manufacturing and industrial purposes, including railroads, gas-works, elevators, breweries, etc., amounted to 9.24 gallons per head of population per day, while in Yonkers in 1897 the total consumption for commercial purposes was 27.4 gallons per head per day. In the city of New York, as nearly as can be estimated, the consumption for commercial purposes is probably not far from 25 gallons per inhabitant per day. Reviewing all these results, it may be stated that the water consumption for commercial and industrial purposes will generally range from 10 to 30 gallons per inhabitant per day.

3. The consumption of water for public purposes is a smaller amount than either of the two preceding. It covers such uses as public buildings, schools, street-sprinkling, sewer-flushing, fountains, fires, and other miscellaneous objects, more or less similar to those just named. The total use of this character was 3.75 gallons per inhabitant per day for Boston in 1892, and 5.57 gallons per inhabitant per day for Fall River in 1899. A few other cities give the following results: Minneapolis in 1897, 5 gallons; Indianapolis, 3 gallons; Rochester, N. Y., 3 gallons; Newton, Mass., 4 gallons; Madison, Wis., 10 gallons. In Paris it is estimated that not far from 2.5 gallons per head of population per day are used. It is probable, therefore, that an amount of 5 gallons per day per inhabitant will

cover this particular line of consumption.

4. A substantial portion of the water-supply of every city fails to serve any useful purpose, for the reason that it runs to waste either by intention or by neglect. The sources of this waste are defective plumbing, including leaky faucets and cocks; deliberate omission to close faucets and cocks, constituting wilful waste; defective or broken mains, including leaky joints; and waste to prevent freezing.

=149. Waste of Public Water.=—All these wastes except the last are inexcusable. There is no difficulty in detecting defective plumbing, and its existence is generally known to the householder; but if the wasted water is not measured and paid for, it is far too frequently considered more economical to continue the waste than to pay for the plumber's services. In a multitude of cases cocks are left open indefinitely for all sorts of insignificant reasons; in closets, under the erroneous impression that the continuous running of the stream will materially aid in a more effective cleansing of soil- and sewer-pipes, failing completely to appreciate that a far more powerful stream is required for that purpose; sometimes in sinks, for refrigerating purposes, and in many other inexcusably wrong ways. These sources of wilful waste lead to large losses and constitute one of the most unsatisfactory phases of administration of a public water system. Such losses result in a vicious waste of public money. The amount of water flowing from leaky joints and from leaks in pipes and mains is necessarily indeterminate because it escapes without evidence at the surface except in rare cases. In every instance where examinations have been made and a careful record kept of the amount of water supplied to a city, it has been found that the aggregate of the measured amounts consumed fail nearly to equal the total supply. There are probable errors both in the measurement of the quantities supplied and in the quantities consumed, but the large discrepancy cannot be accounted for in this manner. In many cases consumed water has even been carefully measured by meters, as at Yonkers, New York, Newton, Milton, and Fall River, Mass., Madison, Wis., and at other places, but yet the discrepancy appears to be nearly as wide as ever. Again, in 1893 observations were carefully made on the consumption of the water received by the Mystic supply of the Boston system at _all_ hours of the twenty-four. Obviously between 1 and 4 A.M. the useful consumption should be nearly nothing, but, on the contrary, it was found to be nearly 60 per cent of the average hourly consumption for the entire twenty-four hours. The waste at Buffalo, N. Y., in 1894 was estimated at 70 per cent of the total supply. Similar observations in other places have given practically the same results. It has also been found that, in a number of instances, where old watercourses have been completely obliterated by considerable depths of filling required by the adopted grades of city streets and lots, and excavations for buildings have subsequently been opened practically the full volume of the former streams are flowing along the original but filled channel. This result has been observed under a practically impervious paved city surface. It is difficult to imagine the source of such a supply except from defective pipe systems or sewers. A flow of a least 100,000 gallons per day from a broken pipe which found its way into a sewer has also been discovered without surface evidence. These and many other results of experience conclusively demonstrate that much water flows to waste unobserved from leaky joints and defective or broken pipes.

Inasmuch as cast-iron water-pipes are produced in lengths which net 12 feet as laid, there will be at least 440 joints per mile. Furthermore, as leaky joints and broken pipes are as likely to occur at one place as another, it seems reasonable to estimate leakage through them as proportionate to the length of the pipe-line in a system; and that conventional law is frequently assumed. New pipe-lines have sometimes shown a leakage of 500 to 1200 gallons per mile of line per day. Civil engineers have sometimes specified the maximum permissible leakage of a new pipe-line at 60 to 80 gallons per mile of line per day for each inch in diameter of pipe, thus permitting 600 to 800 gallons to escape from a 10-inch pipe. In 1888 the late Mr. Chas. B. Brush reported a leakage of about 6400 gallons per mile per day from a practically new 24-inch cast-iron main, 11 miles long, of the Hackensack Water Company, the pressure being 110 pounds per square inch. Tests of water-pipes in German and Dutch cities have been reported as showing less waste than 300 gallons per mile per day, but such low results, unless for very low pressures and short lines, may reasonably be doubted. Obviously losses of this character will probably increase with the age of the pipe. By a very ingenious procedure based upon his own experience, Mr. Emil Kuichling of Rochester, N. Y., reaches the conclusion that a reasonable allowance for the waste from leaky joints and defective pipes is 2500 to 3000 gallons per mile of cast-iron pipe-line per day. If, as is frequently the case, the population per mile of pipe ranges from 300 to 1000, the preceding allowance amounts to 3 to 10 gallons per head of population per day. The loss or waste due to running cocks or faucets to prevent freezing cannot be estimated with sufficient accuracy to receive a definite valuation, but it must be considered an element of the total item of waste.

=150. Analysis of Reasonable Daily Supply per Head of Population.=—It has repeatedly been found that the losses or wastes set forth in the preceding statements amount apparently to quantities varying from 30 to 50 per cent of the total supply; or, to put it a little differently, the water unaccounted for in even the best systems now constructed apparently may reach one third to one half of

the total supply. This is an exceedingly wasteful and unbusinesslike showing. It is probable that the statement is, to some extent at least, an exaggeration. It is practically certain that either the amount supplied or the amounts consumed, or both, are never measured with the greatest accuracy, and that the errors are such as generally swell the apparent quantity wasted. After making judicious use of the data thus afforded by experience, it is probable that the following tabular statement given by Messrs. Turneaure and Russell represents limits within which should be found the daily average supply of water in a well-constructed and well-administered system.

+---------------------------+---------------------------------+ | | Gallons per Head per Day. | | Use. +----------+----------+----------+ | | Minimum. | Average. | Maximum. | +---------------------------+----------+----------+----------+ | Domestic | 15 | 25 | 40 | | Industrial and commercial | 5 | 20 | 35 | | Public | 3 | 5 | 10 | | Waste | 15 | 25 | 30 | +---------------------------+----------+----------+----------+ | Total | 38 | 75 | 115 | +---------------------------+----------+----------+----------+

The values given in the preceding table are reasonable and sufficient to supply the legitimate needs of any community, but, as will be shown in the succeeding table, there are cities in this country whose average consumption is more than twice the maximum rate given above.

=151. Actual Daily Consumption in Cities of the United States.=—The following table exhibits the average daily consumption of water throughout the entire year for the cities given, as determined for the years indicated in the table.

The city of Buffalo shows a daily consumption of 271 gallons per inhabitant, and Allegheny, Pa., 247 gallons per inhabitant. There are a considerable number showing an average daily consumption per inhabitant of 160 gallons or more. All such high averages exhibit extravagant use of water, or otherwise inefficient administration of the water-supply. The reduction of such high rates of consumption is one of the most difficult problems confronting the administration of public works. The use of the meter has proved most efficient in preventing wastes or other extravagant consumption, as in that case every consumer pays a prescribed rate for the amount which he takes.

TABLE I.

----------+----------+----------+-------+---------- | | |Consumption | | | Per | per |Population.|Population|Cent of| Inhabitant | | per Tap. | Taps | Daily, | | |Metered| Gallons. ----------+----------+----------+-------+---------- | 1890. | 1890. | 1890. | 1890. ----------+----------+----------+-------+---------- New York | 1,515,301 | 13.9 | 20.2 | 79 Chicago | 1,099,850 | 7.1 | 2.5 | 140 Philadelphia | 1,046,964 | 6.1 | 0.3 | 132 Brooklyn | 838,547 | 8.7 | 2.5 | 72 St. Louis | 451,770 | 11.8 | 8.2 | 72 Boston | 448,477 | 6.6 | 5.0 | 80 Cincinnati | 305,891 | 8.5 | 4.1 | 112 San Francisco | 298,997 | 9.9 | 41.4 | 61 Cleveland | 270,055 | 8.7 | 5.8 | 103 Buffalo | 255,664 | 6.3 | 0.2 | 186 New Orleans | 242,039 | 54.0 | 0.4 | 37 Washington | 230,392 | 6.5 | 0.3 | 158 Montreal | 216,000 | 5.3 | 1.7 | 67 Detroit | 205,876 | 5.1 | 2.1 | 161 Milwaukee | 204,468 | 11.1 | 31.9 | 110 Toronto | 181,000 | 4.0 | 4.1 | 100 Minneapolis | 164,738 | 16.5 | 6.3 | 75 Louisville | 161,129 | 11.9 | 5.9 | 74 Rochester | 133,896 | 5.4 | 11.4 | 66 St. Paul | 133,156 | 12.7 | 4.2 | 60 Providence | 132,146 | 9.4 | 62.4 | 48 Indianapolis | 105,436 | 35.6 | 7.6 | 71 Allegheny | 105,287 | 7.0 | 0 | 238 Columbus | 88,150 | 11.5 | 6.4 | 78 Worcester | 84,655 | 8.9 | 89.4 | 59 Toledo | 81,434 | 18.6 | 9.4 | 72 Lowell | 77,696 | 9.2 | 22.9 | 66 Nashville | 76,168 | 14.9 | 0.8 | 146 Fall River | 74,398 | 14.9 | 74.6 | 29 Atlanta | 65,533 | 20.0 | 89.6 | 36 Memphis | 64,495 | 11.9 | 3.7 | 124 Quebec | 63,000 | 10.4 | 0 | 160 Dayton, O. | 61,220 | 20.0 | 3.8 | 47 Camden, N. J. | 58,313 | . . . | . . . | 131 Des Moines, Ia. | 50,093 | 20.0 | 60.0 | 55 Ottawa, Ont. | 44,000 | 4.2 | 0 | 130 Yonkers, N. Y. | 32,033 | 12.0 | 82.4 | 68 Newton, Mass. | 24,379 | 5.5 | 67.4 | 40 Madison, Wis. | 13,426 | 11.0 | 31.0 | 40 Albany, N. Y. | 98,000 | . . . | 0.4 | 162 New Bedford, Mass. | 55,000 | . . . | . . . | 99 Springfield, Mass. | 49,299 | . . . | . . . | 87 Holyoke, Mass. | 40,000 | . . . | . . . | 77 ----------+----------+----------+-------+---------- ----------+-------+----------+---------- | |Consumption|Consumption | Per | per | per |Cent of| Inhabitant| Inhabitant | Taps | Daily, | Daily, |Metered| Gallons. |Gallons. ----------+-------+----------+---------- | 1895. | 1895. | 1900. ----------+-------+----------+---------- New York | 27.0 | 100 | 115 Chicago | 2.8 | 139 | 190 Philadelphia | 0.74 | 162 | 229 Brooklyn | 1.9 | 89 | . . . St. Louis | 7.4 | 98 | 111 Boston | 5.2 | 100 | 143 Cincinnati | 6.5 | 35 | 121 San Francisco | 28.0 | 63 | 73 Cleveland | 4.5 | 142 | 175 Buffalo | 0.85 | 271 | 262 New Orleans | . . . | 35 | 48 Washington | 1.5 | 200 | 174 Montreal | 1.6 | 83 | . . . Detroit | 8.2 | 152 | 156 Milwaukee | 51.0 | 101 | 84 Toronto | 3.7 | 100 | Minneapolis | 16.0 | 88 | 93 Louisville | 6.6 | 97 | . . . Rochester | 18.0 | 71 | 83 St. Paul | 1.7 | 60 | 51 Providence | 74.0 | 57 | 54 Indianapolis | 7.1 | 74 | 79 Allegheny | 7.1 | 247 | . . . Columbus | 9.3 | 127 | 183 Worcester | 90.0 | 66 | 67 Toledo | 35.0 | 70 | 59 Lowell | 33.0 | 82 | 83 Nashville | 24.0 | 139 | 140 Fall River | 82.0 | 35 | 35 Atlanta | 99.0 | 42 | 61 Memphis | 4.6 | 100 | 98 Quebec | 0 | 170 | . . . Dayton, O. | 24.0 | 50 | 62 Camden, N. J. | 0 | 200 | 185 Des Moines, Ia. | 42.6 | 43 | 48 Ottawa, Ont. | 0 | 0 | . . . Yonkers, N. Y. | 99.8 | 100 | 76 Newton, Mass. | 77.3 | 65 | 62 Madison, Wis. | 61.0 | 52 | 44 Albany, N. Y. | 12.3 | . . . | 192 New Bedford, Mass. | 15.4 | . . . | 101 Springfield, Mass. | 31.9 | . . . | 88

Holyoke, Mass. | 5.82 | . . . | [4]103 ----------+-------+----------+----------

[4] Estimated.

=152. Actual Daily Consumption in Foreign Cities.=—It has been for a long time a well recognized fact that the daily use of water in American municipalities is far greater per inhabitant than in European cities. It is difficult to explain the marked difference, but it is probably due in large part to the more extravagant general habits of the American people. Examinations in a number of cases have shown that the actual domestic use of water, at least in some of the American cities, is not very different from that found in corresponding foreign cities. Table II exhibits the consumption of water in European cities, as compiled from various sources and given by Turneaure and Russell.

TABLE II.

----------+----------+---------- | |Consumption | Estimated | per Capita City. | Population. | Daily, | | Gallons. ----------+----------+---------- England, 1896-97:[5] | | London | 5,700,000 | 42 Manchester | 849,093 | 40 Liverpool | 790,000 | 34 Birmingham | 680,140 | 28 Bradford | 436,260 | 31 Leeds | 420,000 | 43 Sheffield | 415,000 | 21 Nottingham | 272,781 | 24 Brighton | 165,000 | 43 Plymouth | 98,575 | 59 Germany, 1890 (Lueger): | | Berlin | 1,427,200 | 18 Breslau | 330,000 | 20 Cologne | 281,700 | 34 Dresden | 276,500 | 21 Düsseldorf | 144,600 | 25 Stuttgart | 139,800 | 26 Dortmund | 89,700 | 78 Wiesbaden | 62,000 | 20 France, 1892 (Bechmann): | | Paris | 2,500,000 | 53 Marseilles | 406,919 | 202 Lyons | 401,930 | 31 Bordeaux | 252,654 | 58 Toulouse | 148,220 | 26 Nantes | 125,000 | 13 Rouen | 107,000 | 32 Brest | 70,778 | 3 Grenoble | 60,855 | 264 Other countries, 1892-96 (Bechmann): | | Naples | 481,500 | 53 Rome | 437,419 | 264 Florence | 192,000 | 21 Venice | 130,000 | 11 Zurich | 80,000 | 60 Geneva | 70,000 | 61 Amsterdam | 515,000 | 20 Rotterdam | 240,000 | 53 Brussels | 489,500 | 20 Vienna | 1,365,000 | 20 St. Petersburg | 960,000 | 40 Bombay | 810,000 | 61 Sidney | 423,600 | 38 Buenos Ayres | 680,000 | 34 ----------+----------+----------

[5] Compiled, except the figures for London, by Hazen. _Engineering News_, 1899, XLI. p. 111.

These foreign averages, with three exceptions, represent reasonable quantities of water used, and they have been confirmed as reasonable by many special investigations made in this country.

=153. Variations in Rate of Daily Consumption.=—The preceding observations are all based upon an average total consumption found by dividing the total annual consumption by the number of days in the year. This is obviously sufficient in a determination of the total supply needed, but it is not sufficient in those matters which involve a rate of supply during the different hours of the day, or the amount of the supply for the summer months as compared with those of the winter. As a general rule the greatest supply will be required during the hot summer months when lawn- and street-sprinkling is most active. It appears from observations made in a considerable number of the large cities of the United States that the maximum monthly average consumption may run from about 110 to nearly 140 per cent of the monthly average throughout the year. As an approximate value only, it may be assumed for ordinary purposes that the maximum monthly demand will be 125 per cent of the average.

The daily rate taken throughout the year is considerably more variable than the monthly. There are days in some portions of the year when consumption by hotels and industrial activities is at a minimum. On the other hand, there are other days when those activities are at a maximum and the total draft will be correspondingly high. Experience has shown that the maximum total draft may vary from about 115 to nearly 200 per cent of the average. It is permissible, therefore, to take approximately for general purposes the maximum total daily consumption as 150 per cent of the average. Manifestly any total consumption will have an hourly rate which may vary greatly from the early morning hours, when the draft should be almost nothing, to the forenoon hours on certain days of the week, when the draft is a maximum. These variations have frequently been investigated, and it has been shown that the maximum rate per hour of a maximum day may sometimes rise higher than 300 per cent of the average hourly rate for the year. These considerations obviously attain their greatest importance in connection with the capacity of the plant, either power or gravity, from which the city directly draws its supply. The hourly capacity of the pumps or steam-plant furnishing the supply need not necessarily be equal to the maximum, since storage-reservoirs may be and usually are used; but the capacity of the pipe system leading from such storage-reservoirs must be equal to the maximum hourly rate required.

=154. Supply of Fire-streams.=—The draft on a water-supply for fire-extinguishing purposes may have an important influence upon the hourly rate of consumption. These observations are particularly pertinent in connection with the water-supply of small cities where the draft of fire-engines may be considered a large percentage of the total hourly consumption. It is obviously impossible to

assign precisely the number of fire-streams which may be required simultaneously in a city having a given population, but experiences of a considerable number of civil engineers furnish reasonable bases on which such estimates may be made. Table III exhibits such estimates as made by the civil engineers indicated. It is given by Mr. Emil Kuichling in the Transactions of the American Society of Civil Engineers for December, 1897. Probably no more reasonable estimate can be now presented.

TABLE III.

TABLE EXHIBITING ESTIMATED NUMBER OF FIRE-STREAMS REQUIRED SIMULTANEOUSLY IN AMERICAN CITIES OF VARIOUS MAGNITUDES.

---------- | Number of Fire-streams Required Simultaneously. Population of +---------- +---------- +---------- +---------- Community. | 1 | 2 | 3 | 4 | Freeman. | Shedd. | Fanning. | Kuichling. ---------- +---------- +---------- +---------- +---------- 1,000 | 2 to 3 | .. | .. | 3 4,000 | .. | .. | 7 | 6 5,000 | 4 to 8 | 5 | .. | 6 10,000 | 6 to 12 | 7 | 10 | 9 20,000 | 8 to 15 | 10 | .. | 12 40,000 | 12 to 18 | 14 | .. | 18 50,000 | .. | .. | 14 | 20 60,000 | 15 to 22 | 17 | .. | 22 100,000 | 20 to 30 | 22 | 18 | 23 150,000 | .. | .. | 25 | 34 180,000 | .. | 30 | .. | 38 200,000 | 30 to 50 | .. | .. | 40 250,000 | .. | .. | .. | 44 300,000 | .. | .. | .. | 48 ---------- +---------- +---------- +---------- +----------

The discharge of each fire-stream will of course vary with its diameter and the pressure at the fire-engine, but as an average it is reasonable to assume that each stream will discharge 250 gallons per minute. The quantity of water required, therefore, to supply the estimated number of streams given in Table III is found by simply multiplying the number of those streams by 250, to ascertain the total number of gallons consumed per minute. If _x_ is the number of thousand inhabitants in any city, and if _y_ represents the required number of streams, then Mr. Kuichling deduces the following formulæ for _y_ by the use of the preceding tables, i.e., these formulæ express the results given in the preceding table as nearly as simple forms of formulæ permit. ___ { _y_ min. = 1.7√_x_ + 0.033_x_,} { } For Freeman's data: { _x_ } (1) { _y_ max. = --- + 10. } { 5 } _____ ___ For Shedd's data: _y_ = √5_x_ = 2.24 √_x_. (2)

_x_ For Fanning's data: _y_ = --- + 9. (3) 10 ___ For the author's data: _y_ = 2.8 √_x_. (4)

While for the average ordinary consumption of water, expressed in gallons per head and day, _q_, Mr. Coffin's formula, as given in his paper previously cited, may be taken

_q_ = 40_x_■■¹■. (5)

By combining equation (5) with equation (4), remembering that the maximum rate of consumption is usually about 1.5 times the average, the total draft in gallons per minute upon the discharging system at the time of a conflagration will become as follows:

___ 3 40 × 1000 _Q_ = 250(2.8 √_x_) + ---- ---------- _x_¹■¹■ 2 1440

(___ _x_¹■¹■) = 250(2.8√_x_ + --------) (6) (6)

This maximum rate of consumption during a conflagration does not affect the total supply of a large city like New York, Boston, or Chicago, but it may become of relatively great importance in a small city or town. In a large city this draft may and frequently does tax the capacity of a small district of the discharging system. In designing such systems, therefore, even for large cities, it is necessary to insure all districts against a small local supply when a large one may pressingly be needed.

CHAPTER XV.

=155. Waste of Water, Particularly in the City of New York.=—The quantity of water involved in designing a water-supply for cities and towns is much larger than that which is actually needed. The experience of civil engineers in many cities, both in this country and in Europe, shows conclusively that the portion of water actually wasted or running away without serving any purpose will usually run from 30 to 50 per cent of the total amount brought to the distributing system. In the city of New York there is strong reason to believe that the wastage is not less than two thirds of the total quantity supplied. It is frequently assumed that both the quantities supplied and the quantities uselessly wasted in New York are larger than in other places. As a matter of fact those quantities are actually smaller than in some other large cities. While the supply per inhabitant in New York City is much larger than should be required, the use of water by its citizens is not extravagant when gauged by the criterion of use in other large cities. This question was most carefully and exhaustively investigated in 1899 and the early part of 1900 by Mr. John R. Freeman of Boston, acting for the comptroller of the city of New York.

The usual wastes of a water-supply system may be distributed under six principal heads. First, leaky house-plumbing; second, and "possibly first in order of magnitude," leaky service-pipes connecting the house pipe system with street-mains; third, leaving water-cocks open unnecessarily; fourth, leaky joints in street-mains or pipes; fifth, possibly pervious beds and banks of distributing-reservoirs; sixth, stealing or "unlawful diversion" of water through surreptitious connections.

The sixth item is probably an extremely small one in New York, although instances of that kind of waste have been found. It is an old wastage known as far back in time as the ancient Roman water-supply. The second and third items probably constitute the bulk of the wastage in this city.

=156. Division of Daily Consumption in the City of New York.=—In the course of his search for the various sources of consumption, Mr. Freeman concluded from his examinations and from the use of the various means placed at his command for measuring the daily consumption between December 2nd and December 5th, 1899, and December 8th and December 15th, 1899, that the average daily consumption could be divided as follows:

Gallons per Inhabitant per Day.

Probable average amount really used 40 Assumed incurable waste 10} Curable waste, probably 65} 75 ---- Daily uniform rate of delivery by Croton Aqueduct 115

In his investigations Mr. Freeman had the elevation of water in the Central Park reservoir carefully observed every six minutes throughout the twenty-four hours. At the same time the uniform flow through the new Croton Aqueduct was known as accurately as the flow through such a conduit can be gauged at the present time. Knowing, therefore, the concurrent variation of volume in the Central Park reservoir supplied by the new Croton Aqueduct and the rate of flow in that aqueduct, the consumption of water per twenty-four hours would be known with the same degree of accuracy with which the flow in the aqueduct is measured. It was found by these means that the actual consumption between the hours of 2 and 4 A.M. was at the rate of 94 gallons per inhabitant per day, although the actual use at that time was as near zero as it is possible to approach during the whole twenty-four hours. Nearly all of that rate of consumption represents waste.

Summing up the whole matter in the light of his investigations, Mr. Freeman made the following as his nearest estimate to the actual consumption of the daily supply of water of New York City:

Gallons per Inhabitant ACTUAL USE: per Day. Domestic (average) 12 - 20 Manufacturing and commercial 20 - 30 City buildings, etc. 2 - 4 Fires, street flushing and sprinkling 0.4 - 0.7 ---------- Total 34 - 55

INCURABLE WASTE (probabilities): Leaks in mains 1 - 2 Leaks in old and abandoned service-pipes 1 - 2 Poor plumbing, all taps metered and closely inspected 2 - 3 Careless and wilful wastes 1 - 2 Under-registry of meters 1 - 1 ------- Total incurable waste and under-registry 6 -10 ======== Minimum use and waste 40 -65

NEEDLESS WASTE: Leaks in street-mains (a guess) 15- 10 Leaks in service-pipes between houses and street-mains 15- 10 (a guess) Defective plumbing (a guess) 25- 15 Careless and wilful opening of cocks (a guess) 17- 14 To prevent freezing in winter and for cooling in summer 3 - 1 -------- Total needless waste 75- 50 ======== Total consumption 115-115

=157. Daily Domestic Consumption.=—The quantity assigned in the preceding statement to domestic use is confirmed by the abundant experience in other cities where services are carefully metered, as in Fall River, Lawrence, and Worcester, Mass., and in Woonsocket, R. I., where measurements by meters show that the domestic consumption has varied from 11.2 to 16.3 gallons per inhabitant per day. Furthermore, annual reports of the former Department of Public Works and the present Department of Water-supply for the City of New York show that during the years 1890 to 1898 such meters as have been used in the territory supplied by the Croton and the Bronx aqueducts indicate a daily consumption varying from 13.8 to 24.2 gallons per inhabitant per day. The same character of confirmatory evidence can be applied to the quantities assigned to manufacturing and commercial uses, city buildings and fires, street flushing and sprinkling.

=158. Incurable and Curable Wastes.=—The items composing incurable waste, unfortunately, cannot be so definitely treated. It is perfectly well known, however, among civil engineers, that a large amount of leakage takes place from corporation cocks, which are those inserted in the street-mains to form the connection between the latter and the house service-pipes. Again, many of these service-pipes are abandoned and insufficiently closed, or not closed at all, leaving constantly running streams whose continuous subsurface discharges escape detection and frequently find their way into sewers. Water-pipes which have been laid many years

frequently become so deeply corroded as to afford many leaks and sometimes cracks. Doubtless there are many portions of a great distributing system, like that in New York City, which need replacing and afford many large leaks, but undiscoverable from the surface. Many lead joints of street-mains also become leaky with age, while others are leaky when first laid in spite of inspection during construction. Just how much these items of waste would aggregate it is impossible accurately to state, but from careful observations made in other places 5 to 10 gallons per day per head of population seems reasonable. A three-year-old cast-iron fire-protection pipe 5.57 miles long and mainly 16 inches in diameter, under an average pressure of 114 pounds per square inch, was tested in Providence in 1900 and showed a leakage at lead joints only of 446 gallons per mile per twenty-four hours, which was equivalent to .22 gallon per foot of lead joint per twenty-four hours. Further tests in 1900 of seven lines of new pipe laid by the Metropolitan Board of Boston, and tested under pressures varying from 50 to 150 pounds per square inch by Mr. F. P. Stearns, chief engineer, and Mr. Dexter Brackett, engineer of Distribution Department, and having an aggregate length of 51.4 miles with diameters ranging from 16 to 48 inches, gave an average leakage per lineal foot of pipe in gallons per twenty-four hours ranging from .6 to 3.7 gallons (average 2.47 gallons), equivalent to an average leakage of 3 gallons per twenty-four hours per lineal foot of lead joint. The possible rates of leakage from street-mains are to be applied to a total length of pipe-lines of 833 miles for the boroughs of Manhattan and the Bronx. The borough of Brooklyn has somewhat over 600 miles of street-mains, but they are not to be considered in connection with the Croton and Bronx water-supply.

All these considerations either confirm or make reasonable the estimates of the various items of actual use and waste set forth by Mr. Freeman.

=159. Needless and Incurable Waste in City of New York.=—Concisely summing up his conclusions, it may be stated that in the year 1899 the average consumption per inhabitant of the boroughs of Manhattan and the Bronx was 115 gallons; of these 115 gallons the needless average waste may be 65 gallons, while the incurable or necessary waste may probably be taken at 10 gallons per inhabitant per day. It is further probable that the total underground leakage in New York City is to be placed somewhere between 20 to 35 gallons per inhabitant per day.

=160. Increase in Population.=—The total volume of daily supply to any community is determined by the population; but the population is as a whole constantly increasing. It becomes necessary, therefore, to estimate the capacity of a water-supply system in view of the future population of the city to be supplied. No definite rule can be set as to the future period for which the capacity of any desired system is to be estimated. It may be stated that no shorter period of time than probably ten years should be considered, indeed it is frequently prudent to provide for a period of not less than twenty years, and it may sometimes be necessary or advisable to consider a possible source of supply for even fifty years. Provision must be made not only for the present population, but for the increase during those periods of time, or at least for the possible development that may be needed.

The increase in population of cities will obviously vary for different locations with the character of the occupations followed and with the development of such important factors of industrial life as railroad connections, facilities for marine commerce, the capacity for development of the surrounding country, and other influences which aid in the increase of commerce and industrial activity and the growth of population. It has been observed, as a matter of experience, that large cities generally reach a point where their subsequent increase of population is represented by a practically constant percentage, the value of that percentage depending upon local considerations. In 1893, when it was desired to estimate the future population of London for as much as forty years, it was found that the increase for the ten years from 1881 to 1891 was 18.2 per cent, with an average of about 20 per cent for several previous decades. It could, therefore, be reasonably estimated for the city of London that its population at the end of any ten-year period would be 18.2 per cent greater than its population at the beginning of that period. In Appendix 1 of the report of the Massachusetts State Board of Health upon the Metropolitan water-supply for the city of Boston made in 1895, the increases for the two ten-year periods 1870-1880 and 1880-1890 were 6 per cent and 9.6 per cent respectively for the city proper, but for the population within a ten-mile radius from the centre of the city they were 28.7 per cent and 33.7 per cent respectively. The corresponding percentages for the cities of New York, Philadelphia, and Chicago for the same periods are as shown in the following tabular statement:

Population.	Percentages of Increase.
1870.	1880.	1890.	1870-80.	1880-90.
New York	1,626,119	2,131,051	2,821,802	31	32
Philadelphia	726,247	921,458	1,162,577	27	26
Chicago	310,996	550,618	1,075,158	77	95[6]

---

[6] Includes added territory.

Obviously every estimate of this kind must be made upon the merits of the case under consideration. The probable increase of population for any particular city is sometimes estimated by considering the circumstances of growth of some other city of practically the same size, and if possible with the same commercial industries or residential environment, or making suitable allowances for variations in these respects. Since it is imperative to secure as accurate estimates as practicable, both methods or other suitable methods should be employed, in order that the results may be confirmed or modified by comparison. In every case the supply system should be designed to meet reasonable estimated requirements for the longest practicable future period, preferably not less than twenty years.

=161. Sources of Public Water-supplies.=—One of the most important features of a proposed water-supply is its source, since not only the potable qualities are largely affected by it, but frequently the amount also. The two general classes into which potable waters are divided in respect to their sources are surface-waters and ground-waters. Surface-waters include rain-water collected as it falls, water from rivers or smaller streams, and water from natural lakes; they are collected in reservoirs and lakes or impounding reservoirs. Ground-waters are those collected from springs, from ordinary or shallow wells, from deep or artesian wells, and from horizontal galleries, like those sometimes constructed near and parallel to subsurface streams or in subsurface bodies of water, affording opportunity for filtration from the latter through sand or other open materials to them.

The quality of water will obviously be affected by the kind of material through which it percolates or flows. Surface-waters, flowing over the surface of the ground or percolating but a short distance below the surface, naturally have contact with vegetable matter, unless they are collected in a country where the soil is sandy and where the vegetation is scarce. If such waters flow through swamps or over beds of peat or other similar vegetable mould or soil, they may become so impregnated with organic matter or so deeply colored by it that they are not available for potable purposes. Ground-waters, on the other hand, possess the advantage of having flowed through comparatively great depths of sand or other earthy material essentially free of organic matter. They may, however, in some locations, carry prejudicial amounts of objectionable salts in solution, rendering them unfit for use. As a rule, ground-waters are apt to be of better quality than surface-waters, but they do not generally stand storage in reservoirs as well as surface potable waters. It is advisable to store them in covered reservoirs from which the light is excluded, rather than in open reservoirs. They are sometimes impregnated with salts of iron to such an extent as to make it necessary to resort to suitable processes for their removal, and they are also occasionally found so hard as to require the employment of methods of softening them.

Both sources of supply are much used in the United States. Table IV shows the percentages of the various classes of supplies as found in this country during the year 1897; the total number of supplies having been at that time nearly 4000.

TABLE IV.

WATER-SUPPLIES OF THE UNITED STATES.

Source. Per Cent of Total.

{Rivers 25 Surface-waters: {Lakes 7 {Impounding reservoirs 6 {Combinations .5 ----- 38.5

{Shallow wells 26 {Artesian wells 10 Ground-waters: {Spring 15 {Galleries and tunnels 1 {Combinations 2 ----- 54

Surface- and {Rivers and ground-waters 6 ground-waters: {Lakes and ground-waters 1 {Impounding reservoirs and ground-waters .5 ---- 7.5 ------- Total 100.0

It will be observed that a little more than one half of the supplies are from ground-waters. The practice in connection with European public water-supplies is different in that a considerably larger percentage of the total is taken from ground-waters.

The original source of essentially all the water available for public water-supplies is the rainfall. It becomes of the greatest necessity, therefore, to secure all possible information regarding rainfall wherever it may be necessary to construct a public water-supply. Civil engineers and other observers have for many years maintained continuous records of rainfall observations at various points throughout the country, but it is within only a comparatively short time that the number of those points has been large. Through the extension of the work of the Weather Bureau, points of rainfall observation are now scattered quite generally throughout all States of the Union. The oldest observations are naturally found in connection with stations located in the Eastern States, where the rainfall is more uniformly distributed than in many other portions of the country. Obviously rainfall records become of the greatest importance in those localities like the semiarid regions of the far West where long periods of no rain occur.

=162. Rain-gauges and their Records.=—The instrument used for the collection of rain in order to determine the amount falling in a given time is the rain-gauge, which may be fitted with such appliances as to give a continuous record of the rate of rainfall. It has been found that the location of the rain-gauge has a very important influence upon the amount of rain which it collects. It should be placed where wind currents around high structures in its vicinity cannot affect its record. The top of a large flat-roofed building is a good location in a city, although the elevation above the surface of the ground, as is well known, affects the quantity of water collected by the gauge. The collection will be greater at a low elevation than at a high one, in consequence of the greater wind currents at the higher point, it being well known that less rain will be collected where there is the most wind, other things being equal.

[Illustration: Ordinary Rain-gauge.]

=163. Elements of Annual and Monthly Rainfall.=—In consequence of the great variations in the rate of rainfall, not only for different portions of the country, but at different times during the same storm, it becomes necessary to determine various quantities such as the maximum, minimum, and mean annual rainfall, the actual monthly rainfall for different months of the year, and the maximum and minimum monthly rainfall for as long a period as possible. The minimum monthly rainfall and the minimum annual rainfall are of special importance in connection with public water-supply and water-power questions, since those minima will, in connection with the area of a given watershed, determine the greatest amount of water which can be made available for use. In entering upon the consideration of such questions, therefore, civil engineers must inform themselves with the greatest detail as to the characteristics of the monthly and the annual rainfall of the locality in which their works are to be located.

[Illustration: MONTHLY VARIATIONS IN RAINFALL.

FIG. 1.]

TABLE V.

GENERAL RAINFALL STATISTICS FOR THE UNITED STATES.

---------- | | Per Cent| | | of | Per Cent | Mean | Summer | Driest Station. | Yearly | and | Year to |Rainfall.| Autumn | Mean | | Rain to| Year. | | Mean | | | Yearly. | ---------- North Atlantic: | | | Boston | 45.4 | 50 | 60 New York | 44.7 | 52 | 62 Philadelphia | 42.3 | 52 | 70 Washington | 42.9 | 51 | 69 South Atlantic: | | | Wilmington | 53.7 | 61 | 75 Charleston | 49.1 | 61 | 48 Augusta | 48.0 | 50 | 81 Jacksonville | 54.1 | 65 | 74 Key West | 38.2 | 70 | 54 Gulf and Lower Mississippi: | | | Montgomery | 52.5 | 42 | 76 Mobile | 62.6 | 51 | 68 New Orleans | 60.3 | 52 | 64 Galveston | 47.7 | 58 | 50 Nashville | 50.2 | 46 | 67 Ohio Valley: | | | Pittsburg | 36.6 | 53 | 70 Cincinnati | 42.1 | 50 | 60 Indianapolis | 42.2 | 51 | 59 Cairo | 42.6 | 47 | 62 Louisville | 47.2 | 48 | 74 Lake Region: | | | Detroit | 32.5 | 56 | 65 Cleveland | 36.6 | 54 | 71 Duluth | 30.7 | 63 | 65 Upper Mississippi Valley: | | | St. Louis | 40.8 | 52 | 55 Chicago | 34.0 | 54 | 66 Milwaukee | 31.0 | 55 | 66 Madison | 33.2 | 58 | 39 The Plains: | | | Omaha | 31.4 | 63 | 57 North Platte | 18.1 | 61 | 56 Denver | 14.3 | 48 | 59 Cheyenne | 12.7 | 55 | 39 The Plateau: | | | Tucson | 11.7 | 65 | 44 Santa Fé | 14.6 | 69 | 53 Salt Lake City | 18.8 | 39 | 55 Walla Walla | 15.4 | 38 | 46 Pacific Coast: | | | Astoria | 77.0 | 33 | 64 Portland | 46.2 | 31 | 67 Sacramento | 19.9 | 16 | 42 San Francisco | 23.4 | 17 | 51 Los Angeles | 17.2 | 15 | 33 San Diego | 9.7 | 18 | 30 ---------- | | | | | | | Per Cent| Per Cent| Number Station. | Two | Three | of | Driest | Driest | Years' | Years. | Years. | Record. | | | | | | ---------- North Atlantic: | | | Boston | 70 | 80 | 79 New York | 77 | 80 | 61 Philadelphia | 75 | 80 | 72 Washington | 71 | 74 | 45 South Atlantic: | | | Wilmington | 80 | 81 | 26 Charleston | 55 | 62 | 89 Augusta | 88 | 87 | 27 Jacksonville | 77 | 83 | 27 Key West | 61 | 73 | 49 Gulf and Lower Mississippi: | | | Montgomery | 80 | 83 | 24 Mobile | 75 | 78 | 26 New Orleans | 75 | 77 | 26 Galveston | 65 | 72 | 26 Nashville | 73 | 83 | 32 Ohio Valley: | | | Pittsburg | 78 | 85 | 54 Cincinnati | 72 | 71 | 62 Indianapolis | 76 | 82 | 27 Cairo | 75 | 81 | 25 Louisville | 81 | 85 | 25 Lake Region: | | | Detroit | 72 | 79 | 46 Cleveland | 74 | 81 | 41 Duluth | 81 | 88 | 26 Upper Mississippi Valley: | | | St. Louis | 65 | 75 | 60 Chicago | 80 | 86 | 30 Milwaukee | 74 | 73 | 53 Madison | 58 | 68 | 28 The Plains: | | | Omaha | 63 | 70 | 27 North Platte | 67 | 72 | 22 Denver | 71 | 77 | 27 Cheyenne | 62 | 75 | 27 The Plateau: | | | Tucson | 79 | 80 | 19 Santa Fé | 63 | 66 | 37 Salt Lake City | 64 | 74 | 29 Walla Walla | 81 | 86 | 27 Pacific Coast: | | | Astoria | 68 | 77 | 34 Portland | 76 | 79 | 27 Sacramento | 67 | 84 | 47 San Francisco | 73 | 78 | 47 Los Angeles | 48 | 59 | 24 San Diego | 54 | 61 | 47 ----------

The diagram Fig. 1 and Table V are constructed from data given in the bulletins of the Weather Bureau and exhibit some of the general features of the rainfall for different points throughout this country. The heavy lines of the diagram show the average monthly precipitation at the points indicated, for periods of a considerable number of years, as shown in the table. It will be observed that the rainfall is comparatively uniform in the North Atlantic States but quite variable on the Pacific coast, as well as in the Mississippi and

Missouri valleys and west of those valleys.

=164. Hourly or Less Rates of Rainfall.=—Although not often of great importance in connection with public water-supply systems, it is sometimes necessary to possess data regarding maximum hourly (or less) rates of precipitation in connection with sewer or drainage work. The earlier records give exaggerated reports of maximum rates of rainfall, although that rate varies rapidly with the time. Throughout a rain-storm the rate of precipitation is constantly varying and the maximum rate seldom if ever extends over a period equal to a half-hour; usually it lasts but a few minutes only. In this country an average rate of 1 inch per hour, extending throughout one hour, is phenomenal, although that rare amount is sometimes exceeded. A maximum rate of about 4 inches per hour, lasting 15 to 30 minutes, is, roughly speaking, about as high as any precipitation of which we have reliable records. The waste ways or other provisions for the discharge of surplus or flood-waters of the Metropolitan Water-supply of Boston are designed to afford relief for a total precipitation of 6 inches in twenty-four hours. It is safe to state that an excess of that accommodation will probably never be required.

=165. Extent of Heavy Rain-storms.=—In all engineering questions necessitating the consideration of these great rain-storms it is necessary to remember that their extent is frequently much greater than the areas of watersheds usually contemplated in connection with water-supply work. The late Mr. James B. Francis found in the great storm of October, 1869, which had its maximum intensity in Connecticut, that the area over which 6 inches or more of rain fell exceeded 24,000 square miles, and that the area over which a depth of 10 inches or more fell was 519 miles. Again, in the New England storm of February, 1886, 6 inches or more of rain fell over an area of at least 3000 square miles. Storm records show that as much as 8 or 10 inches in depth have fallen over areas ranging from 1800 to 500 square miles, respectively, in a single storm.

=166. Provision for Low Rainfall Years.=—The capacity of any public water-supply must evidently be sufficient to meet not only the general exigencies of the year of lowest rainfall, but also the conditions resulting from the driest periods of that year. It is customary among civil engineers to consider months as the smaller units of a dry year. It is necessary, therefore, to examine not only the annual rainfalls but the monthly rates of precipitation during critical years, i.e., usually during dry years.

It is impossible to determine absolutely the year of least rainfall which may be expected, but evidently the longer the period over which observations have extended the nearer that end will be attained. It is sometimes assumed that the lowest annual rainfall likely to be expected in a long period of years is 80 per cent of the average annual rainfall for the same period. Or, it is sometimes assumed that the average rainfall for the lowest two or three consecutive years will be 80 per cent of the average for the entire period, and that the year of minimum rainfall may be expected to yield two thirds of the annual average precipitation. Such features will necessarily vary with the location of the district considered. Conclusions which may be true for the New England or northern Atlantic States probably will not hold for the south Atlantic and Gulf States. Data for such conclusions must be obtained from the rainfall of the locality considered. Table VI exhibits the comparative monthly rainfall which J. T. Fanning suggests may be used approximately for the average Atlantic coast districts.

TABLE VI.

+----------+----------+----------+----------+ | | Mean | | Probable | | | Monthly | Respective | Depth in | | | Rainfall, | Ratios. | Inches of | | | Inches. | | Actual | | | | | Rainfall. | +----------+----------+----------+----------+ | January | 4 × 1.65 = 6.6 | | February | 4 × 1.50 = 6.0 | | March | 4 × 1.65 = 6.6 | | April | 4 × 1.45 = 5.8 | | May | 4 × .85 = 3.4 | | June | 4 × .75 = 3.0 | | July | 4 × .35 = 1.4 | | August | 4 × .25 = 1.0 | | September | 4 × .30 = 1.2 | | October | 4 × .45 = 1.8 | | November | 4 × 1.20 = 4.8 | | December | 4 × 1.60 = 6.4 | +----------+----------+----------+----------+

If the average monthly rainfall throughout the year were one inch, the values of the ratios would show the actual monthly precipitation. In general the table would be used by dividing the total yearly rainfall by 12, and then multiplying that monthly average by the proper ratio taken from the table opposite the month required. Such tables should only be used for approximate purposes and when actual rainfall records are not available for the district considered.

=167. Available Portion of Rainfall or Run-off of Watersheds.=—If the public water-supply is to be drawn from a stream where the desired rainfall records exist, it is necessary to know what portion of the rainfall, either in the driest or in other years, may be available. This is one of the departments of the hydraulics of streams for which much data yet remain to be secured. The watersheds or areas drained by some streams, like the Sudbury River of the Boston, and the Croton of the New York water-supply, have, however, been studied with sufficient care to give reliable data. The amount of water flowing in a stream from any watershed for a given period, as a year, is called the annual "run-off" of the watershed, and it is usually expressed as a certain percentage of

the total rainfall on the area drained. For certain purposes it is sometimes more convenient to express the run-off from the watershed as the number of cubic feet of water per second per square mile of area. Table VII, taken from Turneaure and Russell, exhibits run-off data for a considerable number of streams in connection with both average and minimum rainfalls.

TABLE VII.

STATISTICS OF THE FLOW OF STREAMS.

Area		Average Yearly.	Year of Minimum Stream.	Drained,			Flow.	Square	Years.	Miles.		Rain,	Flow,	Per	Rain,	Flow,	Per			Inch.	Inch.	Cent	Inch.	Inch.	Cent
Sudbury	75.2	1875-97	45.77	22.22	48.6	32.78	11.19	34.1
Cochituate	18.87	1863-96	47.08	20.33	43.2	31.20	9.76	31.3
Mystic	26.9	1878-96	43.79	19.96	45.6	31.22	9.32	29.8
Connecticut	10,234	1871-85	44.69	25.25	56.5	40.02	18.25	45.6
Croton	338	1870-94	48.38	24.57	50.8	38.52	14.54	37.8
Upper Hudson	4,500	1888-96	39.70	23.36	59.0	33.49	17.46	52.2
Genesee	1,060	1894-96	39.82	12.95	32.5	31.00	6.67	21.5
Passaic	822	1877-93	47.08	25.44	54.0	35.64	15.23	42.7
Upper Mississippi	3,265	1885-99	26.57	4.90	18.4	22.86	1.62	7.1

		Average for	Average for June	Area		December to May.	to November.	Stream.	Drained,			Square	Years.	Miles.		Rain,	Flow,	Per	Rain,	Flow,	Per			Inch.	Inch.	Cent	Inch.	Inch.	Cent
Sudbury	75.2	1875-97	22.98	17.52	76.0	22.61	4.70	20.8
Cochituate	18.87	1863-96	22.97	14.87	64.7	24.10	5.46	22.7
Mystic	26.9	1878-96	22.11	15.12	68.4	21.66	4.84	22.4
Connecticut	10,234	1871-85	20.13	17.95	89.1	24.56	7.30	29.7
Croton	338	1870-94	23.39	17.81	76.1	24.99	6.76	27.0
Upper Hudson	4,500	1888-96	18.20	16.23	89.0	21.50	7.13	33.0
Genesee	1,060	1894-96	19.58	10.20	52.2	20.24	2.75	13.6
Passaic	822	1877-93	22.47	18.22	81.1	24.39	7.19	29.5

The information to be drawn from this table is sufficient to give clear and general relations between the recorded precipitation and run-off. The percentage of run-off is seen to vary quite widely, but as a rule it is materially less for the year of minimum flow than for the average year. That feature of the table is an expression of the general law, other things being equal, that the smaller the precipitation the less will be the percentage of run-off. A number of influences act to produce that result. During a year of great precipitation the earth is more nearly saturated the greater part of the time, and hence when rain falls less of it will percolate into the ground and more of it will run off. Again, if the ground is absolutely dry, a certain amount of rain would have to fall before any run-off would take place. The area and shape of a watershed will also affect to some extent the flow of the stream which drains it. A larger run-off would reasonably be expected from a long narrow watershed than from one more nearly circular in outline. The greater the massing of the watershed, so to speak, the more opportunity there is for the water to be held by the ground and the less would be the run-off.

TABLE VIII.

AVERAGE YIELD OF SUDBURY WATERSHED, 1875-1899, INCLUSIVE, VARIOUSLY EXPRESSED.

(Area of watershed, 75.2 square miles.)

Per Square Mile.	Rainfall.	Month.	Cubic Feet	Million	Collected,	Per Cent	Total,	per Second.	Gallons	Inches.	Collected.	Inches.		per Day.		
January	1.937	1.252	2.233	51.6	4.33
February	2.904	1.877	3.050	71.7	4.26
March	4.489	2.901	5.175	117.4	4.41
April	3.124	2.019	3.485	107.5	3.24
May	1.680	1.086	1.936	58.1	3.33
June	.735	.475	.821	28.0	2.93
July	.305	.197	.352	9.3	3.77
August	.478	.309	.551	13.3	4.16
September	.376	.243	.419	13.0	3.23
October	.829	.536	.956	21.9	4.37
November	1.474	.953	1.645	39.0	4.22
December	1.612	1.042	1.859	51.9	3.58
Year	1.655	1.070	22.482	49.1	45.83

=168. Run-off of Sudbury Watershed.=—Table VIII has been given by Mr. Charles W. Sherman, as representing the average yield of the Sudbury watershed for the period 1875 to 1899, inclusive, expressed in several different ways. The average rainfall was 45.83 inches, and the percentage which represents the run-off is 49.1 per cent of the total. The average monthly run-off varies from .305 cubic foot (for July) to 4.489 cubic feet (for March) per second per square mile. As a general rule it may be stated that the average run-off from the drainage areas of New England streams amounts very closely to 1,000,000 gallons per square mile per day. The area of the Sudbury watershed is 75.2 square miles, with 6.5 per cent of that total area occupied by the surface of lakes or reservoirs. As will presently be seen, the amount of exposed water surface in any watershed has an appreciable influence upon its

run-off.

=169. Run-off of Croton Watershed.=—The total area of the Croton watershed, from which New York City draws its supply, i.e., the area up-stream from the new Croton Dam, is 360.4 square miles, of which 16.1 square miles, or 4.47 per cent, of its total area is water surface. Mr. John R. Freeman found in the investigations covered by his report to the comptroller of the city of New York in 1900 that the average annual rainfall on that area for the thirty-two years beginning 1868 and ending 1899 was 48.07 inches, and that the average run-off for the same period was 47.7 per cent of the total average rainfall, equivalent to a depth of 22.93 inches.

[Illustration: Aqueducts near Jerome Park Reservoir, New York City.]

Table IX gives the main elements of the rainfall and run-off for the Croton watershed during the thirty-two year period, for the averages just given.

TABLE IX.

RAINFALL ON CROTON WATERSHED IN TOTAL INCHES—1868-1898. NATURAL FLOW OF CROTON RIVER AT OLD CROTON DAM, IN EQUIVALENT INCHES. PERCENTAGE OF RUN-OFF TO RAINFALL FOR EACH YEAR.

----------+---------+---------+---------- Year. | Total | Total | |Rainfall.| Run-off.| Per Cent. ----------+---------+---------+---------- 1868 | 50.33 | 33.33 | 66.22 1869 | 48.36 | 23.61 | 48.82 1870 | 44.63 | 19.20 | 43.02 1871 | 48.94 | 19.46 | 39.76 1872 | 40.74 | 16.92 | 41.53 1873 | 43.87 | 25.02 | 57.03 1874 | 42.37 | 25.10 | 59.24 1875 | 43.66 | 24.77 | 56.73 1876 | 40.68 | 21.09 | 51.84 1877 | 48.23 | 20.22 | 41.92 1878 | 55.70 | 27.17 | 48.78 1879 | 47.04 | 19.65 | 41.77 1880 | 36.92 | 12.63 | 34.21 1881 | 46.69 | 19.25 | 41.23 1882 | 52.35 | 24.28 | 46.38 1883 | 42.70 | 13.33 | 31.22 1884 | 51.28 | 24.08 | 46.96 1885 | 43.67 | 17.71 | 40.55 1886 | 47.74 | 20.10 | 42.10 1887 | 57.29 | 26.61 | 46.45 1888 | 60.69 | 35.27 | 58.12 1889 | 55.70 | 31.39 | 56.36 1890 | 54.05 | 25.95 | 48.01 1891 | 47.20 | 23.48 | 49.75 1892 | 44.28 | 17.68 | 39.93 1893 | 54.87 | 29.05 | 52.94 1894 | 47.33 | 20.56 | 43.44 1895 | 40.58 | 15.95 | 39.31 1896 | 45.85 | 23.26 | 50.73 1897 | 53.12 | 25.59 | 48.17 1898 | 57.40 | 29.72 | 51.77 1899 | 44.67 | 22.28 | 49.88 Average for| 48.07 | 22.93 | 47.70 32 years. | | | ----------+---------+---------+----------

The table shows that the least annual rainfall was 36.92 inches for 1880, and that the run-off represented a depth of 12.63 inches only, or 34.21 per cent of the total annual precipitation. As a rule the same feature of a low percentage of run-off will be found belonging to the years of low rainfall, although there are many irregularities in the results. On the other hand, the high percentages of run-off are for the years 1868, 1888, and 1889, and they will generally be found belonging to years of relatively great precipitation. A low percentage of run-off will also be lower if the year to which it belongs follows a dry year or a dry cycle of two or three years. Similarly the high percentages of run-off will, as a rule, be higher if they follow years of high precipitation; that is, if they belong to a cycle of relatively great rainfall.

=170. Evaporation from Reservoirs.=—If it is contemplated to build reservoirs on a watershed the capacity of which is being estimated on the basis of either the driest year or the driest two- or three year cycle, it is necessary to make a deduction from the rainfall for the evaporation which will take place from the surface of the proposed reservoir. In order that that deduction may be made as a proper allowance for added water surface in a drainage area, it is necessary that the amount of evaporation be determined for the district considered. The rate of evaporation is dependent upon the area of water surface, upon the wind, and upon the temperature both of the water and air above it. Numerous evaporation observations have been made both in this and other countries, and extensive evaporation tables have been prepared by the Weather Bureau, from which a reasonable estimate of the monthly evaporation for all months in the year may be made for almost any point in the United States. Particularly available observations have been made by Mr. Desmond Fitzgerald of Boston on the Chestnut Hill reservoirs of the Boston Water-supply, and by Mr. Emil Kuichling, engineer of the Rochester Water-works, on the Mount Hope reservoir of the Rochester supply. Table X exhibits the results of the observations of both these civil engineers.

[Illustration: Aqueduct Division Wall of Jerome Park Reservoir, New York City.]

As would be anticipated, the period from May to September, both inclusive, shows by far the greatest evaporation of the whole year, while December, January, and February are the months of least evaporation. The total annual evaporation at Boston was 39.2 inches and 34.54 inches at Rochester.

TABLE X.

MEAN MONTHLY EVAPORATIONS. ----------+----------+---------- | | | Chestnut Hill Reservoir,| Mount Hope Reservoir, Month. | Boston, Mass. | Rochester, N. Y. | | ----------+----------+----------+----------+---------- | | Per Cent | | Per Cent |Evaporation,| of Yearly |Evaporation,| of Yearly | Inches. |Evaporation.| Inches. |Evaporation. ----------+----------+----------+----------+---------- January | 0.96 | 2.4 | 0.52 | 1.5 February | 1.05 | 2.7 | 0.54 | 1.6 March | 1.70 | 4.3 | 1.33 | 3.9 April | 2.97 | 7.6 | 2.62 | 7.6 May | 4.46 | 11.4 | 3.93 | 11.4 June | 5.54 | 14.2 | 4.94 | 14.3 July | 5.98 | 15.2 | 5.47 | 15.8 August | 5.50 | 14.0 | 5.30 | 15.4 September | 4.12 | 10.4 | 4.15 | 12.0 October | 3.16 | 8.1 | 3.16 | 9.1 November | 2.25 | 5.7 | 1.45 | 4.2 December | 1.51 | 3.9 | 1.13 | 3.2 +----------+----------+----------+---------- Total for year | 39.20 | | 34.54 | +----------+----------+----------+---------- Mean temperature| 48°.6 | 47°.8 ----------+----------+----------

A reference to data of the Weather Bureau will show that annual evaporation as high as 100 inches, or even more, may be expected on the plateaux of Arizona and New Mexico. Other portions of the arid country in the western part of the United States will indicate annual evaporations running anywhere from 50 to 90 inches per year, while on the north Pacific coast it will fall as low as 18 to 40 inches.

=171. Evaporation from the Earth's Surface.=—Data are lacking for anything like a reasonably accurate estimate of evaporation from the earth's surface. It is well known that the loss of water from that source is considerable in soils like those of swamps, particularly when exposed to the warm sun, but no reliable estimate can be obtained for the exact amount. Nor is this necessary for the usual water-supply problems, since it is included in the difference between the total rainfall of any district and the observed run-off in the streams. Indeed evaporation from reservoirs is similarly included for reservoirs existing when the run-off observations are made.

CHAPTER XVI.

=172. Application of Fitzgerald's Results to the Croton Watershed.=—The evaporation data determined by Messrs. Fitzgerald and Kuichling are sufficient for all ordinary purposes in the North Atlantic States. In the discussion of the capacity of the Croton watershed Mr. Fitzgerald's results will be taken, as the conditions of the Croton watershed in respect to temperature and atmosphere are affected by the proximity to the ocean, and other features of the case make it more nearly like the Metropolitan drainage area near Boston than the more elevated inland district near Rochester.

If the monthly amounts of evaporation be taken from the preceding table, and if it further be observed that a volume of water 1 square mile in area and 1 inch thick contains 17,377,536 gallons, the following table (Table XI) of amounts of evaporation from the reservoirs in the Croton watershed, including the new Croton Lake, will result, since the total area of water surface of all these reservoirs is 16.1 square miles.

TABLE XI.

Jan. 0.96 × 16.1 × 17,377,536 = 268,600,000 gallons. Feb. 1.05 × " × " = 293,800,000 " Mar. 1.70 × " × " = 475,700,000 " April 2.97 × " × " = 831,000,000 " May 4.46 × " × " = 1,247,900,000 " June 5.54 × " × " = 1,550,100,000 " July 5.98 × " × " = 1,673,200,000 " Aug. 5.50 × " × " = 1,538,900,000 " Sept. 4.12 × " × " = 1,152,800,000 " Oct. 3.16 × " × " = 884,200,000 " Nov. 2.25 × " × " = 629,600,000 " Dec. 1.51 × " × " = 422,500,000 " ----- ---------- 39.20 Total = 10,968,300,000 "

It will be seen from this table that the total annual evaporation from all the reservoir surfaces of the Croton watershed, as it will exist when the new Croton Lake is completed, will be nearly 11,000,000,000 gallons, enough to supply the boroughs of Bronx and Manhattan at the present rate of consumption for about forty days.

=173. The Capacity of the Croton Watershed.=—The use of the preceding figures and numbers can be well illustrated by considering the capacity of the Croton watershed in its relations to the present water needs of the boroughs of Bronx and Manhattan which that watershed is designed to supply. The total area of the Croton watershed is 360.4 square miles, of which 16.1 square miles, as has already been observed, is water surface. As a matter of fact the run-off observations from that watershed have been maintained or computed for the thirty-two-year period from 1868 to 1899, inclusive, covering the evaporation from the reservoirs and lake surfaces as they have existed during that period. The later observations, therefore, include the effects of evaporation from the more lately constructed reservoirs, but none of these data cover evaporation from the entire surface of the new Croton Lake, whose excess over that of the old reservoir is nearly one third of the total water surface of the entire shed. As a margin of safety and for the purpose of simplification, separate allowance will be made for the evaporation from all the reservoir and lake surfaces of the entire watershed as it will exist on the completion of the new Croton Lake, as a deduction from the run-off. The

preceding table (Table XI) exhibits those deductions for evaporation as they will be made in the next table.

In Table IX the year 1880 yields the lowest run-off of the entire thirty-two-year period. The total precipitation was 36.92 inches, and only 34.21 per cent of it was available as run-off. The first column in Table XII gives the amount of monthly rainfall for the entire year, the sum of which aggregates 36.92 inches. Each of these monthly quantities multiplied by .3421 will give the amount of rainfall available for run-off, and the latter quantity multiplied by the number of square miles in the watershed (360.4) will show the total depth of available water concentrated upon a single square mile. If the latter quantity be multiplied by 17,378,000, the total number of gallons available for the entire month will result, from which must be subtracted the evaporation for the same month. Carrying out these operations for each month in the year, the monthly available quantities for water-supply will be found, as shown in the last column.

TABLE XII.

(Jan. 3.43 × .3421 = 1.173) × 360.4 × 17,378,000 - 268,600,000 = 7,077,700,000 (Feb. 3.40 × " = 1.163) × " × " - 293,800,000 = 6,989,900,000 (Mar. 3.90 × " = 1.334) × " × " - 475,700,000 = 7,879,000,000 (April 3.57 × " = 1.221) × " × " - 831,000,000 = 6,816,000,000 (May 1.04 × " = .356) × " × " - 1,247,900,000 = 982,000,000 (June 1.40 × " = .479) × " × " - 1,550,100,000 = 1,449,800,000 (July 5.86 × " = 2.005) × " × " - 1,673,200,000 = 10,890,000,000 (Aug. 4.16 × " = 1.423) × " × " - 1,538,900,000 = 7,373,100,000 (Sept. 2.42 × " = .828) × " × " - 1,152,800,000 = 4,032,900,000 (Oct. 2.83 × " = .968) × " × " - 884,200,000 = 5,178,500,000 (Nov. 2.32 × " = .794) × " × " - 629,600,000 = 4,343,100,000 (Dec. 2.59 × " = .886) × " × " - 422,500,000 = 5,126,300,000 ----- 36.92

The sum of the twelve monthly available quantities will give the total number of gallons per year applicable to meeting the water demands of the boroughs of Bronx and Manhattan.

=174. Necessary Storage for New York Supply to Compensate for Deficiency.=—At the present time the average daily consumption per inhabitant of those two boroughs is 115 gallons, and if the total population be taken at 2,200,000, the total daily consumption will be 2,200,000 × 115 = 253,000,000 gallons. If the latter quantity be multiplied by 30.5, the latter being taken as the average number of days in the month throughout the year, the average monthly draft of water for the two boroughs in question will be 7,716,500,000 gallons. The subtraction of the latter quantity from the monthly results in the preceding table will exhibit a deficiency which must be met by storage or a surplus available for storage. Table XIII exhibits the twelve monthly differences of that character.

TABLE XIII.

7,077,700,000 — 7,716,500,000 = - 638,800,000 6,989,900,000 — " = - 726,600,000 7,879,000,000 — " = + 162,500,000 6,816,000,000 — " = - 900,500,000 982,000,000 — " = - 6,734,500,000 1,449,800,000 — " = - 6,266,700,000 10,890,000,000 — " = +3,173,500,000 7,373,100,000 — " = - 343,400,000 4,032,900,000 — " = - 3,683,600,000 5,178,500,000 — " = - 2,538,000,000 4,343,100,000 — " = - 3,373,400,000 5,126,300,000 — " = - 2,590,200,000 ---------- ---------- -27,795,700,000 +3,336,000,000 + 3,336,000,000 ---------- -24,459,700,000

It is seen from this table that the total monthly deficiencies aggregate 27,795,700,000 gallons and that there are only two months in which the run-off exceeds the consumption, the surplus for those two months being only 3,336,000,000 gallons. The total deficiency for the year is therefore 24,459,700,000 gallons. Dividing the latter quantity by the average daily draft of 253,000,000 gallons, there will result a period of 97 days, or more than one quarter of a year, during which the minimum annual rainfall would fail to supply any water to the city at all. These results show that in case of a low rainfall year, like that of 1880, the precipitation upon the Croton watershed would supply sufficient water for the boroughs of Bronx and Manhattan at the present rate of consumption for three fourths of the year only. A distressingly serious water famine would result unless the year were begun by sufficient available storage in the reservoirs of the basin at least equal to 24,459,700,000 gallons. Should such a low rainfall year or one nearly approaching it be one of a two- or three-year low rainfall cycle, such a reserve storage would be impossible and the resulting conditions would be most serious for the city. If an average year, for which the total rainfall would be about 48 inches preceded such a year of low rainfall, the conditions would be less serious. The figures would stand as follows:

Total run-off = 17,377,536 × 360.4 × 22.93 - 17,377,536 × 16.1 × 39.2 = 132,640,000,000 gallons.

Total annual consumption = 92,345,000,000 " ---------- Available for storage = 40,295,000,000 " Deficiency = 24,459,700,000 " ---------- Surplus = 15,835,300,000 "

The average year would, therefore, yield enough run-off water if stored to more than make up the deficiency of the least rainfall year by nearly 16,000,000,000 gallons. In order to secure the desired volume it would therefore be necessary to have storage capacity at least equal to 24,459,700,000 gallons; indeed, in order to meet all the exigencies of a public water-supply it would be necessary to have far more than that amount. As a matter of fact there are in the Croton watershed seven artificial reservoirs with a total storage capacity of nearly 41,000,000,000 gallons, besides a number of small ponds in addition to the new Croton Lake which with water surface at the masonry crest of the dam has a total additional storage capacity of 23,700,000,000 gallons. The storage capacity of the new Croton Lake may be increased by the use of flash-boards 4 feet high placed along its crest, so that with its water surface at grade 200 its total capacity will be increased to 26,500,000,000 gallons. After the new Croton reservoir is in use the total storage capacity of all the reservoirs and ponds in the Croton watershed will be raised to 70,245,000,000 gallons, which can be further augmented by the Jerome Park reservoir when completed by an amount equal to 1,900,000,000 gallons. This is equivalent, at the present rate of consumption, to a storage supply for 285 days for the boroughs of Manhattan and the Bronx.

=175. No Exact Rule for Storage Capacity.=—This question of the amount of storage capacity to be provided in connection with public water-supplies is one which cannot be reduced to an exact rule. Obviously if the continuous flow afforded from any source is always greater per day than any draft that can ever be made upon it, no storage-reservoirs at all would be needed, although they might be necessary for the purpose of sedimentation. On the other hand, as in the case of New York City, if the demand upon the supply has reached its capacity or exceeded it for low rainfall years, it may be necessary to provide storage capacity sufficient to collect all the run-off of the watershed. The civil engineer must from his experience and from the data before him determine what capacity between those limits is to be secured. When the question of volume or capacity of storage is settled the mode of distribution of that volume or capacity in reservoirs is to be determined, and that affects to some extent the potability of the water. If there is a large area of shallow storage, the vegetable matter of the soil may affect the water in a number of ways. Again, it is advisable in this connection to consider certain reservoir effects as to color and contained organic matter in general.

=176. The Color of Water.=—The potability[7] of water collected from any watershed is materially affected by its color. Although iron may produce a brownish tinge, by far the greater amount of color is produced by dissolved vegetable matter. Repeated examinations of colored water have shown that discoloration is in many cases at least a measure of the vegetable matter contained in it. While this may not indicate that the water is materially unwholesome, it shows conclusively the existence of conditions which are usually productive of minute lower forms of vegetation from which both bad taste and odors are likely to arise.

[7] What is generally known as the "Michigan standard of the purity of drinking-water," as specified by the Michigan State Laboratory of Hygiene, is here given:

"1. The total residue should not exceed 500 parts per million. "2. The inorganic residue may constitute the total residue. "3. The smaller amount of organic residue the better the water. "4. The amount of earthy bases should not exceed 200 parts per million. "5. The amount of sodium chloride should not exceed 20 parts per million (i.e., 'chlorine' 12.1 parts per million). "6. The amount of sulphates should not exceed 100 parts per million. "7. The organic matter in 1,000,000 parts of the water should not reduce more than 8 parts of potassium permanganate (i.e., 'required oxygen' 2.2 parts per million). "8. The amount of free ammonia should not exceed 0.05 part per million. "9. The amount of albuminoid ammonia should not exceed 0.15 part per million. "10. The amount of nitric acid should not exceed 3.5 parts per million (i.e., 'N as nitrate' .9 part per million). "11. The best water contains no nitrous acid, and any water which contains this substance in quantity sufficient to be estimated should not be regarded as a safe drinking-water. "12. The water must contain no toxicogenic germs as demonstrated by tests upon animals.

"The water must be clear and transparent, free from smell, and without either alkaline or acid taste, and not above 5 French standard of hardness."

This standard is too high to be attained ordinarily in natural waters.

There are two periods in the year of maximum intensity of color, one occurring in June and the other in November. The former is due to the abundant drainage of peaty or other excessively vegetable soils from the spring rains. After June the sun bleaches the water to a material extent until the autumn, when the dying vegetation imparts more or less coloring to the water falling upon it. This last agency produces its maximum effect in the month of November.

There are various arbitrary scales employed by which colors may be measured and discolored waters compared. Among others, dilute solutions of platinum and cobalt are used, in which the relative proportions of those substances are varied so as to resemble

closely the colors of the water. The amount of platinum used is a measure of the color, one unit of which corresponds to one part of the metal in 10,000 parts of water. Again, the depth at which a platinum wire 1 mm. (.039 inch) in diameter and 1 inch long can be seen in the water is also taken as a measure of the color, the amount of the latter being inversely as the depth. This method has found extended and satisfactory use in connection with the Metropolitan Water-supply of Boston, the Cochituate water having a degree of color represented by .25 to .30, while the Sudbury water has somewhat more than twice as much. The Cochituate water is practically colorless.

The origin of the color of water is chiefly the swamps which drain into the water-supply, or the vegetation remaining upon a new reservoir site when the surface soil has not been removed before the filling of the reservoir. The drainage of swamps should not, as a rule, be permitted to flow into a public water-supply, as it is naturally heavily charged with vegetable matter and is correspondingly discolored. This matter, like many others connected with the sanitation of potable public waters, has been most carefully investigated by the State Board of Health of Massachusetts in connection with the Boston water-supply. Its work has shown the strong advisability of diverting the drainage of large swamps from a public supply as carrying too much vegetable matter even when highly diluted by clear water conforming to desirable sanitary standards.

=177. Stripping Reservoir Sites.=—The question of stripping or cleaning reservoir sites of soil is also one which has been carefully studied by the Massachusetts State Board of Health. As a consequence large amounts of money have been expended by the city of Boston in stripping the soil from reservoir sites to the average depth in some cases of 9 inches for wooded land and 12½ inches for meadow land. This was done in the case of the Nashua River reservoir having a superficial area of 6.56 square miles at a cost of nearly $2,910,000, or about $700 per acre. It has been found that the beneficial effect of this stripping is fully secured if the black loam in which vegetation flourishes is removed.

[Illustration: Wachusetts Reservoir, showing Stripping of Soil.]

This stripping of soil is indicative of the great care taken to secure a high quality of water for the city of Boston, but it is not done in the Croton watershed of the New York supply. It cannot be doubted that the quality of the Croton supply would have been sensibly enhanced by a similar treatment of its reservoir sites. Mr. F. B. Stearns, chief engineer of the Metropolitan Water-supply of Boston, states that in some cases the effects of filling reservoirs without removing the soil and vegetable matter have “continued for twenty years or more without apparent diminution.” On the other hand, water discolored by vegetable matter becomes bleached to some extent at least by standing in reservoirs whose sites have been stripped of soil.

=178. Average Depth of Reservoirs should be as Great as Practicable.=—In the selection of reservoir locations those are preferable where the average depths will be greatest and where shallow margins are reduced to a minimum. It may sometimes be necessary to excavate marginal portions which would otherwise be shallow with a full reservoir. There should be as little water as possible of a less low-water depth than 10 or 12 feet, otherwise there may be a tendency to aquatic vegetable growth. The following table exhibits the areas, average depths, capacity, and other features of a number of prominent storage-reservoirs.

COMPARATIVE TABLE OF AREAS, DEPTHS, AND CAPACITIES OF STORAGE RESERVOIRS WITH HEIGHTS AND LENGTHS OF DAMS.

LEGEND: (A) = Area Square Miles. (B) = Average Depth, Feet. (C) = Length of Dam, Feet. (D) = Capacity, Million Gallons.

Name and Location of Reservoir.	(A)	(B)	Maximum Height| Above Ground.	Above Rock.	(C)	(D)
Swift River, Mass	36.96	53	144	...	2,470	406,000
Nashua River, Mass	6.56	46	129	158	1,250	63,068
Nira, near Poona, India	7.25	27	100	...	3,000	41,143
Tansa, Bombay, India	5.50	33	127	131	8,770	37,500
Khadakvasla, Poona, India	5.50	32	100	107	5,080	36,737
New Croton, N. Y.	....	..	157	225	1,270	32,000
Elan and Claerwen, Birmingham, Eng., water-works						
(total for six reservoirs)	2.34	43	98-128	...	4,460	20,838
All Boston water-works reservoirs combined	5.82	14	14-65	...	.....	15,867
Vyrnwy, Liverpool, Eng.	1.75	..	84	129	1,350	14,560
Ware River, Mass.	1.62	33	71	...	785	11,190
Sodom, N. Y.	....	..	72	89	500	9,500
Reservoir No. 5, Boston water-works	1.91	19	65	70	1,865	7,438
Titicus, N. Y.	....	..	105	115	.....	7,000
Hobbs Brook, Cambridge water-works	1.00	12	23	...	.....	2,500
Cochituate, Boston water-works	1.35	8	..	...	.....	2,160
Reservoir No. 6, Boston water-works	0.29	25	52	...	1,500	1,500

=179. Overturn of Contents of Reservoirs Due to Seasonal Changes of Temperature.=—It will be noticed that the average depth is less than about 20 feet in few cases only. If the water is deep, its mean temperature throughout the year will be lower than if

shallow. During the warmer portion of the year the upper layers of the water are obviously of a higher temperature than the lower portions, since the latter receive much less immediate effect from the sun's rays. As the upper portions of the water are of higher temperature, they are also lighter and hence remain at or near the top. For the same reason the water at the bottom of the reservoir remains there throughout the warm season and until the cool weather of the autumn begins. The top layers of water then continue to fall in temperature until it is lower than that of the water at the bottom, when the surface-water becomes the heaviest and sinks. It displaces subsurface water lighter than itself, the latter coming to the surface to be cooled in turn.

This operation produces a complete overturning of the entire reservoir volume as the late autumn or early winter approaches. It thus brings to the surface-water which has been lying at the bottom of the reservoir all summer in contact with what vegetable matter may have been there. The depleted oxygen of the bottom water is thus replenished with a corresponding betterment of condition. It is the great sanitary effort of nature to improve the quality of stored water entrusted to its care, and it continues until the surface is cooled to a temperature perhaps lower than that of the greatest density of water.

Another great turn-over in the water of a lake or reservoir covered with ice during the winter occurs in the spring. When the ice melts, the resulting water rises a little in temperature until it reaches possibly its greatest density at 39°.2 Fahr., and then sinks, displacing subsurface water. This goes on until all the ice is melted and until all water cooled by it, near the surface, below 39°.2 Fahr. has been raised to that temperature. The period of summer stagnation then follows.

=180. The Construction of Reservoirs.=—The natural topography and sometimes the geology of the locality determines the location of the reservoir. The first requirement obviously is tightness. If for any reason whatever, such as leaky banks or bottom, porous subsurface material, or for any other defect, the water cannot be retained in the reservoir, it is useless. Some very perplexing questions in this connection have arisen. Indeed reservoirs have been completed only to be found incapable of holding their contents. Such results are evidently not creditable to the engineers who are responsible for them, and they should be avoided.

[Illustration: YARROW RESERVOIR, LIVERPOOL WATER-SUPPLY]

[Illustration: SAN LEANDRO DAM, SAN FRANCISCO WATER-WORKS]

[Illustration: TITICUS DAM, NEW YORK WATER-SUPPLY]

In order that the bottom of the reservoir may be water-tight it must be so well supported by firm underlying material that it will not be injured by the weight of water above it, which in artificial reservoirs may reach 30 to 100 feet or more in depth. The subsurface material at the site of any proposed structure of this character must, therefore, be carefully examined so as to avoid all porous material, crevasses in rocks, or other open places where water might escape. Objectionable material may frequently be removed and replaced with that which is more suitable, and rock crevices and other open places may sometimes be filled with concrete and made satisfactory. Whatever may be the conditions existing, the finished bottom of the reservoir should be placed only on well-compacted, firm, unyielding material.

The character of the reservoir bottom will depend somewhat upon the cost of suitable material of which to construct it. If a bottom of natural earth cannot be used, a pavement of stone, brick, or concrete may be employed from 8 inches to a foot or a foot and a half in thickness. The reservoir banks must be placed upon carefully prepared foundations, sometimes with masonry core-walls. They are frequently composed of clayey and gravelly material mixed in proper proportions and called puddle, although that term is more generally applied to a mixture of clay and gravel designed to form a truly impervious wall in the centre of the reservoir embankment. Some engineers require the core-wall, as it is called, to be constructed of masonry, with the earth or gravelly material carried up each side of this wall in layers 6 to 9 inches thick, well moistened and each layer thoroughly rolled with a grooved roller, or treated in some equivalent manner in order that the whole mass may not be in strata but essentially continuous and as nearly impervious as possible. The masonry core-wall should be founded on bed-rock or its equivalent. Its thickness will depend upon the height of the embankment. If the latter is not more than 20 or 25 feet high, the core-wall need not be more than 4 to 6 feet thick, but if the embankment reaches a height of 75 feet or even 100 feet, it must be made 15 to 20 feet thick, or possibly more, at the base. Its top should be not less than 4 or 6 feet thick, imbedded in the earth and carried well above the highest surface of water in the reservoir.

The thickness of the clay puddle-wall employed as the central core of the reservoir embankment is usually made much thicker than that of masonry. As a rough rule it may be made twice as thick as the masonry core at the deepest point and not less than about 6 feet at the top. The thickness of the puddle core is sometimes varied to meet the requirements of the natural material in which it is embedded at different depths.

Frequently, when embankments are under about 20 feet high, the core-walls may be omitted, excavation having been made at the base of the embankment down to rock or other impervious material, and if the entire bank is carried up with well-selected and puddled material.

The interior slopes of reservoir embankments are usually covered with roughly dressed stone pavement 12 to 18 inches thick, laid upon a broken stone foundation 8 to 12 inches thick, for a protection against the wash of waves, the pavement in any case being placed upon the bank slope after having been thoroughly and firmly compacted. The sloping and bottom pavements, of whatever material they may be composed, should be made continuous with each other so as to offer no escape for the water. In some cases where it has been found difficult to make the interior surfaces of reservoirs water-tight, asphalt or other similar water-tight layers have been used with excellent results.

The care necessary to be exercised in the construction of storage or other reservoirs when earth dams or embankments are used can better be appreciated when it is realized that almost all such banks, even when properly provided with masonry or clay-puddle core-walls, are saturated with water, even on the down-stream side, at least throughout their lower portions. A board of engineers appointed by the commissioners of the Croton Aqueduct in the summer of 1901 made a large number of examinations in the earth embankments in the Croton watershed, and found that with scarcely an exception those embankments were saturated throughout the lower portions of their masses, although in every case a masonry core-wall had been built. The results of those investigations showed that the water had percolated through the earth portion of the embankments and even through the core-walls, which had been carried down to bed-rock. This induced saturation, more or less, of the material on the down-stream slopes of the embankments. When material is thus filled with water, unless it is suitably selected, it is apt to become soft and unstable, so that any superincumbent weight resting upon it might produce failure. The fact that such embankments may become saturated with water fixes limits to their heights, since the surface of saturation in the interior of the bank has generally a flatter slope than that of the exterior surface. The height of the embankment therefore should be such that the exterior slope cannot cut into the saturated material at its foot, at least to any great extent. From what precedes it is evident that the height of an earth embankment will depend largely upon the slope of the exterior surface. This slope is made 1 vertical to 2, 2½, or 3 horizontal. The more gradual slope is sometimes preferable. It is advisable also to introduce terraces and to encourage the growth of sod so as to protect the surface from wash. The inner paved slope may be as steep as 1 vertical to 1½ or 2 horizontal.

[Illustration: BOG BROOK DAM NO. 1.—RESERVOIR 1.]

[Illustration: TITICUS DAM.—RESERVOIR M.]

[Illustration: AMAWALK DAM.—RESERVOIR A.

Earth Dams in Croton Watershed, showing Slopes of Saturation.]

=181. Gate-houses, and Pipe-lines in Embankments.=—It is necessary to construct the requisite pipe-lines and conduits leading from the storage-reservoirs to the points of consumption, and sometimes such lines bring the water to the reservoir. Wherever such pipes-line or conduits either enter or leave a reservoir gates and valves must be provided so as properly to control the admission and outflow of the water. These gate-houses, as they are called, because they contain the gates or valves and such other appurtenances or details as are requisite for operation and maintenance, are usually built of substantial masonry. They are the special outward features of every reservoir construction, and their architecture should be characteristic and suitable to the functions which they perform. Where the pipes are carried through embankments it is necessary to use special precautions to prevent the water from flowing along their exterior surfaces. Many reservoirs have been constructed under defective design in this respect, and their embankments have failed. Frequently small masonry walls are built around the pipes and imbedded in the bank, so as to form stops for any initial streams of water that might find their way along the pipe. In short, every care and resource known to the civil engineer must be employed in reservoir construction to make its bottom and its banks proof against leakage and to secure permanence and stability in every feature.

=182. High Masonry Dams.=—The greatest depths of water impounded in reservoirs are found usually where it is necessary to construct a high dam across the course of a river, as at the new Croton dam. In such cases it is not uncommon to require a dam over 75 to 100 feet high above the original bed of the river, which is usually constructed of masonry with foundations carried down to bed-rock in order to secure suitable stability and prevent flow or leakage beneath the structure. It is necessary to secure that result not only along the foundation-bed of the dam, but around its ends, and special care is taken in those portions of the work.

The new Croton dam is the highest masonry structure of its class yet built. The crest of its masonry overflow-weir is 149 feet above the original river-bed, with the extreme top of the masonry work of the remaining portion of the dam carried 14 feet higher. A depth of earth and rock excavation of 131 feet below the river-bed was necessary in order to secure a suitable foundation on bed-rock. The total maximum height, therefore, of the new Croton dam, from the lowest foundation-point to the extreme top, is 294 feet, and the depth of water at the up-stream face of the dam will be 136 feet when the overflow is just beginning, or 140 feet if 4 feet additional head be secured by the use of flash-boards. In the prosecution of this class of work it is necessary not only to reach bed-rock, but to remove all soft portions of it down to sound hard material, to clean out all crevices and fissures of sensible size, refilling them with hydraulic cement mortar or concrete, and to shape the exposed rock surfaces so as to make them at least approximately normal to the resultant loads upon them, to secure a complete and as nearly as possible water-tight bond with the superimposed masonry. If any streams or other small watercourses should be encountered, they must either be stopped or led off where they will not affect the work, or, as is sometimes done, the water issuing from them may be carried safely through the masonry mass in small pipes. The object is to keep as much water out of the foundation-bed as possible, so as to eliminate upward pressure underneath the dam caused by the head of water in the subsequently full reservoir. It is a question how much dependence can be placed upon the exclusion of water from the foundation-bed. In the best class of work undoubtedly the bond can be good enough to exclude more or less water, but it is probably only safe and prudent so to design the dam as to be stable even though water be not fully excluded.

[Illustration: Cross-section of New Croton Dam.]

The stability of the masonry dam must be secured both for the reservoir full and empty. With a full reservoir the horizontal pressure of water on the up-stream face tends to overturn the dam down-stream. When the water is entirely withdrawn the pressure under the up-stream edge of the foundation becomes much greater, so that safety and stability under both extreme conditions must be assured. There are a number of systems of computation to which engineers resort in order to secure a design which shall certainly be stable under all conditions. That which is commonly employed in this country is based upon two fundamental propositions, under one of which the pressure at any point in the entire masonry mass must not exceed a certain safe amount per square foot, while the other is of a more technical character, requiring that the centre of pressure shall, in every horizontal plane of the dam, approach nowhere nearer than one third the horizontal thickness of the masonry to one edge of it. A further condition is also prescribed which prevents any portion of the dam from slipping or sliding over that below it. As a matter of fact when the first two conditions are assured the third is usually fulfilled concurrently. Obviously there will be great advantage accruing to a dam if the entire mass of masonry is essentially monolithic. In order that that may be the case either concrete or rubble is usually employed for the great mass of the masonry structure, the exterior surfaces frequently being composed of a shell of cut-stone, so as to provide a neat and tasteful finish. This exterior skin or layer of cut masonry need not average more than 1½ to 2½ feet thick.

The pressures prescribed for safety in the construction of masonry dams vary from about 16,000 to 28,000 or 30,000 pounds per square foot. Sometimes, as in the masonry dams found in the Croton watershed, limits of 16,000 to 20,000 pounds per square foot are prescribed for the upper portions of the dams and a gradually increasing pressure up to 30,000 pounds per square foot in passing downward to the foundation-bed. There are reasons of a purely technical character why the prescribed safe working pressure must be taken less on the down-stream or front side of the dam than on the up-stream or rear face.

The section of a masonry dam designed under the conditions outlined will secure stability through the weight of the structure alone, hence it is called a gravity section. In some cases the rock bed and sides of a ravine in which the stream must be dammed will permit a curved structure to be built, the curvature being so placed as to be convex up-stream or against the water pressure. In such a case the dam really becomes a horizontal arch and, if the curvature is sufficiently sharp, it may be designed as an arch horizontally pressed. The cross-section then has much less thickness (and hence less area) than if designed on a straight line so as to produce a gravity section. A number of such dams have been built, and one very remarkable example of its kind is the Bear Valley dam in California; it was built as a part of the irrigation system.

[Illustration: Foundation Masonry of New Croton Dam.]

CHAPTER XVII.

=183. Gravity Supplies.=—When investigation has shown that a sufficient quantity of water may be obtained for a required public supply from any of the sources to which reference has been made, and that a sufficient storage capacity may be provided to meet the exigencies of low rainfall years, it will be evident if the water can be delivered to the points of consumption by gravity, or

whether pumping must be employed, or recourse be made to both agencies.

If the elevation of the source of supply is sufficiently great to permit the water to flow by gravity either to storage-reservoirs or to service-reservoirs and thence to the points of consumption, a proper pipe-line or conduit must be designed to afford a suitable channel. If the topography permits, a conduit may be laid which does not run full, but which has sufficient grade or slope to induce the water to flow in it as if it were an open channel. This is the character of such great closed masonry channels as the new and old Croton aqueducts of the New York water-supply and the Sudbury and Wachusetts aqueducts of the Boston supply. These conduits are of brick masonry backed with concrete carried sometimes on embankments and sometimes through rock tunnels. When they act like open channels a very small slope is employed, 0.7 of a foot per mile being a ruling gradient for the new Croton aqueduct, and 1 foot per mile for the Sudbury. Where these conduits cross depressions and follow approximately the surface, or where they pass under rivers, their construction must be changed so that they will not only run full, but under greater or less pressure, as the case may be.

=184. Masonry Conduits.=—In general the conduits employed to bring water from the watersheds to reservoirs at or near places of consumption may be divided into two classes, masonry and metal, although timber-stave pipes of large diameter are much used in the western portion of the country. The masonry conduits obviously cannot be permitted to run full, meaning under pressure, for the reason that masonry is not adapted to resist the tension which would be created under the head or pressure of water induced in the full pipe. They must rather be so employed as to permit the water to flow with its upper surface exposed to the atmosphere, although masonry conduits are always closed at the top. In other words, they must be permitted to run partially full, the natural grade or slope of the water surface in them inducing the necessary velocity of flow or current. Evidently the velocity in such masonry conduits is comparatively small, seldom exceeding about 3 feet per second. The new and old Croton aqueducts, the Sudbury and Wachusetts aqueducts of the Metropolitan Water-supply of Boston, are excellent types of such conveyors of water. They are sometimes of circular shape, but more frequently of the horseshoe outline for the sides and top, with an inverted arch at the bottom for the purpose of some concentration of flow when a small amount of water is being discharged and for structural reasons.

The interiors of these conduits are either constructed of brick or they may be of concrete or other masonry affording smooth surfaces. In the latest construction Portland-cement concrete or that concrete reinforced with light rods of iron or steel is much used. Bricks, if employed, should be of good quality and laid accurately to the outline desired with about ¼-inch joints, so as to offer as smooth a surface as possible for the water to flow over. In special cases the interiors of these conduits may be finished with a smooth coating of Portland-cement mortar. If conduits are supported on embankments, great care must be exercised in constructing their foundation supports, since any sensible settlement would be likely to form cracks through which much water might easily escape. When carried through tunnels they are frequently made circular in outline. They must occasionally be cleaned, especially in view of the fact that low orders of vegetable growths appear on their sides and so obstruct the free flow of water.

=185. Metal Conduits.=—Metal conduits have been much used within the past fifteen or twenty years. Among the most prominent of these are the Hemlock Lake aqueduct of the Rochester Water-works, and that of the East Jersey Water Company through which the water-supply of the city of Newark, N. J., flows. When these metal conduits or pipes equal 24 to 30 or more inches in diameter they are usually made of steel plates, the latter being of such thickness as is required to resist the pressure acting within them. The riveted sections of these pipes may be of cylindrical shape, each alternate section being sufficiently small in diameter just to enter the other alternate sections of little larger diameter, the interior diameter of the larger sections obviously being equal to the interior diameter of the smaller sections plus twice the thickness of the plate. Each section may also be slightly conical in shape, the larger ends having a diameter just large enough to pass sufficiently over the smaller end of the next section to form a joint. Large cast-iron pipes are also sometimes used to form these metal conduits up to an interior diameter of 48 inches. The selection of the type of conduit within the limits of diameter adapted to both metals is usually made a matter of economy. The interior of the cast-iron pipe is smoother than that of the riveted steel, although this is not a serious matter in deciding upon the type of pipe to be used.

Steel-plate conduits have been manufactured and used up to a diameter of 9 feet. In this case the pipe was used in connection with water-power purposes and with a length of 153 feet only, the plates being ½ inch thick. The steel-plate conduits of the East Jersey Water Company's pipes are as follows:

Diameter. Thickness. Length.

48 inches ¼ inch } 48 " ■/■■ " } 21 miles. 48 " ■ " } 36 " ¼ " 5 "

The diameters and lengths of the metal pipes or conduits of the Hemlock Lake conduit of the Rochester Water-works are as follows:

36-inch wrought-iron pipe 9.60 miles. 24 " " " 2.96 " 24 " cast-iron pipe 15.82 " ----- Total 28.39 "

All metal conduits or pipes are carefully coated with a suitable asphalt or tar preparation or varnish applied hot and sometimes baked before being put in place. This is for the purpose of protecting the metal against corrosion. Cast-iron pipes have been used longer and much more extensively than wrought-iron or steel, but an experience extending over thirty to forty years has shown that the latter class of pipes possesses satisfactory durability and may be used to advantage whenever economical considerations may be served.

=186. General Formula for Discharge of Conduits—Chezy's Formula.=—It is imperative in designing aqueducts of either masonry or metal to determine their discharging capacity, which in general will depend largely upon the slope of channel or head of water and the resistance offered by the bed or interior of the pipe to the flow of water. The resistance of liquid friction is so much more than all others in this class of water-conveyors that it is usually the only one considered. There is a certain formula much used by civil engineers for this purpose; it is known as Chezy's formula, for the reason that it was first established by the French engineer Antoine Chezy about the year 1775, although it is an open question whether the beginnings of the formula were not made twenty or more years prior to that date. Its demonstration involves the general consideration of the resistance which a liquid meets in flowing over any surface, such as that of the interior of a pipe or conduit, or the bed and banks of a stream.

The force of liquid friction is found to be proportional to the heaviness of the liquid (i.e., to the weight of a cubic unit, such as a cubic foot), to the area of wetted surface over which the liquid flows, and nearly to the square of the velocity with which the liquid moves. Hence if _l■_ is the length of channel, _p_ the wetted portion of the perimeter of the cross-section, _w_ the weight of a cubic unit of the liquid, and _v_ the velocity, the total force of liquid friction for the length _l′_ of channel will be _F = ζwpl′v²_, ζ being the coefficient of liquid friction. The path of the force _F_ for a unit of time is _v_, and the work _W_ which it performs in that unit of time is equal to the weight _wal′_ falling through the height _h′_, _a_ being the area of the cross-section of the stream.

[Illustration: FIG. 2.]

Hence _W_ = ζ_wpl■v².v_ = _wal′h′._ (7)

_a_ _____ _____ ζ_v²v_ = ---- _h■_, _v_ = √(1/ζ) (_a/p_) (_h′/v_) = _c_√_rs_. (8) _p_

In this equation

_____ _a_ _c_ = √(1/ζ); _r_ = ---- = hydraulic mean radius; _p_ _h■_ _s_ = ----- = sine of inclination of stream's bed. _v_

As the motion of the water is assumed to be uniform, the head lost by friction for the total length of channel _l_ is the total fall _h_, and by equation (8), since

_h′ h_ --- = _s_ = ---, _v l_

_v² l_ _h_ = ---- ---------. (9) _c²_ (_a/p_)

If, as in the case of the ordinary cast-iron water-pipes of a public supply system, the cross-section _a_ is circular,

_a_ (π_d²_/4) _d_ --- = --------- = ---, _p_ π_d_ 4

and

4.2_g l v² l v²_ _h_ = ----- --- ------ = _f_ --- -----, (10) _c² d_ 2_g d_ 2_g_

in which _f_ = 8_g_ ÷ _c²_.

The quantity _f_ is sometimes called the "friction factor." For smooth, new pipes from 4 feet down to 3 inches in diameter its value may be taken from .015 to .03. An approximate mean value may be taken at .02.

The last member of equation (8) is Chezy's formula, and it is one of the most used expressions in hydraulic engineering. Some values for the coefficient _c_ will presently be given. The quantity _r_ found by dividing the area of the cross-section of the stream by the wetted portion of its perimeter is called the "hydraulic mean radius," or simply the "mean radius." The other quantity, _s_,

appearing in the formula is, as shown by the figure, the sine of the inclination of the bed of the stream.

In order to determine the discharge of any pipe, conduit, or open channel carrying a known depth of water, it is only necessary to compute _r_ and _s_ from known data and select such a value of the coefficient _c_ as may best fit the circumstances of the particular case in question. The substitution of those quantities in Chezy's formula, i.e., equation (8), will give the mean velocity _v_ of the water which, when multiplied by the area of cross-section of the stream, will give the discharge of the latter per second of time. It is customary to compute _r_ in feet. The coefficient _c_ is always determined so as to give velocity in feet per second of time. Hence if the area of the cross-section of the stream, _a_, is taken in square feet, as is ordinarily the case, the discharge _av_ will be in cubic feet per second.

[Illustration: Progress View of Construction of New Croton Dam.]

=187. Kutter's Formula.=—The coefficient _c_ in Chezy's formula is not a constant quantity, but it varies with the mean radius _r_, with the sine of inclination _s_, and with the character of the bottom and sides of the open channel, i.e., with the roughness of the interior surface of the closed pipe. Many efforts have been made and much labor expended in order to find an expression for this coefficient which may accurately fit various streams and pipes. These efforts have met with only a moderate degree of success. The form of expression for _c_ which is used most among engineers is that known as Kutter's formula, as it was established by the Swiss engineer W. R. Kutter. This formula is as follows:

$$c = \frac{\left(1.811 + \frac{.00281}{n} + 41.65\right) + \frac{1}{s}}{1 + \left(\frac{.00281}{r} + 41.65\right)\frac{n}{\sqrt{r}}}$$

The quantity _n_ in this formula is called the "coefficient of roughness," since its value depends upon the character of the surface over which the water flows. It has the following set of values for the surfaces indicated:

_n_ = 0.009 for well-planed timber; _n_ = 0.010 for neat cement; _n_ = 0.011 for cement with one third sand; _n_ = 0.012 for unplaned timber; _n_ = 0.013 for ashlar and brickwork; _n_ = 0.015 for unclean surfaces in sewers and conduits; _n_ = 0.017 for rubble masonry; _n_ = 0.020 for canals in very firm gravel; _n_ = 0.025 for canals and rivers free from stones and weeds; _n_ = 0.030 for canals and rivers with some stones and weeds; _n_ = 0.035 for canals and rivers in bad order.

=188. Hydraulic Gradient.=—Before illustrating the use of Chezy's formula in connection with masonry and metal conduits, of which mention has already been made, it is best to define another quantity constantly used in connection with closed iron or steel pipes. This quantity is called the "hydraulic gradient." If a closed iron or steel pipe is running full of water and under pressure and if small vertical tubes be inserted in the top of the pipe with their lower ends bent so as to be at right angles to its axis, the water will rise to heights in the tubes depending upon the pressures of water in the pipe or conduit at the points of insertion. Such tubes with the water columns in them are called piezometers. They are constantly used in connection with water-pipes in order to show the pressures at the points where they are inserted. A number of such pipes being inserted along an iron pipe or conduit, a line may be imagined to be drawn through the upper surfaces of the columns of water, and that line is called the "hydraulic gradient." It represents the upper surface of water in an open channel discharging with the same velocity existing in the closed pipe.

In case Chezy's formula is used to determine the velocity of discharge in a closed pipe running under pressure, the sine of inclination _s_ must be that of the hydraulic gradient and not the sine of inclination of the axis of the closed pipe. In the determination of this quantity _s_ by the use of piezometer tubes, if a straight pipe remains of constant section between any two points, it is only necessary to insert the tubes at those points and observe the difference in levels of the water columns in them. That difference of levels or elevations will represent the height which is to be divided by the length of pipe or conduit between the same two points in order to determine the sine _s_.

[Illustration: Progress View of Construction of New Croton Dam.]

The hydraulic gradient plays a very important part in the construction of a long pipe-line or conduit. If any part of the pipe should rise above the hydraulic gradient, the discharge would no longer be full below that point. It is necessary, therefore, always to lay the pipe or the closed conduit so that all parts of it shall be below the hydraulic gradient. Caution is obviously necessary to lay a pipe carrying water deep enough below the surface of the ground in cold climates to protect the water against freezing. At the same time if the pipe-line is a long one it must follow the surface of the ground approximately in order to save expensive cutting. There will, therefore, generally be summits in pipe-lines, and inasmuch as all potable water carries some air dissolved in it, that air is liable to accumulate at the high points or summits. If that accumulation goes on long enough, it will seriously trench upon the carrying

capacity of the pipe and decrease its flow. It is therefore necessary to provide at summits what are called blow-off cocks to let the air escape. At the low points of the pipe-line, on the contrary, the solid matter, such as sand and dirt, carried by the water is liable to accumulate, and it is customary to arrange blow-offs also at such points, so as to enable some of the water to escape and carry with it the sand and dirt.

[Illustration: IN LOOSE EARTH.]

[Illustration: IN ROCK.

Weston Aqueduct. Sections of Aqueduct and Embankment.]

[Illustration: SECTION OF EMBANKMENT.]

[Illustration: ON EMBANKMENT.

Weston Aqueduct. Sections of Aqueduct and Embankment. Gradient, 1 in 5000.]

=189. Flow of Water in Large Masonry Conduits.=—In order to apply Chezy's formula first to the flow of the masonry aqueducts of the New York and Boston water-supplies, it is necessary to have the outlines of those conduits so that the wetted perimeter and hence the mean radius may be determined for any depth of water in them.

[Illustration: OUTLINES OF AQUADUCTS.

FIG. 3.]

The figure shows the desired cross-sections drawn carefully to scale. Table XIV has been computed and arranged from data taken from various official sources so as to show the depth, mean velocity, discharge per second and per twenty-four hours, and the coefficient used in Chezy's formula, together with the coefficient of roughness _n_ in Kutter's formula for the conduits shown in the figure.

This table exhibits in a concise and clear manner the use of Chezy's formula in this class of hydraulic work.

TABLE XIV.

LEGEND: (A) = Depth, in Feet. (B) = Hydraulic Radius _r_, Feet. (C) = Coefficient _c_. (D) = Mean Velocity, Feet.

| | | |

will vary considerably with the degree of roughness of the interior surface of the pipe, with the slope _s_, and with the mean radius _r_. An important distinction must be made between riveted steel pipes and those of cast-iron, for the reason that the rivet-heads on the inside of the former exert an appreciable influence upon the coefficient _c_. The rivet-heads add to the roughness or unevenness of the interior of the pipe. Table XV gives the elements of the flow or discharge in the two pipe-lines which have been taken as types, as determined by actual measurements; it also exhibits similar elements for timber-stave pipes, to which reference will be made later.

[Illustration: CROTON AQUEDUCT

IN EARTH.]

As would be expected, the velocity of flow in these pipes may be and generally is considerably higher than the velocity of movement in masonry channels. Both Tables XV and XVI give considerable range of coefficients computed and arranged from authoritative sources, and the coefficients _c_ for Chezy's formula represent the best hydraulic practice in connection with such works at the present time. In using the formula for any special case, great care must be taken to select a value for _c_ which has been established for conditions as closely as possible to those in question. This is essential in order that the results of estimated discharges may not be disappointing, as they sometimes have been where that condition so necessary to accuracy has not been fulfilled.

TABLE XV.

VALUES OF COEFFICIENT _c_. LEGEND: (A) = Hydraulic Radius _r_. (B) = Hydraulic Gradient. (C) = Mean Velocity.

| | Pipe-line. | Diameter. | | | | (A) | (B) | (C)

Hemlock Lake |36″ wrought-iron | 9″ |.000411| 1.532 ” ” |24″ wr't and cast| 6″ |.00239 | 3.448 Rush Lake to Mt. Hope |24″ cast-iron | 6″ |.00255 | 3.448

Sudbury aqueduct |48″ ” ” | 12″ | | 3.738 ” ” |48″ ” ” | 12″ | | 4.965 ” ” |48″ ” ” | 12″ | | 6.195 ” ” |48″ ” ” | 12″ | | 3.738 ” ” |48″ ” ” | 12″ | | 4.965 ” ” |48″ ” ” | 12″ | | 6.195

East Jersey Water Co. |48″ steel riveted| 12″ |.002 | 4.62 | pipe | | | Timber-stave pipe, Ogden, Utah|72″.5 | | | .5 ” ” ” ” ” |72″.5 | | | 1.0 ” ” ” ” ” |72″.5 | | | 1.5 ” ” ” ” ” |72″.5 | | | 2.0 ” ” ” ” ” |72″.5 | | | 2.5 ” ” ” ” ” |72″.5 | | | 3.0 ” ” ” ” ” |72″.5 | | | 3.5 ” ” ” ” ” |72″.5 | | | 4.0

LEGEND: (A) = Coefficient _c_. (B) = Cubic Feet per Second. (C) = Gallons per 24 Hours.

| | Discharge. | Pipe-line. | | (A) | (B) | (C) | Remarks.

Hemlock Lake | 87.3 |10.83124|7,000,000| ” ” | 99.7 |10.83124|7,000,000| 1892. Rush Lake to Mt. Hope | 96.5 |10.83124|7,000,000+--------- Sudbury aqueduct |140.14 | | | ” ” |142.11 | | | Pipe new ” ” |144.09 | | | 1880. | | | +--------- | | | | After | | | | cleaning, ” ” |139.94†| | | 1894-95. ” ” |141.74†| | | Before ” ” |143.16†| | | cleaning, | | | |_c_ = 108 | | | +--------- East Jersey Water Co. |103.3 | 58.02 |7,500,000| 1891. Timber-stave pipe, Ogden, Utah| 72 | | | 1897. ” ” ” | 96 | | | ” ” ” |109 | | | ” ” ” |115 | | | ” ” ” |119 | | | ” ” ” |122 | | | ” ” ” |124 | | | ” ” ” |126 | | |
---

† These values correspond to the formula _c_ = 131.88_v_■■■■■.

TABLE XVI.

___ VALUES OF _c_ IN _v_ = _c_√_rs_.

| No. | 1 | 2 | 3 | 4 | 5 | 6

| | | 4 | | | | | Age | New |Years| New | New | New | New

Velocity, | Diam. | | | | | | Feet/sec. | Inches | 36 | 36 | 38 | 38 | 42 | 42

0.5 | | | | | | | 1 | | 86 | | | | 96 1.48 | | | | | | | 1.5 | | 90.6| | | | |103 2.0 | | 95.2| | | | |107.9 2.44 | | | | | |115.9| 2.5 | | 99.4| | | | |111 3 | |103.3| | | | |112.6 3.23 | | | |114 | | | 3.27 | | | |116.6| | | 3.32 |_c_ in _v_ =| | | | | | 3.5 | ___ |107 | | | | |113 3.52 | _c√rs_. | | | | | | 3.9 | | | | |109.2| | 3.96 | | | | | | 4 | |110.6| | | | | 112.8 4.5 | |114 | | | | | 111.8 4.93 | | |106.3| | | | 5 | |117.2| | | | | 110.8 5.5 | |120.4| | | | | 110.2 6 | |123.6| | | | | 110 12.6 | | | | | | |

Kutter's _n_ =| | | | | | | coefficient | | .014| .013| .013| .013| .013| .013 of roughness | | | | | | |

| No. | 7 | 8 | 9 | 10 | 11 |12 | 13

| | | | 4 | 4 | | | 5 | Age | New | New |Years|Years| New | New|Years
---
Velocity, | Diam. | | | | | | | Feet per sec. | Inches | 42 | 48 | 48 | 48 | 48 | 72 | 103

0.5 | | | | | | | |110 |126.5 1 | | |101 |101.2| 78 | 97.2| 97.1|110 |116.6 1.48 | | | | | | | 1.5 | |102.8|105.4| 84.6|100.8| 98.7|111 |112.7 2.0 | | |104.3|108.8| 89.6|103.3|100.3|110 |110.3 2.44 | | | | | | | | 2.5 |

|105.5|111.2| 92.4|104.9|101.6|108 |108.8 3 | |106.4|111.8| 93 |105.3|102.2|108 |107.7 3.23 | | | | | | | 3.27 | | | | | | | 3.32 |_c_ in _v_ =| | | | | | | 3.5 | ___ |107.2|113.4| 93.2|104.8|103.6|110 |106.9 3.52 | _c√rs_. | | | | | | | 3.9 | | | | | | | 3.96 | | | | | | | 4 | |107.8|113.2| 94 |104 |104.2|111 |106.2 4.5 | |108.2|112.4| 94.2|103.7|104.7| |105.6 4.93 | | | | | | | 5 | |108.4|112 | 94.4|103.7|105.1| | 5.5 | |108.5|111.7| 94.7|103.7|105.2| | 6 | |108.5|111.6| 94.9|103.7|105.2| | 12.6 | | | | | | |

----------+----------+-----+-----+-----+-----+-----+----+----- Kutter's _n_ =| | | | | | | | coefficient | | .013| .013| .016| .014| .014|.014| .015 of roughness | | | | | | | | ----------+----------+-----+-----+-----+-----+-----+----+-----

Exp. Nos. 1-2. Clemens Herschel, 1802. East Jersey Conduit, cylindrical joints. Nos. 3-4. E. Kuichling, 1895. New Rochester conduit, cylindrical joints. No. 5. I. W. Smith, 1896. Portland, Oregon, water-works. Nos. 6-7. Clemens Herschel, 1896. East Jersey conduit, taper joints. No. 8. Clemens Herschel, 1892. East Jersey conduit, cylindrical joints. Nos. 9-10. Clemens Herschel, 1896. East Jersey conduit, cylindrical joints. No. 11. Clemens Herschel, 1896. East Jersey conduit, taper joints. No. 12. Marx, Wing, Hoskins, 1897. Pioneer El. Power Co., Ogden, Utah. No. 13. Clemens Herschel, 1887. Holyoke, Mass., testing flume.

[Illustration: CROTON AQUEDUCT

IN ROCK.]

=191. Change of Hydraulic Gradient by Changing Diameter of Pipe.=—It has already been seen, in the case of closed pipes or conduits, that the hydraulic gradient with slope _s_ governs the velocity of flow, and also that all parts of the pipe-line must be kept below that gradient. It is sometimes desirable, in order to meet conditions either of topography or of flow, to raise or lower the hydraulic gradient over the whole or some portion of the pipe-line. This can easily be done to any needed extent by varying the diameter of the pipe. An increase in diameter will in general decrease the velocity of the water and increase its pressure, thus increasing correspondingly the height of the columns of water in the piezometer tubes. As the top surface of the latter determines the hydraulic gradient, it is seen that increasing the diameter of a portion of the pipe-line will correspondingly raise the gradient over the same portion. Thus by a proper relative variation of diameters the hydraulic gradient of a given pipe-line may readily be controlled within sufficient limits to meet any ordinary requirements of this character.

=192. Control of Flow by Gates at Upper End of Pipe-line.=—Obviously, if the pressure in the pipe-line is diminished, less thickness of metal will be required to resist it, and a corresponding degree of economy may be reached by a decrease in the quantity of metal. In the 21 miles of 48-inch steel-plate pipe of the East Jersey Water Company there is a fall of 340 feet; if, therefore, the flow through that pipe were regulated by a gate or gates at its lower end, the lower portion of the line would be subjected to great intensity of pressure. If, however, the flow through the pipe is controlled by a gate or gates at its upper end, enough water only may be admitted to enable it to flow full with the velocity due to the hydraulic gradient. By such a procedure the pressure upon the pipe over and above that which is necessary to produce the gradient is avoided. This condition is not only judicious in the reduction of the amount of metal required, but also in reducing both the leakage and the tendency to further leakage, which is largely increased by high pressures. This feature of control of pressure in a long pipe-line with considerable fall is always worthy of most careful consideration.

=193. Flow in Old and New Cast-iron Pipes—Tubercles.=—The velocity of flow through cast-iron mains or conduits or through the cast-iron pipes of a distribution system of public water-supply depends largely upon the condition of the interior surface of the pipes as affected by age. All cast-iron pipes before being shipped from the foundry where they are manufactured are immersed in a hot bath of suitable coal-tar pitch composition in order to protect them from corrosion. After having been in use a few years this coating on the interior of the pipes is worn off in spots and corrosion at once begins. The iron oxide produced under these circumstances forms projections, or tubercles as they are called, of greatly exaggerated volume and out of all proportion to the actual weight of oxide of iron. When the pipes are emptied these tubercles are readily removed by scraping, but before their removal they greatly obstruct the flow of water through the pipes. Indeed this obstruction is so great that the discharging capacity of cast-iron mains must be treated in view of its depreciation from this source.

Table XVII exhibits the value of the coefficient _c_ to be used in Chezy's formula for all cast-iron pipes having been in use for the periods shown.

TABLE XVII.

TABLE OF VALUES OF _f_ AND _c_. LEGEND: (A) = Diameter, Inches. (B) = Hydraulic Radius _r_, Inches. (C) = Velocity, Feet per Second. (D) = Coefficient _c_. (E) = Coefficient _f_. ---------+-----------------------+-----+----+-----+-----+------ | | | | | Authority.|

Pipe-line. | | | | | | | (A) |(B) | (C) | (D) | (E) | | | | | | ---------+-------------------------+-----+----+-----+-----+------ Darcy |New Pipe | 3.22| .8 | 0.29| 78.5| .0418 | | | |10.71|100.0| .0257 ---------+-------------------------+-----+----+-----+-----+------ Darcy |Old cast-iron pipe lined | 9.63|2.41| 1.00| 72.5| .0489 | with deposit | | |12.42| 74.0| .0468 ---------+-------------------------+-----+----+-----+-----+------ Darcy |Pipe above cleaned | 9.63|2.41| 0.91| 90.0| .0316 | | | |14.75| 98.0| .0269 ---------+-------------------------+-----+----+-----+-----+------ Brush |Cast-iron pipe tar-coated|20 |5 | 2.00|114.0| .0197 | and in service 5 years. | | | 3.00|110.0| .0214 ---------+-------------------------+-----+----+-----+-----+------ Darrach |Cast-iron pipe in service|20 |5 | 2.71| 67.5| .0568 | 11 years | | | 5.11| 83.0| .0376 ---------+-------------------------+-----+----+-----+-----+------ Darrach |Cast-iron pipe in service|36 |9 | 1.58| 60.0| .0716 | 7 years | | | 2.37| 66.0| .0586 ---------+-------------------------+-----+----+-----+-----+------

Obviously it is not possible to clean the smaller pipes of a distribution system, but large cast-iron conduits may be emptied at suitable periods and have their interior surfaces cleaned of tubercles or other accumulations. At the same time, if necessary, a new coal-tar coating can be applied.

Table XVIII exhibits the values of the coefficient _c_ to be used in Chezy's formula for new and clean coated cast-iron pipes. It represents the results of actual hydraulic experience and is taken from Hamilton Smith's "Hydraulics." A comparison between this table and that which precedes will show how serious the effect of tubercles may be on the discharging capacity of a cast-iron pipe.

____ In using Chezy's formula, _v_ = _c_√_rs_,

in connection with either Table XVII or XVIII, the slope or sine of inclination _s_ of the hydraulic gradient may be readily computed by equation (10), which gives the head lost by friction in a closed circular pipe as

_l v²_ _h_ = _f_ - --- ----. _d_ 2_g_

It is only necessary in a straight pipe or one nearly straight to compute the quantity

_h f v²_ _s_ = --- = --- ------. _l d_ 2_g_

TABLE XVIII.

____ VALUES OF _c_ IN FORMULA: _v_ = _c_√_rs_. --------+------+-------+-------+-------+-------+-------+------- Velocity| Diameters in Feet (_d_ = 4_r_). _v_, | Feet per|------+-------+-------+-------+-------+-------+------- Second.| .05 | .1 | 1 | 1.5 | 2 | 2.5 | 3 --------+------+-------+-------+-------+-------+-------+------- 1 | | 80.0 | 96.1 | 102.8 | 108.8 | 112.7 | 116.7 2 | 77.8 | 88.9 | 104.0 | 110.9 | 116.2 | 120.3 | 123.8 3 | 82.4 | 93.7 | 108.7 | 115.6 | 120.8 | 124.8 | 128.3 4 | 85.6 | 97.0 | 112.0 | 118.9 | 124.0 | 128.1 | 131.5 5 | 87.6 | 99.3 | 114.4 | 121.3 | 126.5 | 130.6 | 134.1 6 | 89.1 | 101.0 | 116.3 | 123.2 | 128.6 | 132.6 | 136.3 7 | 90.0 | 102.4 | 118.0 | 125.0 | 130.4 | 134.6 | 138.2 8 | 90.0 | 103.3 | 119.3 | 126.4 | 132.0 | 136.3 | 140.0 9 | 90.7 | 104.0 | 120.4 | 127.7 | 133.3 | 137.7 | 141.6 10 | 90.8 | 104.5 | 121.4 | 128.8 | 134.5 | 139.0 | 142.9 11 | 90.9 | 104.7 | 122.0 | 129.7 | 135.6 | 140.2 | 144.2 12 | 91.0 | 104.8 | 122.5 | 130.4 | 136.4 | 141.1 | 145.2 13 | 91.0 | 105.0 | 122.9 | 131.0 | 137.1 | 141.9 | 146.1 14 | 91.0 | 105.0 | 123.2 | 131.5 | 137.6 | 142.5 | 146.7 15 | 91.0 | 105.0 | 123.6 | 131.8 | 138.0 | 142.9 | 147.2 20(?)| | | 123.9 | 132.9 | | | --------+------+-------+-------+-------+-------+-------+------- Velocity| Diameters in Feet (_d = 4r_). _v_, | Feet per+------+-------+-------+-------+-------+-------+------- Second.| 3.5 | 4 | 5 | 6 | 7 | 8 --------+------+-------+-------+-------+-------+-------+------- 1 |120.2 | 123.0 | 127.8 | 131.8 | 134.8 | 137.5 2 |127.0 | 129.9 | 134.3 | 138.0 | 141.0 | 143.3 3 |131.4 | 134.2 | 138.6 | 142.3 | 145.4 | 147.6 4 |134.6 | 137.4 | 141.9 | 145.5 | 148.6 | 151.0 5 |137.1 | 140.0 | 144.7 | 148.1 | 151.2 | 153.6 6 |139.4 | 142.3 | 146.9 | 150.5 | 153.5 | 7 |141.5 | 144.5 | 149.0 | 152.7 | | 8 |143.3 | 146.3 | 151.0 | 154.9 | | 9 |145.0 | 148.1 | 152.8 | 156.7 | | 10 |146.4 | 149.7 | 154.6 | | | 11 |147.7 | 151.0 | | | | 12 |148.8 | 152.3 | | | | 13 |149.8 | 153.2 | | | | 14 |150.5 | 154.0 | | | | 15 |151.1 | 154.6 | | | | 20(?)| | | | | | --------+------+-------+-------+-------+-------+-------

=194. Timber-stave Pipes.=—In the western part of the country long conduits or pipe-lines are frequently constructed of timber called redwood. Staves of suitable thickness, sometimes 1¾ inches, are accurately shaped and finished with smooth surfaces so as to form large pipes of any desired diameter. These staves are held rigidly in place with steel bands drawn tight with nuts on screw ends, so as to close tightly the joints between them. Such wooden conduits are rapidly and cheaply built and are very durable. They have the further advantage of requiring no interior coating, as the timber surface remains indefinitely unaffected by the water flowing over it. The latter part of Table XV shows coefficients for Chezy's formula which may be used for such a class of timber conduits. As the interior surfaces of such closed conduits are always very smooth, the coefficients are seen to be relatively large, and such pipes are, therefore, well adapted to maintain unimpaired discharging capacity for great lengths of time.

CHAPTER XVIII.

=195. Pumping and Pumps.=—When it is impossible to secure water at sufficient elevation to be delivered to the points of consumption by gravity, it is necessary to resort to pumping in order to raise it to the desired level. Indeed it is sometimes necessary to resort to pumping in connection with a gravity supply in order to deliver water to the higher parts of the distribution system, the lower points being supplied by gravity. This combination of gravity supply with pumping is not unusual. That part of New York north of Thirty-fourth Street between Lexington and Fifth avenues, north of Thirty-fifth Street between Fifth and Sixth avenues, north of Fifty-first Street between Sixth and Ninth avenues, north of Fifty-fifth Street between Ninth and Tenth avenues, north of Fifty-eighth Street between Tenth and Eleventh avenues, and north of Seventy-second Street between Eleventh Avenue and the North River, with elevation of 60 feet or more above mean high tide-water, is supplied from the high-service reservoir near High Bridge, the water being elevated to it from the Croton supply by the pumping-station at the westerly end of the bridge. The elevation of the water surface in the High Bridge reservoir is 208 feet, and that of the large reservoir in Central Park 115 feet, above mean high tide-water. Some specially high points on the northern part of Manhattan Island are supplied from the High Bridge tower, whose water surface is 316 feet above mean high tide.

[Illustration]

[Illustration: Skeleton Pumps.]

The pumps employed for the purpose of elevating water to distributing-reservoirs are among the finest pieces of machinery built by engineers at the present time. They are usually actuated by steam as a motive power, the steam being supplied from suitable boilers or batteries of boilers in which coal is generally used as fuel. The modern pumping-engine is in reality a combination of three classes of machinery, the boilers, the steam-engines, and the pumps. There are various types of boilers as well as of engines and pumps, all, when judiciously designed and arranged, well adapted to the pumping-engine process. The pumps are generally what are called displacement pumps; that is, the water in the pump-cylinder is displaced by the reciprocating motion of a piston or plunger. These pumps may be either double-acting or single-acting; in the former case, as the piston or plunger moves in one direction it forces the water ahead of it into the main or pipe leading up to the reservoir into which the water is to be delivered, while the water rising from the pump-well follows back of the piston or plunger to the end of its stroke. When the motion is reversed the latter water is forced on its way upward through the main, while the water rises from the pump-well into the other end of the water-cylinder. In the case of single-acting pumps water is drawn up into the water-cylinder from the pump-well during one stroke and forced up through the main during the next stroke, one operation only being performed at one time. The pump-well is a well or tank, usually of masonry, into which the water runs by gravity and from which the pump raises it to the reservoir. For the purposes of accessibility and convenience in repairing, the pump is always placed at an elevation above the water in the pump-well, the pressure of the atmosphere on the water in the well forcing the latter up into the pump-cylinder as the piston recedes in its stroke. The height of a column of water 1 square inch in section representing the pressure of the atmosphere per square inch is about 34 feet, but a pump-cylinder should not be placed more than about 18 feet above the surface of the water in the pump-well in order that the water may rise readily as it follows the stroke of the plunger.

In the operation of the ordinary pump the direction of the water as it flows into and out of the pump-cylinder must necessarily be reversed, and this is true also with the type of pump called the differential plunger-pump, which is really a single-acting pump designed so as to act in driving the water into the main like a double-acting pump, i.e., both motions of the plunger force water through the main, but only one draws water from the pump-well into the pump-cylinder. Valves may be so arranged in the pump-piston as to make the progress of the water through the pump continuous in one direction and so avoid the irregularities and shocks which necessarily arise to some extent from a reversal of the motion of the water.

The steam is used in the steam-cylinders of a pumping-engine precisely as in every other type of steam-engine. At the present time compound or triple-expansion engines are generally used, among the well-known types being the Worthington duplex direct-acting pump without crank or fly-wheel, the Gaskill crank and fly-wheel pumping-engine, the Allis and the Leavitt pumping-engines, both of the latter employing the crank and fly-wheel and both may be used as single- or double-acting pumps, usually as the latter. The characteristic feature of the well-known Worthington pumping-engine is the movement of the valves of each of the two engines by the other for the purpose of securing a quiet seating of the valves and smooth working.

One of the most important details of the pumping-engine is the system of valves in the water-cylinder, and much ingenuity has been successfully expended in the design of proper valve systems. These pump-valves must, among other things, meet the following

requirements as efficiently as possible: they must close promptly and tightly, so that no water may pass through them to create slip or leakage; they should have a small lift, so as to allow prompt closing, and large waterways, to permit a free flow through them with little resistance; they must also be easily operated, so as to require little power, and, like all details of machinery, they should be simple and easily accessible for repairing when necessary.

As steam is always used expansively, its force impelling the plunger will have a constant value during the early portion of the stroke only, and a much less value, due to the expansion of the steam, at and near the end of the stroke, while the head of water against which the pump operates is practically constant. There is, therefore, an excess of effort during the first part of the stroke and a deficiency during the latter part. Unless there should be some means of taking up or cushioning this difference, the operation of the pump would be irregular during the stroke and productive of water-hammer or blows to the engine. Two means are employed to remove this undesirable effect, i.e., the fly-wheel and the air-chamber, or both. In the one case the excess of work performed by the steam in the early part of the stroke is stored up as energy in the accelerated motion of the fly-wheel and given out by the latter near the end of the stroke, thus producing the desired equalization. The air-chamber is a large reservoir containing air, attached to and freely communicating with the force-main or pipe near its connection with the pumps. In this case the excess of work performed at the beginning of the stroke is used in compressing the air in the air-chamber, sufficient water entering to accomplish that purpose. This compressed air acts as a cushion, expanding again at the end of the stroke and reinforcing the decreasing effort of the steam.

=196. Resistances of Pumps and Main—Dynamic Head.=—Obviously the water flowing through the pipes, pump-cylinders, and pump-valves will experience some resistance, and it is one purpose in good pumping-engine design to make the progress of the water through the pump so direct and free as to reduce these losses to a minimum. Similarly the large pipe or main, called the force-main, leading from the pump up to the reservoir into which the water is delivered, sometimes several thousand feet long, will afford a resistance of friction to the water flowing through it. The head which measures this frictional loss is given by equation (10) on page 239. All these resistances will increase rapidly with the velocity with which the water flows through the pipes and other passages, as do all hydraulic losses. It is obviously advisable, therefore, to make this velocity as low as practicable without unduly increasing the diameter of the force-main. This velocity seldom exceeds about 3 feet per second.

[Illustration: Allis Pump.]

[Illustration: Section of Allis Pumping-Engine.]

The static head against which the pumping-engine operates is the vertical height or elevation between the water surfaces in the pump-well and the reservoir. The head which represents the resistances of the passages through the pump and force-main, when added to the sum of the static head and the head due to the velocity in the force-main, gives what is called the dynamic head; it represents the total head against which the pump acts. If _h_ represents the static head, _h■_ the head due to all the resistances, and _h″_ the head due to the velocity in the force-main, then the dynamic head will be

$$H = h + h_{\blacksquare} + h'' = h + f \frac{l}{d} \frac{v^2}{2g} + n \frac{v^2}{2g} + \frac{v^2}{2g},$$

in which _f_ has a value of about .015 and _n_ is a coefficient which when multiplied by the velocity head will represent the loss of head incurred by the water in passing through the pump-cylinder and valves. The latter quantity is variable in value; but it is seldom more than a few feet.

=197. Duty of Pumping-engines.=—It is thus seen that the collective machines and force-main forming the pumping system afford opportunity for a number of serious losses of energy found chiefly in the boiler, the engine, and the pump. The excellence of a pumping-plant, including the boilers, may obviously be measured by the amount of useful work performed by a standard quantity, as 100 pounds of coal. Sixty or more years ago, in the days of the old Cornish pumping-engine, the standard of excellence or "duty" was the number of foot-pounds of work, i.e., the number of pounds lifted one foot high, performed by one bushel of coal. As early as 1843 the Cornish pumping-engine reached a duty, per bushel of coal, of 107,500,000 foot-pounds. These pumping-engines were single-acting, the steam raising a weight the descent of which forced the water up the delivery-pipe.

At a later date and until about ten years ago the usual standard or criterion applied to pumping-engines for city water-works was the amount of work performed in lifting water for each 100 pounds of coal consumed; this result was also called the "duty" of the engine. In order to determine the duty of a pumping-engine it was thus only necessary to observe carefully for a given period of time, i.e., twenty-four hours or some other arbitrary period, the amount of coal consumed, the condition of the furnace-fires at the

beginning and end of the test being as nearly the same as possible, and measure at the same time the total amount of water discharged into the reservoir. The total weight of water raised multiplied by the total number of feet of elevation from the water surface in the pump-well to that in the reservoir would give the total number of foot-pounds of useful work performed. This quantity divided by the number of hundred pounds of coal consumed would then give what is called the "duty" of the pumping-engine.

=198. Data to be Observed in Pumping-engine Tests.=—Obviously it is necessary to observe a considerable number of data with care. No pump works with absolute perfection. A little water will run back through the valves before they are seated, and there will be a little leakage either through the valves or through the packing around the piston or plunger, or both sources of leakage may exist. That leakage and back-flow represent the amount of slip or water which escapes to the back of the plunger after having been in front of it. In well-constructed machinery this slip or leakage is now very small and may be but a small fraction of one per cent. Inasmuch as the amount of work performed by the steam will be the same whether this slip or leakage exists or not, the latter is now frequently ignored in estimating the duty of pumping-engines, the displacement of the piston or plunger itself being taken as the volume of water pumped at each stroke.

Again, in discussing the efficiency of the steam portion of the machinery the amount of partial vacuum maintained in the vacuum-pump, which is used to move the water of the condensed steam, is affected by atmospheric pressure, as is the work which is performed. Hence in complete engine tests it is necessary to observe the height of the barometer during the test. It is also necessary to observe the temperature of feed-water supplied to the boiler, and to use accurate appliances for ascertaining with the greatest exactness practicable the weight of dry steam used in the steam-cylinders and the amount of water which it carries. It is not necessary for the present purpose to discuss with minuteness these details, but it is evident from the preceding observations that the complete test of a pumping-engine involves the accurate observation of many data and their careful use in computations. The determination of the duty alone is but a simple part of those computations, and the duty is all that is now in question.

=199. Basis of Computations for Duty.=—It was formerly necessary in giving the duty of a pumping-engine to state whether the 100 pounds of coal was actually coal as shovelled into the furnace, or whether it was that coal less the weight of ash remaining after combustion. It was also necessary to specify the quality of coal used, because the heating capacity of different coals may vary materially. For these different reasons the statement of the duty of a pumping-engine in terms of a given weight of coal consumed involved considerable uncertainty, hence in 1891 a committee of the American Society of Mechanical Engineers, appointed for the purpose, took into consideration the best method of determining and stating the duty of a pumping-engine. The report of that committee may be found in vol. XII of the Transactions of that Society. The committee recommended that in a duty test 1,000,000 heat-units (called British Thermal Units or, as abbreviated, frequently B.T.U.) should be substituted for 100 pounds of coal. In other words, that the following should be the expression for the duty:

$$\text{Duty} = \frac{\text{foot-pounds of work done}}{\text{total number of heat-units consumed}} \times 1{,}000{,}000.$$

For some grades of coal in which 1,000,000 heat-units would be available for every 100 pounds the numerical value of the duty expressed in the new terms would be unchanged, but for other grades of coal the new expression of the duty might be considerably different.

=200. Heat-units and Ash in 100 Pounds of Coal, and Amount of Work Equivalent to a Heat-unit.=—The following table exhibits results determined by Mr. George H. Barrus (Trans. A. S. M. E., vol. XIV. page 816), giving an approximate idea of the total number of heat-units which are made available by the combustion of 100 pounds of coal of the kinds indicated:

Semibitumintous: George's Creek Cumberland, Percentage of Ash. 1,287,400 to 1,421,700 6.1 to 8.6 Pocahontas, 1,360,800 to 1,460,300 3.2 to 6.2 New River, 1,385,800 to 1,392,200 3.5 to 5.7

Bituminous: Youghiogheny, Pa., lump, 1,294,100 5.9 Youghiogheny, Pa., slack, 1,166,400 10.2 Frontenac, Kan., 1,050,600 17.7 Cape Breton Caledonia, 1,242,000 8.7

Anthracite: 1,152,100 to 1,318,900 9.1 to 10.5

[Illustration: Worthington Pump.]

Each unit or B.T.U. represents the amount of heat required to raise one pound of water at 32° Fahr. 1° Fahr., and it is equal to 778 foot-pounds of work. In other words, 778 foot-pounds of work is said to be the mechanical equivalent of one heat-unit. The amount of work, therefore, which one pound of dry steam is capable of performing at any given pressure and at the corresponding

temperature may readily be found by multiplying the number of available heat-units which it contains, and which may be readily computed if not already known, by 778, or as in a pumping-engine duty trial, knowing by observation the number of pounds of steam at a given pressure and temperature supplied through the steam-cylinders, the number of heat-units supplied in that steam is at once known or may easily be computed. Then observing or computing the total weight of water raised by the pumping-engine, as well as the total head (the dynamic head) against which the pumping-engine has worked, the total number of foot-pounds of work performed can be at once deduced. This latter quantity divided by the number of million heat-units will give the desired duty.

[Illustration: Section of Worthington Pump.]

=201. Three Methods of Estimating Duty.=—At the present time it is frequently, and perhaps usually, customary to give the duty in terms of 100 pounds of coal consumed, as well as in terms of 1,000,000 heat-units. Frequently, also, the duty is expressed in terms of 1000 pounds of dry steam containing about 1,000,000 heat-units. As has sometimes been written, the duty unit is 100 for coal, 1000 for steam, and 1,000,000 for heat-units.

=202. Trial Test and Duty of Allis Pumping-engine.=—The following data are taken from a duty test of an Allis pumping-engine at Hackensack, N. J., in 1899 by Prof. James E. Denton. This pumping-engine was built to give a duty not less than 145,000,000 foot-pounds for each "1000 pounds of dry steam consumed by the engine, assuming the weight of water delivered to be that of the number of cubic feet displaced by the plungers on their inward stroke, i.e., to be 145,000,000 foot-pounds at a steam pressure of 175 pounds gauge." The capacity of the engine was to be 12,000,000 gallons per twenty-four hours at a piston speed not exceeding 217 feet per minute. The engine was of the vertical triple-expansion type with cylinders 25.5 inches, 47 inches, and 73 inches in diameter with a stroke of 42¹/■■ inches, the single-acting plunger being 25.524 inches in diameter. The following data and figures illustrate the manner of computing the duty:

DUTY PER 1000 POUNDS OF DRY STEAM BY PLUNGER DISPLACEMENT.

1. Circumference of plungers, _Cl_ 80.1875 ins. 2. Length of stroke, 7 42.0625 ins. 3. Number of plungers (single-acting) 3 4. Aggregate displacement of plunger per revolution =

$$3_C^2l_ \text{ ------ } = _d_ \text{ 64,4557.1 cu. ins. } 4\pi$$

5. Revolutions during 24 hours, _N_ 43,337 6. Weight of one cubic foot of water, _w_ 62.42 lbs. 7. Total head pumped against, _H_ 266.61 ft. 8. Total feed-water per 24 hours, _W_ 160,354 lbs. 9. Duty per 1000 lbs. of feed-water =

$$_d \times w\ H \times N_ \times 1000 \text{ ------ } \times \text{ ---------- } 1728\ _W_$$

$$266.61 \times 43{,}337 \times 1000 = 2{,}331{,}976 \times \text{ ---------- } = 168{,}027{,}200 \text{ ft.-lbs. } 160{,}354$$

10. Percentage of moisture in steam at engine-throttle valve 0.3 per cent.

$$168{,}027{,}200 \text{ 11. Duty per 1000 lbs. of dry steam, ---------- } = 168{,}532{,}800 \text{ 0.997 ft.-lbs.}$$

DUTY PER MILLION HEAT-UNITS.

12. Average steam pressure at throttle above atmosphere. 173 lbs. 13. Average feed-water temperature. 78°.5 Fahr. 14. Total heat in one pound of steam containing 0.3 per cent. of moisture above 32° Fahr. 1,194.2 B. T. U. 15. Heat per lb. of feed-water above 32° Fahr. 46.5 " ------- 16. Heat supplied per lb. of feed-water above 32° Fahr. 1,147.7 " 17. Duty per lb. of feed-water. 168,027.2 ft.-lbs. 18. Duty per million B. T. U. 146,403,614 "

=203. Conditions Affecting Duty of Pumping-engines.=—Manifestly the duty of a pumping-engine by whatever standard it may be measured will vary with the conditions under which it is made. A new engine running under the favoring circumstances of a short-time test may be expected to give a higher duty than when running under the ordinary conditions of usage one month after another. Hence it can scarcely be expected that the monthly performance, and much less the yearly performance, of an engine will show as high results as when tested for a day or two or for less time.

=204. Speeds and Duties of Modern Pumping-engines.=—The following table gives the piston or plunger speeds of a number of the best modern pumping-engines, and the corresponding duties, with the standards by which those duties are measured.

LEGEND: (A) = Piston Speed in Feet per Minute. (B) = Duty in Foot-pounds. ----------+------+----------+---------- Engine. | (A) | (B) | Expressed in ----------+------+----------+---------- Ridgewood Station, Brooklyn, | | |

Worthington engine |164.0 |137,953,585| 1000 lbs. of | | | dry steam 14th St. pumping-station, | | | Chicago; built by Lake Erie | | | Engine Works |210.54|133,445,000| Million B.T.U. Allis engine at Hackensack, | | | N. J. |210.65|146,403,416| " " Snow pump at Indianapolis |214.6 |150,100,000| " " Leavitt pump at Chestnut Hill | |144,499,032| " " Nordberg at Wildwood |256.0 |162,132,517| " " Allis at Chestnut Hill, tested | | | May 1, 1900 |192.5 |157,002,500| Million B.T.U. Allis at St. Louis, tested | | | February 26, 1900 |197.16|158,077,324| " " Barr at Waltham, Mass. |194.28|128,865,000| 1000 lbs. of | | | dry steam Allis at St. Paul, Minn. |189.0 |144,463,000| " " " Lake Erie Engine Works at | | | Buffalo |207.7 |135,403,745| Million B.T.U.

These results show that material advances have been made in pumping-engine designs within a comparatively few years.

CHAPTER XIX.

=205. Distributing-reservoirs and their Capacities.=—The water of a public supply seldom runs from the storage-reservoir directly into the distributing system or is pumped directly into it, although such practices may in some cases be permissible for small towns or cities. Generally distributing-reservoirs are provided either in or immediately adjacent to the distributing system of pipes, meaning the water-pipes large and small which are laid through the streets of a city or town, and the service-pipes leading from the latter directly to the consumers.

The capacity ordinarily given to these distributing-reservoirs is not controlled by any rigid rule, but depends upon the local circumstances of each case. If they are of masonry and covered with masonry arches, as required for the reception of some filtered waters, they are made as small as practicable on account of their costs. If, on the contrary, they are open and formed of suitably constructed embankments, like the distributing-reservoirs of New York City in Central Park and at High Bridge, they are and should be of much greater capacity. The storage volume of the High Bridge reservoir amounts to 11,000,000 gallons, while that of the Central Park reservoir is 1,000,000,000 gallons. Again, the capacity of the old receiving-basin in Central Park is 200,000,000 gallons. These reservoirs act also as equalizers against the varying draft on the system during the different portions of the day and furnish all desired storage for the demands of fire-streams, which, while it lasts, may be a demand at a high rate. It may be approximately stated under ordinary circumstances that the capacity of distributing-reservoirs for a given system should equal from two or three to eight or ten days supply. It is advantageous to approach the upper of those limits when practicable. The volume of water retained in these reservoirs acts in some cases as a needed storage, while repairs of pumping-machinery or other exigencies may temporarily stop the flow into them. The larger their capacity the more effectively will such exigencies be met.

=206. System of Distributing Mains and Pipes.=—Gate-houses must be placed at the distributing-reservoirs within which are found and operated the requisite gates controlling the supply into the reservoir and the outflow from it into the distributing system. The latter begins at the distributing-reservoir where there may be one or two or more large mains, usually of cast-iron. These mains conduct the water into the branching system of pipes which forms a network over the entire city or town. A few lines of large pipes are laid so as to divide the total area to be supplied into convenient portions served by pipes of smaller diameter leading from the larger, so that practically every street shall carry its line or lines of piping from which every resident or user may draw the desired supply. Obviously, as a rule, the further the beginning of the distributing system is departed from in following out the ramifications of the various lines the smaller will the diameter of pipe become. The smallest cast-iron pipe of a distributing system is seldom less than 3 inches, and sometimes not less than 4 or 6 inches. There should be no dead ends in any distributing system. By a dead end is meant the end of a line of pipes, which is closed so that no water circulates through it. Whenever a branch pipe ceases it should be extended so as to connect with some other pipe in the system in order to induce circulation. The entire distributing system should therefore, in its extreme as well as central portions, constitute an interlaced system and not a series of closed ends. This is essential for the purity and potability of the water-supply. A circulation in all parts of the entire system is essential and it should be everywhere secured.

The diagram shows a portion of the distributing system of the city of New York. It will be noticed that there is a complete connection of the outlying portions, so as to make the interlacing and corresponding circulation as complete and active as possible.

[Illustration: FIG. 4.—New York City Distributing System.]

=207. Diameters of and Velocities in Distributing Mains and Pipes.=—In laying out a distributing system it will not be possible to base the diameters at different points on close computations for velocity or discharges based upon considerations of friction or other resistances, as the conditions under which the pipes are found are too complicated to make such a method workable. Approximate estimates may be made as to the number of consumers to be supplied at a given section of a main pipe, and

consequently what the diameter should be to pass the required daily supply so that the velocity may not exceed certain maximum limits known to be advisable. Such estimates may be made at a considerable number of what may be termed critical points of the system, and the diameters may be ascertained in that manner with sufficient accuracy. In this field of hydraulics a sound engineering judgment, based upon experience, is a very important element, as it is in a great many other engineering operations.

It will follow from these considerations that as a rule the larger diameters of pipe in a given distributing system will belong to the greater lengths, and it will be found that the velocities of water in the various parts of a system will seldom exceed the following limits, which, although stated with some precision, are to be regarded only as approximate:

For 4-inch pipe 23 feet per second. " 6 " " 23 " " " " 8 " " 17 " " " " 11 " " 12 " " " " 12 " " 12 " " " " 16 " " 9 " " " " 20 " " 8 " " " " 24 " " 7 " " " " 30 " " 7 " " " " 36 " " 7 " " " " 48 " " 7 " " " " 60 " " 7 " " "

=208. Required Pressures in Mains and Pipes.=—In designing distributing systems it is very essential so to apportion the pipes as to secure the requisite pressure at the various street services. Like many other features of a water-supply system no exact rules can be given, but it may be stated that at the street-level a pressure of at least 20 to 30 pounds should be found in resident districts, and from 30 to 35 or 40 pounds in business districts. The character and height of buildings affect these pressures to a large extent. Old pipe systems usually have many weak points, and while pressures requisite to carry water to the top of three- or four-story buildings are needed, any great excess above that would be apt to cause breaks and result in serious leakages. If the distributing system is one in which the pressure for fire-streams is to be found at the hydrants, then greater pressures than those named must be provided. In such cases the pressures in pipes at the hydrants should range from 60 to 100 pounds.

=209. Fire-hydrants.=—Fire-hydrants must be placed usually at street corners, if the blocks are not too long, and so distributed as to control with facility the entire district in which they are found. Unless fire-engines are used to create their own pressure, the lower the pressure at the hydrant the nearer together the hydrants must be placed. It is obvious, however, that when the pressure of the system is depended upon for fire-streams it is desirable to have the pressure comparatively high, so far as the hydrants are concerned, as under those conditions they may be placed farther apart and a less number will be required.

=210. Elements of Distributing Systems.=—The following table gives a number of statistics, exhibiting the elements of the distributing system of a considerable number of cities, including some pumping and meter data pertinent to the costs of pumping on the one hand and the extension of the use of meters on the other.

It contains information of no little practical value in connection with the administration of the distributing systems and the consumption of water in it. This table has been compiled by Mr. Chas. W. Sherman of the New England Water-works Association, and was published in the proceedings of that association for September, 1901. The service-pipes, varying from ½ to 10 inches in diameter, are of cast-iron, wrought-iron, lead, galvanized iron, tin-lined, rubber-lined, cement-lined, enamelled and tarred, the practice varying widely not only from one city to another, but in the same city.

TABLE XIX

LEGEND: (A) = Kind of Pipe. (B) = Size of Pipe. Ins (C) = Total Length in Use, Miles. (D) = Cost of Repairs per Mile. (E) = Total Number of Hydrants in Use. ----------+--------+-----+------+------+---------- Name of City or Town. | (A) | (B) | (C) | (D) | (E) ----------+--------+-----+------+------+---------- Albany, N. Y. | | | 129.7| | 808 ----------+--------+-----+------+------+---------- Atlantic City, N. J. | C.I. | 4-20| 47.6| | 519 | | | | | 808 ----------+--------+-----+------+------+---------- Boston, Mass. | C.I. | 2-48| 713.4| 27.09| 7606 ----------+--------+-----+------+------+---------- | C.L. | | | | Burlington, Vt. | C.I. | 4-30| 38.0| 4.61| 213 | W.I. | | | | ----------+--------+-----+------+------+---------- Cambridge, Mass. | | | | | 968 | | | | | ----------+--------+-----+------+------+---------- Chelsea, Mass. | C.I. | 6-16| 37.8| | 253 | | | | | ----------+--------+-----+------+------+---------- | C.I. | | | | Concord, N. H. | C.L. | 4-30| 60.2| | 267 ----------+--------+-----+------+------+---------- Fall River, Mass. | C.I. | 6-24| 87.3| | 954 | | | | | ----------+--------+-----+------+------+---------- Fitchburg, Mass. | C.I. | 2-20| 66.6| | 499 ----------+--------+-----+------+------+---------- | C.I. | | | | Holyoke, Mass. | W.I. | ½-30| 81.6| 5.14| 860 ----------+--------+-----+------+------+---------- Lowell, Mass. | | | 127.8| | 1098 | | | | | ----------+--------+-----+------+------+---------- | W.I. | | | | Lynn, Mass. | C.L. | 2-20| 129.4| | 952 | C.I. | | | | ----------+--------+-----+------+------+---------- Madison, Wis. | C.I. | 4-16| 34.3| | 169 | | | | | | | | | | ----------+--------+-----+------+------+---------- | C.L. | | | | Manchester, N. H. | C.I. | 4-20| 96.9| | 743

---+---+---+---+---+--- Owned by | C.I. | 6-60| 69.8| | Metropolitan | C.L. | | | | Water-works
+---+---+---+---+--- | C.I. | | | | Tot. Sup. by | C.L. | 4-60|1360.3| | 11913 | Kal. | | | |
---+---+---+---+---+--- | C.I. | | | | Minneapolis, Minn. | Steel.|1¼-50| 269.2| | 3172
---+---+---+---+---+--- New Bedford, Mass. | C.I. | 4-36| 92.7| 24.00| 738
---+---+---+---+---+--- | W.I. | | | | New London, Conn. | C.L. | 4-24| 50.5| 18.71| 258 | C.I. | | | |
---+---+---+---+---+--- Newton, Mass. | C.I. | 4-20| 136.6| 6.43| 935
---+---+---+---+---+--- Providence, R. I. | C.I. | 6-36| 324.6| 0.56| 1886
---+---+---+---+---+--- " H.P. Fire System | C.I. |12-24| 5.6| | 92
---+---+---+---+---+--- | W.I. | | | | Quincy, Mass. | C.I. | 1-36| 144.7| 5.50| 955† | C.L. | | | |
---+---+---+---+---+--- | C.I. | | | | Springfield, Mass. | Kal. | 2-20| 84.1| | 539
---+---+---+---+---+--- Woonsocket, R. I. | C.I. | 4-20| 45.8| 3.57| 548
---+---+---+---+---+--- Yonkers, N. Y. | | | 74.1| | 771
---+---+---+---+---+--- Worcester, Mass. | | 2-40| 173.5| | 1763 | | | | |
---+---+---+---+---+---

† Public hydrants only.

TABLE XIX. (continued)

LEGEND: (F) = Total Number of Gates in Use. (G) = Range of Pressure on Mains at Centre, Pounds. (H) = Size of Service-pipe in Inches. (I) = Total Number of Service-taps in Use. (J) = Total Number of Meters in Use. (K) = Total Pumpage for the Year in Gallons. (L) = Average Static Head against which Pumps Work, Feet. ----+---+---+---+---+--- (F)| (G) | (H) | (I) | (J) | (K) | (L) ----+---+---+---+---+--- 803| | | | 2030 | |
----+---+---+---+---+--- | | ½-4 | 4,249| 3298 | 955,726,046 | 81.7 | | | | | 148,662,947 | 119.5
----+---+---+---+---+--- 8910| 40-90 | ½-8 | 87,525| 4516 | |
----+---+---+---+---+--- | | | | | 618| 70-85 | ½-6 | 3,350| 2311 | 312,896,525 | 289 | | | | | |
----+---+---+---+---+--- | | | 14,207| 860 | 2,651,277,240 | 399| 48-50 | ■-2 | 6,146| 104 | |
----+---+---+---+---+--- 757| | | 3,340| 1010 | 142,772,165 | | | | | | |
----+---+---+---+---+--- 940| 80 | ½-2 | 6,943| 6,544 | 1,388,776,336 | 186.2
----+---+---+---+---+--- | 75 L.S. | | | | | 554| 155 H.S. | ¾-8 | 4,432| 2,427 | |
----+---+---+---+---+--- 734| 80-100 | ■-4 | 3,610| 210 | | | | | | | |
----+---+---+---+---+--- 1188| | | 10,634| 5,586 | 2,042,066,140 | 156.1 | | | | | | | | | | | |
----+---+---+---+---+--- | | | | | 378,782,675 | 966| 45-60 | ¾-4 | 13,504| 2,571 | 1,330,784,875 | | | | | |
| ----+---+---+---+---+--- 234| | | 2,758| 2,586 | 306,637,454 | 223.8 | | | | | |
----+---+---+---+---+--- | | | | | | | | | | | 910| | ½-6 | 5,513| 3,667 | | | | | | | | | | | | | | | | | |
----+---+---+---+---+--- 268| | |134,496| 10,385 |15,027,410,000(a)| | | | | 9,431,140,000(b)| | | | |
2,015,130,000(c)| ----+---+---+---+---+--- 2195| | ■-1 | 20,064| 5,030 | 6,863,135,200 |
----+---+---+---+---+--- | | | | | 1065| 28-64 | ½-10| 9,280| 1,429 | 2,307,429,372 | 167.2 | | | | | |
----+---+---+---+---+--- 318| 40-48 | ½-4 | 3,088| 229 | |
----+---+---+---+---+--- 801| 84 | ½-6 | 7,087| 6,001 | 762,876,073 | 234
----+---+---+---+---+--- 3399| 64-73 | ½-10| 21,566| 17,813 | 3,833,243,445 | 171.6 | | | | |
34,401,038 | 172.4 ----+---+---+---+---+--- 31| 114 | | | | 578,940,480 | 111.2
----+---+---+---+---+--- 1889| 30-35 H.S. | 1-6 | 9,764| 3,122 | | | 100-120 L.S.†| | | | |
----+---+---+---+---+--- 1001| 78-85 | ■-3 | 4,330| 122 | | | | | | | |
----+---+---+---+---+--- 456| 50-120 | ■-6 | 2,193| 1,889 | 340,849,628 | 237.6
----+---+---+---+---+--- 498| | ¼-8 | 4,968| 4,852 | 1,323,696,099 |
----+---+---+---+---+--- | 70 L.S. | | | | | 2432| 150 H.S.† | | 13,292| 12,529 | |

† Public hydrants only.

C.L. = cement-lined. (_a_) = Chestnut Hill high service. (_b_) = Chestnut Hill low service. (_c_) = Spot Pond Pumping-station.

TABLE XIX. (continued)

LEGEND: (M) = Average Dynamic Head against which Pumps Work, Feet. (N) = Duty in Foot-pounds per 100 Pounds of Coal. No Deductions. ----------+-------+-------+-------+---------- | | | | | | | Name of City or Town. |Kind of |Size of| (M) | (N) | Pipe. | Pipe. | | | | | ----------+-------+-------+-------+---------- Albany, N. Y. | .. | .. | .. | .. ----------+-------+-------+-------+---------- Atlantic City, N. J. | C.I. | 4-20 | 123.3| 36,501,217 | | | 119.5| 15,518,455 ----------+-------+-------+-------+---------- Boston, Mass. | C.I. | 2-48 | .. | .. ----------+-------+-------+-------+---------- | C.L. | | | Burlington, Vt. | C.I. | 4-30 | 316 | .. | W.I. | | | ----------+-------+-------+-------+---------- Cambridge, Mass. | .. | .. | .. | .. Chelsea, Mass. | C.I. | 6-16 | .. | .. ----------+-------+-------+-------+---------- Concord, N. H. | C.I. | | | | C.L. | 4-30 | .. | .. ----------+-------+-------+-------+---------- Fall River, Mass. | C.I. | 6-24 | .. | .. Fitchburg, Mass. | C.I. | 2-20 | .. | .. ----------+-------+-------+-------+---------- Holyoke, Mass. | C.I. | ½-30 | .. | .. | W.I. | | | ----------+-------+-------+-------+---------- Lowell, Mass. | .. | .. | 163.9| 93,489,048 ----------+-------+-------+-------+---------- | W.I. | | | Lynn, Mass. | C.L. | 2-20 | 167 | 88,780,036 | C.I. | | 167 | 87,265,319 Madison, Wis. | C.I. | 4-16 | 242.4| 47,530,839 ----------+-------+-------+-------+---------- Manchester, N. H. | C.L. | 4-20 | .. | .. | C.I. | | | ----------+-------+-------+-------+---------- | C.I. | 6-60 | 96.5| 121,800,000 Owned by | C.L. | | | Metropolitan +-------+-------+-------+---------- Water-works | C.I. | 4-60 | 51.8| 109,380,000 Tot. Sup. by | C.L. | | 125.6| 80,400,000 | Kal. | | | ----------+-------+-------+-------+---------- | C.I. | | | Minneapolis, Minn. | Steel.| 1½-50 | .. | 68,016,609 ----------+-------+-------+-------+---------- New Bedford, Mass. | C.I. | 4-36 | 192 | 130,336,508 ----------+-------+-------+-------+---------- | W.I. | | | New London, Conn. | C.L. | 4-24 | .. | .. | C.I. | | | ----------+-------+-------+-------+---------- Newton, Mass. | C.I. | 4-20 | 254 | 72,500,000 ----------+-------+-------+-------+---------- | | | 176.9| 101,301,600 Providence, R. I. | C.I. | 6-36 | 177.7| 60,329,100 | | | 124.7| 68,533,300 " H.P. Fire System | C.I. |12-24 | .. | .. ----------+-------+-------+-------+---------- Quincy, Mass. | C.I. | | | Kal. | 2-20 | .. | .. ----------+-------+-------+-------+---------- | W.I. | | | Springfield, Mass. | C.I. | 1-36 | .. | .. | C.L. | | | ----------+-------+-------+-------+---------- Woonsocket, R. I. | C.I. | 4-20 | 239.5| 51,024,641 Yonkers, N. Y. | .. | .. | .. | .. Worcester, Mass. | .. | 2-40 | .. | .. ----------+-------+-------+-------+----------

TABLE XIX. (continued)

LEGEND: (O) = Cost per Million Gallons raised 1 Foot High. Pumping-station Expenses. (P) = Cost per Million Gallons raised 1 Foot High. Figured on Total Maintenance. (R) = Rate of Interest Per Cent. ------+------------+------------+----------+------------+-------- | | Net Cost of | Bonded | Value of | (O) | (P) | Works | Debt | Sinking | (R) | | to Date. | at Date. |Fund at Date.| ------+------------+------------+----------+------------+-------- .. | $0.264 | $916,723.59| $892,000| $100,407.01| 4½-5 ------+------------+------------+----------+------------+-------- .. | .. |23,054,387.81|11,960,272|10,144,647.08| 3½-6 | | | | | ------+------------+------------+----------+------------+-------- 0.08 | 0.366 | 468,039.73| 248,000| 64,076.40| 3½-4 ------+------------+------------+----------+------------+-------- .. | .. | 5,670,229.52| 3,302,100| 604,326.58| | | | | | | | | | ------+------------+------------+----------+------------+-------- .. | .. | 483,335.52| 300,000| 50,921| | | | | ------+------------+------------+----------+------------+-------- .. | .. | 857,440.98| 650,000| | | | | | ------+------------+------------+----------+------------+-------- .. | .. | 1,937,862.93| 1,920,000| 581,647.78| 5.1 | | | | | ------+------------+------------+----------+------------+-------- .. | .. | 452,091.09| 648,000| 195,908.91| ------+------------+------------+----------+------------+-------- .. | .. | 1,244,742.23| 300,000| 37,403.46| 4 ------+------------+------------+----------+------------+-------- 0.0399| .. | .. | 1,274,700| 287,226.20| | | | | ------+------------+------------+----------+------------+-------- 0.042 | 0.51 | 2,472,821.85| 1,800,300| 524,027.50| 3½-5 ------+------------+------------+----------+------------+-------- 0.159 | .. | 337,630.13| | | | | | | ------+------------+------------+----------+------------+-------- .. | .. | 1,513.012.79| 900,000| 159,466.83| 4-6 | | | | | ------+------------+------------+----------+------------+-------- 0.0314| | | | | | | | | | ------+------------+------------+----------+------------+-------- | | | | | | | | 0.032 | | | | | | | | | | | | | | | | ------+------------+------------+----------+------------+-------- 0.043 | | | | | ------+------------+------------+----------+------------+-------- 0.033 | | | | | ------+------------+------------+----------+------------+-------- 0.0259| 0.2867| 1,820,107.73| 558,000| 148,793.77|av. 4.44 | | | | | | | | | | ------+------------+------------+----------+------------+-------- .. | .. | 706,978.44| 410,000| .. | 3.5-4 ------+------------+------------+----------+------------+-------- 0.05 | 0.59 | 2,034,808.07| 2,075,000| 849,115.40| av. 4.7 | | | | | | | | | | ------+------------+------------+----------+------------+-------- .. |L.S. = 0.0259| 6,470,093.35| 5,920,000| 713,431.62| av. 3.7 ------+------------+------------+----------+------------+-------- .. |H.S. = 0.1134| | | | | | | | ------+------------+------------+----------+------------+-------- .. | .. | .. | 720,500| .. | 4 | | | | | | | | ------+------------+------------+----------+------------+-------- .. | .. | 2,128,559.56| 1,500,000| 461,861.90| av. 5.9

------+-------------+-------------+----------+-------------+-------- 0.061 | 0.37 | 390,841.78| | |
------+-------------+-------------+----------+-------------+-------- .. | .. | 1,577,105.15| 1,475,000| 310,700 | 3.5-7
------+-------------+-------------+----------+-------------+---------

CHAPTER XX.

=211. Sanitary Improvement of Public Water-supplies.=—In the preceding consideration of a public water-supply it has been virtually assumed that the water will reach consumers in the proper sanitary condition; but this is not always the case. With great increase of population and corresponding increase of manufacturing and other industries there arise many sources of contamination, so that pure spring- or river-water for public supplies becomes less available and at the present time in this country it is rarely to be had.

The legal responsibility of parties who allow sewage, manufacturing wastes, or other contaminating matter to flow into streams is already clearly recognized, and many cities and towns are required to dispose of their sewage and other wastes in such manner as to avoid polluting streams of water flowing past sewer outfalls or manufacturing establishments; but even these restraints are not sufficient. If a stream has once been polluted it can scarcely be considered safe as a supply for potable water for public or private purposes. There are certain diseases whose bacilli are water-borne and which are conveyed by drinking-water containing them; prominent among such diseases are typhoid fever and cholera. Experience has many times shown that these bacilli or disease germs may find their way from isolated country houses as well as from the sewage of cities into water that would otherwise be potable. Besides such considerations as these it is equally well known from engineering experience that many waters of otherwise fair quality carry the remains of organic matter in one shape or another which operate prejudicially to the physical condition of those who drink such water. It is therefore becoming more and more the conviction of civil engineers and sanitarians that there are few sources of potable water so free from some degree of pollution that the supplies drawn from them do not require treatment in order to put them into good condition for drinking. It is not intended in this observation to state that there are no streams or springs from which natural waters may not be immediately used for domestic purposes without improving them by artificial means, but it may be stated even at the present time that no water of a public water-supply should be used without treatment, unless the most thorough bacteriological examinations show that its sanitary condition is eminently satisfactory.

It is the common experience of many public water-supplies in this country that during certain seasons of the year, extending through the summer and autumn months, certain low forms of vegetation flourish, causing sometimes discoloration and always offensive tastes and odors. While such waters are usually not dangerous, they certainly are not desirable and may cause the human system to become receptive in respect to pathogenic bacilli. The tendency at the present time, therefore, is to consider the improvement of any water-supply that may be contemplated for any city or town.

=212. Improvement by Sedimentation.=—The two broad methods of improving the water of a public supply at the present time are sedimentation and filtration, the latter generally through clean sand, although sometimes other fine granular material or porous mass is used. The operation of sedimentation is carried on when water is allowed to stand absolutely at rest or to move through a series of basins with such small velocity that the greater portion of the solid material held in suspension is given an opportunity to settle to the bottom. All water which is taken from natural sources, whether surface or underground, carries some solid matter. Some waters, like spring-water or from an underground supply, are so clear as to be very nearly free from solid matter in suspension, but, on the other hand, there are waters, like those from silt-bearing rivers, which carry large amounts. Observations upon the Mississippi River at St. Louis have shown that the suspended matter may reach as much as 1000 parts in one million, although the quantity held in suspension is usually much less than that. Similar observations have been made upon other silt-bearing streams. Such large proportions of suspended solid matter are not usually found in streams used for potable purposes, but there are few surface sources of water-supply the water from which will not be sensibly improved by sedimentation in settling-basins or reservoirs.

The process of sedimentation is usually preliminary to that of filtration. If raw water, i.e., as it comes from its natural source, is conducted directly to filtration-beds, the amount of solid matter is frequently so great that the surface of the filter would be too quickly clogged; hence it is advisable in almost every case to subject to sedimentation any water which is designed to be treated subsequently by filtration.

The degree of turbidity is usually measured by means similar to those employed in gauging discoloration from vegetable matter. One method devised by Mr. Allen Hazen, to which allusion will again be made, is that in which the depth in inches is observed at

which a platinum wire 1 mm. in diameter and 1 inch long can be seen. The degree of turbidity is then represented by the reciprocal of that distance. The permissible turbidity estimated in this manner is taken by different authorities at different values running from .025 to .2. Water of this degree of turbidity appears, when seen through a glass, to be practically clear.

The rapidity with which sedimentation can be performed depends greatly upon the character and degree of comminution of the solid material. If it is coarse, comparatively speaking, it will quickly fall to the bottom; if the solid matter is clay of fine texture, it is dissipated through the water in an excessively high degree of diffusion and will remain obstinately suspended. This has been found to be the case at some points with the Ohio River water. Ordinarily sufficient sedimentation can be accomplished where the water remains at rest from twenty-four to forty-eight hours; in general, observations as to this matter, however, must be applied very cautiously. Water of the Mississippi River at St. Louis has been found to deposit nearly all of its sediment within twenty-four hours. At Cincinnati, on the other hand, the Ohio River water carries so fine a sediment that on an average not more than 75 per cent of it will be deposited in three days by unaided subsidence. Again, at Omaha the water of the Missouri River has been found to be turbid at the end of seventy-two hours. In some cases, as with the waters of the Delaware and Schuylkill at Philadelphia, a greater amount of subsidence has been found to exist at times at the end of twenty-four hours than after forty-eight hours. It is obvious that some special conditions must have produced such results that would not ordinarily occur in connection with the operation of sedimentation.

=213. Sedimentation Aided by Chemicals.=—In cases where simple unaided subsidence proceeds too slowly it can be accelerated by the introduction of suitable chemicals. At Cincinnati, for instance, it was found advantageous to introduce into the water before flowing into the settling-basins a small amount of alum or sulphate of alumina, depending upon the degree of turbidity, the average being about 1.6 grains per gallon, rising to perhaps 4 grains in floods. By these means a few hours of aided sedimentation would produce more subsidence than could be obtained in several days without the chemicals. A similar recommendation has been made for the purpose of improving the water-supply for the city of Washington, D. C., from the Potomac River. In other cases between 5 and 6 grains of lime per gallon have produced effective results.

=214. Amount of Solid Matter Removed by Sedimentation.=—Under adverse conditions, or with sediment which remains obstinately suspended, not more than 25 to 50 per cent of the solid material will be removed by sedimentation, but when the process is working satisfactorily, sometimes by the aid of chemicals acting as coagulants, 90 to 99 per cent even of the solid material may be removed. The operation of sedimentation has another beneficial effect in that the solid matter when being deposited carries down with it large numbers of bacteria, which, in some cases, have been observed to be 80 or 90 per cent of the total contents of the water. In other words, the subsidence of the solid matter clears the water of a large portion of the bacteria.

=215. Two Methods of Operating Sedimentation-basins.=—Sedimentation is carried on in two ways, one being the "fill-and-draw" method and the other the "continuous" method. In the former method a basin or reservoir is first filled with water and then allowed to stand while the subsidence goes on for perhaps twenty-four hours. The clear water is then drawn off, after which the reservoir is again filled. In the continuous method, on the other hand, water is allowed to flow into a single reservoir or series of reservoirs through which it passes at an extremely low velocity, so that its contents will not entirely change within perhaps twenty-four hours or more. In this method the clear water is continuously discharging at a comparatively low rate, the velocity in the reservoir being so small that the solid matter may be deposited as in the fill-and-draw method. Both of these methods are used, and both are effective. The choice will be dependent upon local conditions. In the continuous method the solid matter is largely deposited nearer the point of entrance into the reservoir, but more generally over the bottom in the fill-and-draw method. The velocity of flow in the reservoirs of the continuous method generally ranges between 0.5 inch and 2.5 inches per minute. Occasionally the velocity may be slightly less than the least of these values, and sometimes one or two inches more than the maximum value.

=216. Sizes and Construction of Settling-basins.=—The sizes of the settling-basins will obviously depend to a considerable extent upon the daily consumption of water. There is no general rule to be followed, but the capacity of storage volume of those actually in use run from less than 1 to possibly 14 or 15 days' supply. Under ordinary circumstances their volumes may usually be taken from 5 to 6 or 8 days' supply. Their shape should be such as to allow the greatest economy in the construction of embankments and bottoms. They may generally be made rectangular. Their depths is also a matter, to some extent, of constructive economy. The depth of water will usually be found between about 10 and 16 feet, it being supposed that possibly 2 or 3 feet of depth will be required for the collection of sediment. These basins must be water-tight. The bottom surfaces may be covered with concrete 6 to 9 inches thick, with water-tight firm puddle 12 to 18 inches thick underneath, resting on firm compacted earth. The inner embankment surfaces or slopes may be paved with 10- or 12-inch riprap resting on about 18 inches of broken stone over a layer of puddle of equal thickness with the bottom and continuous with it. Occasionally the bottom and sides may be simply puddled with clay and

lined with brick or riprap pavement, laid on gravel, or broken stone. It is only necessary that the sides and bottoms shall be tight and of such degree of hardness and continuity as to admit of thorough cleaning.

The bottoms of sedimentation-basins may advantageously not be made level. In order to facilitate cleaning away the solid matter settling on them, a valley or depression may be formed along the centre line to which the two portions of the bottom slope. A grade in this channel or central valley of 1 in 500 with slopes on either side of 1 in 200 or 1 in 300 will be effective in the disposition of the solid matter. At the lowest end of the central valley there should be suitable gates through which the accumulated sediment can be moved out of the basin. This sedimentary matter will in many cases be soft mud, but its movement will always be facilitated by the use of suitable streams of water. The frequency of cleaning will depend upon the amount of sediment carried by the water and upon its accumulation in the basin. Whenever its depth ranges from 1 to 2 or 3 feet it is removed.

Complete control of the entrance of the water to and its exit from the basin must evidently be secured by suitable gates or valves and other appliances required for the satisfactory operation of the basin. In some cases the cost of sedimentation-reservoirs with concrete bottoms and sides has risen as high as $9000 per million gallons of capacity; but where the cheaper lining has been used, as in the case of reservoirs at Philadelphia, the range has been from about $3300 to about $4300.

=217. Two Methods of Filtration.=—After the process of sedimentation is completed there will necessarily always be found the remains of organic matter and certain other polluting material which should be removed before the water is allowed to enter the distributing system. This removal is accomplished usually by filtration through clean sand, but occasionally through porous material, such as concrete slabs, porcelain, or other similar material. The latter processes are not much used at the present time, and they will not be further considered.

The filtration of water through sand is carried on by two distinct methods, one called slow sand filtration and the other rapid sand filtration. In the first method the water is simply allowed to filter slowly through beds of sand from 2 to 3 or 5 feet thick and suitably arranged for the purpose. In the second method special appliances and conditions are employed in such manner as to cause the water to flow through the sand at a much more rapid rate. The method of slow sand filtration will first receive attention.

=218. Conditions Necessary for Reduction of Organic Matter.=—The most objectionable class of polluting materials includes organic matter which from one source or another finds its way into natural waters. Such material has originally constituted or formed a part of living organisms and chemically consists of varying proportions of carbon, oxygen, hydrogen, and nitrogen. As found in public water-supplies it is usually in some stage of decomposition. The chemical operations taking place in these decompositions are more or less complicated, but in a general way it may be said that the first step is the oxidizing of the carbon which may produce either carbon monoxide or carbon dioxide and a combination of nitrogen with hydrogen as ammonia. When the conditions are favorable, i.e., when free oxygen is present, the ammonia may be oxidized by it, thus producing nitric acid and water. If, as is generally the case, suitable other substances, as alkalis, are present, the nitric acid combines with them, forming nitrates more or less soluble and essentially innocuous. It is therefore seen that the complete result is a chemical change from the original organic matter, offensive and possibly dangerously polluting, to gaseous and solid matter, the former escaping from the water and the latter either passing off unobjectionably in a soluble state or precipitating to the bottom as inert mineral matter. In order that these processes may be completely effective, two or three conditions are necessary, i.e., sunlight, free oxygen, and certain species of that minute and low class of organisms known as bacteria, the nature and conditions of existence of which have been scientifically known and studied within a period extending scarcely farther back than ten or fifteen years. The precise nature of their operations and their relations to the presence of the necessary oxygen, or just the parts which they play in the process of decomposition, are not completely known, although much progress has been made in their determination. It is positively known that their presence and that of uncombined oxygen are essential. Certain species of these bacteria will live and work only in the presence of sunlight and oxygen; these are known as aerobic bacteria. Other species, forming a class known as anaerobic bacteria, live and effect their operations in the absence of sunlight and oxygen in that offensive mode of decomposition which takes place in cesspools and other closed receptacles for sewage and waste matter. They play an essential part in what promises to be one of the most valuable methods of sewage-disposal in which the septic tank is a main feature.

=219. Slow Filtration through Sand—Intermittent Filtration.=—In the slow sand filtration method of purifying the water of a water-supply the aerobic bacteria only act. In order that their operations may be completed, free oxygen and sunlight are essential requisites, and the first of these is found in every natural water which can be considered potable. Any water which does not contain sufficient free oxygen for this purpose is to be regarded with suspicion, and generally cannot be considered suitable for domestic purposes. The amount of uncombined oxygen contained in any potable natural water is greatly variable and changes much with the

period of exposure in a quiet state, as well as with pressure and temperature. In the river Seine it has averaged nearly 11 parts in a million throughout the year, being lowest in July and August and highest in December and January. It has been found in the experimental work of the Massachusetts State Board of Health that free or dissolved oxygen in potable water may vary from 8.1 parts at 80° Fahr. to 14.7 parts by weight at 32° Fahr. in 1,000,000 at atmospheric pressure.

[Illustration: FIG. 4.]

[Illustration: No. 1. CROSS-SECTION AT NORTH END OF BED.]

[Illustration: No. 2. CROSS-SECTION AT BEGINNING OF PIPE UNDERDRAIN.]

[Illustration: No. 3. CROSS-SECTION AT SOUTH END OF BED.]

[Illustration: No. 4. CROSS-SECTION AT END OF LOWEST GRAVEL UNDERDRAIN.]

[Illustration: No. 5. LONGITUDINAL SECTION OF A BED, AT WESTERLY END OF FILTER.

TYPICAL SECTIONS OF UNIT BEDS IN LAWRENCE CITY FILTER.

APRIL, 1901.

COPIED FROM PLAN FURNISHED BY A.D. MARBLE, CITY ENGINEER.]

In some cases where liability to dangerous contamination exists it may be advisable to increase the available supply of oxygen in the water by using a slow sand filter intermittently, as has been done at Lawrence, Mass. Instead of permitting a continuous flow of water through the sand, that flow is allowed for a period of 6 to 12 hours only, after which the filter rests and is drained for perhaps an equal period. During this intermission another filter-bed is brought into use in the same manner. Alternating thus between two or more filters, the flow in any one is intermittent. In this manner the oxygen of the air finds its way into the sand voids of each drained filter in turn and thus becomes available in the presence of suitable species of bacteria for reducing the organic matter in the water next passing through the filter. Intermittent filters operated in this manner are not much used, but the most prominent instance is that at Lawrence, Mass. At that place the water after being filtered is pumped to a higher elevation for use in the distribution system. The pumps have been run nineteen hours out of the twenty-four, and the water is shut off from the filters five hours before the pumps stop. The gate admitting water to the filter is open one hour before they start. Nine hours of each day the filter does not receive water, and rests absolutely about four hours.

=220. Removal of Bacteria in the Filter.=—The grains of the sand at and near the surface of a slow sand filter, within a short time after its operation is begun, acquire a gelatinous coating, densest at the surface and decreasing rapidly as the mass of sand is entered. This gelatinous coating of the grains is organic in character and probably largely made up of numerous colonies of bacteria whose presence is necessary for the reduction of the organic matter. It is necessary to distinguish between these species of bacteria and those which are pathogenic and characteristic of such diseases as typhoid fever, cholera, and others that are water-borne. Every potable surface-water and possibly all rain-water carry bacteria which are not pathogenic and which apparently accumulate in dense masses at and near the surface of the slow sand filter. As the water finds its way through the sand it loses its organic matter and its bacteria, both those of a pathogenic and non-pathogenic character. Potable water, therefore, is purified and rendered innocuous by the removal in the filter of all its bacteria, including both the harmless and dangerous.

=221. Preliminary Treatment—Sizes of Sand Grains.=—In designing filtration-works consideration must be given to the character of water involved. There are waters which when standing in open reservoirs exposed to the sunlight will develop disagreeable tastes and odors, and it may be necessary to give them preliminary treatment especially for the removal of such objectionable constituents.

The character and coarseness of the sand employed are both elements affecting its efficiency as a filtering material. It should not be calcareous, for then masses of it may be cemented together and injure or partially destroy the working capacity. Again, if it is too coarse and approaches the size of gravel, water may run freely through it without experiencing any purification. Much labor has been expended, especially by the State Board of Health of Massachusetts, in investigating the characteristics of sand and the sizes of grains best adapted to filter purposes. In that work it has become necessary to classify sands according to degrees of fineness or coarseness. The diameter of a grain of sand in the system of classification employed means the cube root of the product of the greatest and least diameters of a grain multiplied by a third diameter at right angles to the greatest and least. The “effective” size of

any given mass of sand means the greatest diameter of the finest 10 per cent of the total mass. There is also a term called the "uniformity coefficient." The uniformity coefficient is the quotient arising from dividing the greatest diameter of the finest 60 per cent of the mass by the greatest diameter of the finest 10 per cent of the same mass. These are arbitrary terms which have been reached by experience as convenient for use in classifying sands. Evidently absolute uniformity in size will be indicated by a uniformity coefficient of 1, and the greater the variety in size the greater will be the uniformity coefficient. Sands taken from different vicinities and sometimes even from the same bed will exhibit a great range in size of grain.

[Illustration: FIG. 5.—Sizes of Grain or Fineness of Sand.]

Fig. 5 represents the actual variety of size of grain as found in eight lots of sand among others examined in the laboratory of the Massachusetts State Board of Health. The vertical scale shows the per cent by weight of portions having the maximum grains less in diameter than shown on the horizontal line. The more slope, like No. 5 or 6, the greater is the variety in size of grain. Those lines more nearly vertical belong to sands more nearly uniform in size of grain.

=222. Most Effective Sizes of Sand Grains.=—Investigations by the Massachusetts State Board of Health indicate that a sand whose effective diameter of grain is .2 mm. (.008 inch) is perhaps the most efficient in removing organic matter and bacteria from natural potable waters. At the same time wide experience with the operation of actual filters seems to indicate that no particular advantage attaches to any special size of grain, so long as it is not too fine to permit the desired rate of filtration or so coarse as to allow the water to flow through it too freely. Experiments have shown that effective sizes of sand from .14 to .38 mm. in diameter possess practically the same efficiency in a slow sand filter. The action of the filter is apparently a partial straining out of both organic material and bacteria, but chiefly the reduction of organic matter in the manner already described and probably the destruction to a large extent of the bacteria, especially those of a pathogenic nature, although at the present time it is impossible to state the precise extent of either mode of action.

=223. Air and Water Capacities.=—Another important physical feature of filter-sands, especially in connection with intermittent filtration, is the amount of voids between the grains. When the intermittent filter is allowed to drain, so that the only water remaining in it is that held between the grains by capillary attraction, generally at the bottom of the filter unless the sand is very fine, the volume of the water which remains in the voids is called the water capacity of the sand. The remaining volume between the grains is called the air capacity of the same sand. It is evident that the air capacity added to the water capacity will make the total voids between the sand grains.

[Illustration: FIG. 6.]

Fig. 6 shows the amount of air and water capacities of the same sands whose sizes of grains are exhibited in Fig. 5. The depth of the sand is supposed to be 60 inches, as shown on the vertical line at the left of the diagram, while the percentages of the total volume representing the amounts of voids is shown on the horizontal line at the bottom of the diagram. Both air and water capacities for each sand are shown by the various numbered lines partially vertical and partially inclined. It will be observed that the fine sands No. 2 and No. 4 have large water capacities, the water capacity being shown by that part of the diagram lying below and to the left of each line. It will be noticed that No. 5 sand is made up of approximately equal portions of fine and coarse grains, the former largely filling the voids between the latter. This mixture, as shown by the No. 5 line, gives a very high water capacity and a correspondingly low air capacity. Obviously a sand with a high water capacity has a correspondingly low air capacity, and in general would not be a very good sand for an intermittent filter, since it is the purpose of the latter to secure in the voids between the sand grains as much oxygen as practicable whenever the filter may be at rest.

=224. Bacterial Efficiency and Purification—Hygienic Efficiency.=—As the function of a filter is to remove as far as possible the organic matter and bacteria of the applied water, there must be some criterion by which its efficiency in the performance of those functions can be expressed. The bacterial efficiency is represented by the ratio found by dividing the number of bacteria after filtration in a prescribed cubic unit, as a cubic centimeter, by the number which the same volume of raw water held before being applied to the filter. This is a rather misleading ratio, for the reason that the effluent water may contain bacteria of certain species which grow in the lower portions of a filter or in the drains which conduct the effluent from it. It is possible, therefore, that bacteria may be found in a filter effluent when all of the bacteria originally held in the water have been removed. Hence the ratio expressing what is called the bacterial purification arises from dividing the number of bacteria actually removed from a cubic centimeter of water by the filter by the number originally held by a cubic centimeter of raw water. The smaller the first of these ratios the higher the degree of efficiency. Extended experience, both in the filters of such laboratories as that of the Massachusetts State Board of

Health and with actual filters of public water-supplies, show that under attainable conditions of operation 98 to 100 per cent of all the bacteria originally found in the water may be removed.

There is also used the term hygienic efficiency which is used in connection with slow sand filters. This means simply the per cent of pathogenic bacteria removed by the filter, and there is good reason to believe that it is at least as high as the bacterial purification.

=225. Bacterial Activity near Top of Filter.=—The work of removal of bacteria and organic matter has been found by extended investigations to be performed almost entirely within 6 or 8 inches of the top surface of the sand; indeed the most active part of that operation is probably concentrated within less than 3 inches of the surface. At any rate the retained bacteria and nitrogenous matter are found to decrease very rapidly within a foot from the upper surface, below which stratum the quantity is relatively very small and its rate of decrease necessarily slow. A little of this nitrogenous or gelatinous matter is found to surround to a slight extent the sand grains found at the bottom of the filter. Some authorities have considered that the more steady uniform efficiency of the deeper filters is due to this effect.

=226. Rate of Filtration.=—The rate at which water can be made to flow through a slow sand filter is of economical importance, for the reason that the higher the rate the less will be the area required to purify a given quantity per day. Foreign engineers and other sanitary authorities advocate generally slower rates of filtration than American engineers are inclined to favor. The usual rate in Europe is not far from 1.6 to 2.5 million gallons per acre per day. There is also considerable range in this country, and the rate may reach 3 million gallons per acre per day. Indeed a considerable number of tests have shown that for short periods of time, at least, some waters may be efficiently filtered at rates as high as 7 to 8 million gallons per acre per day, but probably no American engineer is ready to introduce such high rates as yet. As a matter of fact the rate will depend considerably upon the character of water used. Clear water from mountain lakes and streams uncontaminated and carrying little solid material may be filtered safely and properly at much higher rates of filtration than river or other waters carrying more sediment and more organic matter. This principle is recognized both in Europe and in this country. It would appear from experience that slow sand filters at the present time with rates of 2.5 to 3 million gallons per acre per day may be employed for practically any water that may be considered suitable for a public supply, and that with these rates high degrees of both bacterial purification and hygienic efficiency may be reached.

=227. Effective Head on Filter.=—Inasmuch as the depth of sand ranges from perhaps 3 to 5 feet the water will experience considerable resistance in flowing through it. The distance in elevation between the water surface over the filter and that of the water as it leaves the filter measures the loss of head experienced in passing through the sand and the drainage-passages under it. It has been maintained by some foreign authorities that this loss of head should be not more than 24 to 30 inches; that a greater head would force the water through the sand at such a rate as to render desired purification impossible. Experience both in the laboratory and with public filters in this country does not appear to sustain that view of the matter; considerably greater heads than 30 inches have been used with entirely satisfactory results both as to the removal of organic matter and bacteria. It appears to be best so to arrange the flow of water through the sand and the underdrains as to avoid in either a pressure below the atmosphere, as in that case some of the dissolved air in the water escapes and produces undesirable disturbances in the sand, resulting in reduced efficiency. No precise rule can be given in respect to this feature of filtration, but it seems probable that satisfactory results may be obtained under proper working of filters with a loss of head not greater than the depth of water on the filter added to the depth of sand in it, although that maximum limit would ordinarily not be reached. The depth of water on the filter may be taken from 3 to 5 feet. In this country it is seldom less than the least of these limits, and perhaps not often equal to the greater limit.

=228. Constant Rate of Filtration Necessary.=—Care should be taken in the operation of filters to avoid any sudden change in the texture or degree of compactness of the sand. At the times when workmen must necessarily walk over the surface they should be provided with special broad-based footwear, so as to produce as little effect of this kind as possible where they step. Sudden changes in the degree of compactness cause correspondingly sudden changes in the rate of filtration, and such changes produce a deterioration of efficiency. This may be due to two or three reasons. Possibly such changes may open small channels through which water finds its way too freely; or the breaking of the gelatinous bond between the grains of sand may operate prejudicially. At any rate it is essential to avoid such sudden changes and maintain as nearly uniform a rate of filtration over the entire filter as possible. Again, the age of a filter affects to some extent its efficiency. A month or two of time is required, when a new filter is started, to attain what may be called its normal efficiency. Even after that length of time the filter gains in its power to retain and destroy bacteria. This action is particularly characteristic of filters formed of comparatively coarse sand.

=229. Scraping of Filters.=—More or less solid inert as well as organic matter accumulates on the surfaces of the slow sand filters, so that at the end of proper periods of time, depending upon the character of the water filtered, this surface accumulation must be

scraped off and removed together with the sand into which it has penetrated. In scraping the filter it is impossible to remove less than .25 or .5 inch of sand, and at least .5 to .75 inch is removed whenever a filter is scraped. Sometimes 1 or 2 inches may be removed. This sand may be washed and again placed upon the filter for use. The operation of scraping exhibits a fresh sand surface to the applied water. It has been held, particularly by foreign authorities, that this operation of scraping militates against the efficiency of the filter for the time being. The investigations of the Massachusetts State Board of Health and other experiences in this country do not confirm that view which is based on the assumption that the top nitrogenous film is essential to efficiency. These investigations have shown that this film is not necessary in intermittent filters; that in many instances no diminution of efficiency has resulted from a removal of the film to a depth of .3 inch; that even the presence of that film has not given efficiency to coarse sand when the coating was thick enough to completely clog the filter; and, further, that the material of this nitrogenous film is found at a depth of several inches below the surface. It is practically certain that the scraping to depths not exceeding 1 inch have no sensible effect upon the efficiency under proper management and operation of the filters. This is particularly true if the thickness of sand is from 3 to 5 feet. It is undoubtedly true that with very shallow sand filters from 1 to 2 feet in depth the scraping of the surface may have some effect upon bacterial efficiency.

It has been the custom in connection with some European filters to waste the water which first passes through after cleaning, but the usual practice in this country is to fill slowly the filter with filtered water from below and, after the sand is submerged, to permit it to stand a little while before use. Care taken in this manner will insure an efficiency to a freshly scraped filter sufficient to avoid any wastage.

=230. Introduction of Water to Intermittent Filters.=—Where intermittent filters are used it is of the greatest importance to conduct the water to them so as not to disturb the sand on their surfaces. This can readily be done in a number of ways. If the shape of the filter is not oblong, it will be advisable to form a number of main drains or passages in the sand from which smaller depressions or passages near together may lead the water to all parts of the surface. The flowing of the first water through these depressions will permit the entire surface to be covered so gradually as not to disturb the sand grains, and it is essential that such means or their equivalent be employed. If the filter is long and narrow in shape, the main ditch along one of the longer sides, with depressions at right angles to it or across the filter and near together, will be sufficient to accomplish the desired purpose. Obviously when filters are not intermittently used such precautions are not needed.

=231. Effect of Low Temperature.=—In the early days of the use of sand filters in this country it was frequently supposed that the low temperature of the winter caused decreased bacterial purification and a decrease in power to reduce organic material. It now appears that such is not the case. The effects of low temperature, such as is experienced in winters of this climate, may be overcome by temporarily covering the filters so that heavy ice cannot form and produce disturbances in one way or another prejudicial to efficiency of operation. The agencies which operate to reduce efficiency in cold weather are no longer believed to be those due to low temperature. They are rather indirect and mechanical, and may be readily overcome by the prevention of the formation of ice.

=232. Choice of Intermittent or Continuous Filtration.=—The process of slow sand filtration when continuous has been shown by experience to be entirely effective for ordinary potable waters, but in those cases where the amount of dissolved oxygen may be low and where the amount of organic matter is relatively high it may be advisable to resort to intermittent filtration. Neither method, however, can be depended upon to render potable a water which has been robbed of its free oxygen by an excessive amount of contaminated organic matter. Nor can these processes be expected to remove coloring matter produced by peaty soils or other conditions in which large amounts of vegetable matter have been absorbed by the water. The methods, therefore, have their limitations, although their field of application is sufficiently wide to cover nearly all classes of potable water.

=233. Size and Arrangement of Slow Sand Filters.=—Among the first questions to arise in the design of slow sand filters are their size and arrangement. The total area will be determined by the total daily draft and the rate of filtration. Rates of filtration running from 2.5 to 3 million gallons per acre per day, or even more, have been found satisfactory and are customary in this country. Having given, therefore, the total daily quantity required, it is only necessary to divide that by the rate of filtration per acre and the result will be the number of acres required for the total filter-bed surface. This net area, however, is not sufficient. Unless there is requisite storage of filtered water to meet the variation in the hourly draft for the day, the capacity of the filters must be sufficient to meet the greatest hourly rate, which must be taken at least 1½ times the average hourly demand during the day; indeed this is only prudent in any case.

Again, it is necessary to divide the total filter surface into small portions called beds, so that one or more of them may be withdrawn from use for cleaning or repairs, while a sufficient filter-area remains in operation to supply the greatest hourly draft. This surplus area will usually run from 5 to 20 per cent of the total area of the filter-beds, although for small towns and cities it may be much more. The sizes of the filter-beds will depend upon the local circumstances of each case. It is evident that as each single bed must have its individual set of appliances and its separating walls, the purpose of economy will be best served by making the beds as large as practicable. At the same time they must not be made too large, for in that case the portion out of use might form so large a percentage of the total area as to increase unduly the cost of the entire plant. A size of bed varying between .5 and 1.5 acres is frequently and perhaps generally found in foreign filtering-plants. If filter-beds range in area from .5 acre to 2 acres, the latter for large plants, the purposes of economy and convenience in administration will probably be well served. The grouping of the beds is an important consideration and will depend somewhat, at least, upon the shape of the plot of ground taken for the filters. It is advisable that the inlets to the different beds should, as far as possible, discharge from a single inlet-pipe or main. This will generally be most conveniently accomplished by making the beds rectangular in shape, grouped on each side of the supply-main, with their longest dimensions at right angles to it. This arrangement is illustrated by the grouping of the filter-beds in the Albany plant, shown in Fig. 7. In the case of a single oblong bed, like that at Lawrence, Mass., shown in Fig. 4, page 284, its relatively great length and small width makes it possible to run the main supply along one side, from which branch depressions with concrete bottoms enable the water to be distributed uniformly over its surface in the manner shown in the figure. It is further necessary to group the filter-beds, pumps, sand-cleaning appliances, and other portions of the plant, so that the ends of economy and efficient administration may be served in the highest degree. It is always necessary that these features of the whole filtration system should be carefully kept in view in laying out the entire plant.

=234. Design of Filter-beds.=—The preparation of the site for a group of filtration-beds also involves the consideration of a number of principal questions. In the first place, the depth required for the sand and underdrains will not be far from 5 feet, and there must be a suitable bottom prepared below the collecting-drains. Again, the depth of water above the sand may vary from 3 to 5 feet, making the total depth, including the bottom, of the filter proper about 10 or 11 feet, and this may represent the depth of excavation to be made. If the material on which the filter to be built is soft, it may be necessary to drive piles to support the superincumbent weight. The bottom must be made water-tight. This can be done either by the use of a layer of well rammed or packed clay, 1 to 2 feet in thickness, carrying 6 or 8 inches of concrete, or by a surface of paved brick or stone. If the sides of the filter-beds are of embankments with surface slopes, the latter may be protected in the same manner. If the sides are of walls of masonry, concrete is an excellent material to be used for the purpose.

[Illustration: FIG. 7.—Sedimentation-basin and Filter-beds at Albany, N. Y.]

[Illustration: Filtration-plant at Albany, N. Y.]

In designing the sides of filters or of the piers projecting up through the sand for the support of the roof, in case there is one, it is imperative that care be taken to prevent water from flowing down through the joints between the sand and the sides of piers or the masonry sides of the filter-beds. There should be no vertical joint of that character, but the faces of masonry in contact with the sand should both slope and be made in steps, so that any settlement of the sand will tend to close the joint, while the steps will prevent flow. Nor should there be angles in which sand is to be packed; filleted corners are far preferable and should be used.

=235. Covered Filters.=—It has become the custom where the best results are expected in cold climates, if not in all cases, to cover filters with masonry roofs of domes and cylindrical or groined arches supported on masonry columns. Such roofs are usually covered with earth to a depth of 1 to 2 or 3 feet. They prevent any injurious action on the sides of the filters produced by thick ice or the effects of such ice upon the upper portions of the sand. In summer they also protect against the baking and cracking of the upper surface of the sand when exposed to the sun and prevent, to a considerable extent, the growth of algæ in different portions of the beds. They are expensive, filters with masonry covers costing once and a half to twice as much as open filters, but they enhance the sanitary value of the water. The height of the masonry roof must be about 2 to 3 feet above the upper surface of the water and high enough to offer convenient access to the sand when it is to be cleaned and renewed. The length of span for the arches or domes is seldom more than 12 or 15 feet.

=236. Clear-water Drain-pipes of Filters.=—After the water has passed through the sand it must be withdrawn from the bottom of the filter with as little resistance as practicable. This necessitates, in the first place, the bottom of the filter to be so shaped as to induce the flow of the filtered water toward the lines of drain-pipes which are laid to receive it. These pipes consist of the main members and the branches, the main members being laid along the centres of the beds and the branches running from them. The

bottoms of the filters, therefore, should be formed with depressions in which the main pipes are laid, and with such grades as to expedite the movement of the water flowing through the branches. If the bottoms are of concrete, they can advantageously be made of inverted arches or domes, the drain-pipes being laid along the lines of greatest depression. In such cases the loads produced by the weight of the roof are more nearly uniformly distributed over the bottom. The sizes of the drains will be dependent upon the areas from which they withdraw water. It is advisable to make them rather large, in order that the water may flow through them more freely. They seldom need exceed 6 or 8 inches. They are preferably made of salt-glazed vitrified pipes laid with open joints, around and in the vicinity of which are placed gravel or broken stone, the largest pieces with a maximum diameter of 1 to 2 inches. The largest broken stone or coarsest gravel is near the pipe and should decrease in size as the drain-pipe is receded from, so that the final portions of the gravel farthest removed from the drains will not permit the filter-sand to pass into it. When properly designed and arranged, the loss of head in passing from the farthest points of a filter-bed to the point of exit from the filter will not exceed about .01 to .02 of a foot.

[Illustration: Interior of Covered Filter at Ashland, Wis.]

=237. Arrangement of the Sand at Lawrence and Albany.=—Above this gravel is placed the filtering-sand, about 4 feet thick in the Albany filter and 3 to 4 feet thick in the filter at Lawrence, Mass. The sand in the Albany filter was specified to have not "more than 10 per cent less than .27 mm." in diameter and "at least 10 per cent by weight shall be less than .36 mm." in diameter. Over the entire floor was spread not more than 12 inches of gravel or broken stone, the lower 7 inches consisting of broken stone or gravel with greatest diameter varying from 1 inch to 2 inches; the remaining 5 inches of the lower 1 foot was composed of broken stone or gravel decreasing from 1 inch in greatest diameter to a grain a little coarser than that of the sand above it. In all cases, sand for the filter-bed should be free from everything that can be classed as dirt, including clay, loam, and vegetable matter. Furthermore, it should be free from any mineral matter which might change the character of the water and render it less fit for use.

[Illustration: Partially Filled Covered Sand Filter showing Drain-pipe.]

This filtering-sand is usually placed in position with a horizontal surface. At Lawrence, however, it was placed with a wavy surface, the horizontal distance between the crests of two consecutive waves being 30 feet, the concrete gutter for admitting the water being half-way between, all as shown in the illustrations. The sand of this filter was of two grades, the coarser sand having an effective size of 0.3 mm. (.118 inch) and the finer an effective size of 0.25 mm. (.098 inch). The two different sizes of sand are seen not to be arranged in horizontal layers, but so that the finer is over the drains and the coarser between. The No. 70 sand is capable of passing 70 million gallons per acre per day with a head on it equal to the depth of sand, while the No. 50 sand can pass 50 million gallons per acre per day with a head on it equal to its depth. There appears to be no special advantage in placing the sand in filters other than in horizontal layers with an effective size practically uniform.

=238. Velocity of Flow through Sand.=—The velocity with which water will flow through a given depth of sand with a known depth or head above the surface of the latter has been carefully investigated by the Massachusetts State Board of Health with the following results:

_v_ = the velocity at which a solid column of water, whose section equals in area that of the bed of sand, moves downward through the sand in meters per day; this is practically the number of million gallons passing through the sand per acre per day. _c_ = a constant, having the value of 1000 for clean sand, and 800 for filter-sand after having been some time in use. _d_ = the effective size of the sand-grain in millimeters. _h_ = the head lost by the water in passing through the sand at the rate v; this is the effective head of water producing motion through the sand. _l_ = the thickness of the sand bed. _t_ = the temperature of the water in degrees Fahr.

The velocity _v_, as determined by experiment, takes the following form:

$$v = \frac{cd^2}{10+t} \cdot \frac{h}{l} \cdot 60$$

This formula cannot be used for the flow of water through all sands of all thicknesses and under all circumstances. It is limited to effective diameters of sand between .1 and 3 mm., having a uniformity coefficient not greater than 5. _h_ and _l_ may be taken in any unit as long as both are expressed in the same unit, since the ratio of the two quantities will then not be affected. If the effective head of water on the filter or the head lost is equal to the thickness of the bed of sand, the ratio of _h_ divided by _l_ will be 1. In case the formula is used to express the quantity of water flowing through the sand per acre per day, it must be remembered that _v_ will be the number of million gallons and not the total number of gallons. The formula can only be used when the sand is well

compacted and where the voids of the sand are entirely filled with water.

=239. Frequency of Scraping and Amount Filtered between Scrapings.=—The frequency of the scraping of filters will depend upon the amount of organic matter in the water and upon the rate of filtration. Between the years 1893 and 1900 the periods between scrapings of the Lawrence filter ranged generally from 20 to 32 days, although periods as small as 13 or 19 are found in the records. The quantity of water passed between scrapings varies generally from 67 million to 90 million gallons, although it fell as low as 49 millions and rose as high as 109 millions. In the case of the Albany filter-plant, up to the end of the year 1900 the shortest period between scrapings was about 15 days and the longest about 42 days, the smallest quantity of water passing through any filter between scrapings being 26,735,000 gallons and the largest 76,982,000 gallons. The operation of the Albany filters for the year 1901 shows that the average run of a bed was 26 days between scrapings, with a total of 70,000,000 gallons per acre for that period. These figures represent about the usual workings of slow sand filters at the present time, the period between scrapings running usually between 15 and 30 days, and the quantity from 30 million gallons per acre to 100 million gallons per acre.

[Illustration]

[Illustration: Filters for City of Albany, N. Y.]

=240. Cleaning the Clogged Sand.=—The clogged sand scraped from the top of the filters at the periods of cleaning is removed to a convenient point where appliances and machinery are available for washing it. This is an item of some importance in the administration of filters, as the sand which is removed and washed is at a later period replaced upon the filter-bed. Various methods have been tried for the purpose of cleaning sand efficiently and economically. The continuous ejector sand-washer, one set of which is used at Albany, is probably as efficient as any machine yet devised. It is shown in Fig. 8. It will be observed that the dirty sand is fed to the machine at one end into a hopper-shaped receptacle. In the bottom of this hopper is a nozzle through which water is discharged from a pipe running along the entire bottom of the machine. This jet of water forces the sand upward through a suitable pipe into a reservoir which discharges the sand and water into another hopper, and so on through the series of five. Evidently there may be any number of hoppers in the series, a jet of water being provided at the bottom of each. In this manner the sand and water are thoroughly mixed together and compelled to flow upward from each hopper to the next, the dirty water overflowing also from each hopper into a tank underneath, whence it runs to waste. The clean sand and water flow out of the machine at the end opposite to that at which they entered. After the washed sand is dried it is ready to be replaced in the filter.

=241. Controlling or Regulating Apparatus.=—It is essential to the proper working of a slow sand filter that the amount of water admitted to and passing through it shall be as nearly uniform as practicable. This necessitates controlling or regulating apparatus, of which there are two general classes, the one automatic and the other worked by hand. There are a considerable number of appliances of both classes. The filtered water flows from the end of the drains to one or two small tanks formed by suitable masonry walls immediately outside of the filter-beds and rises to a level determined by the loss of head in passing through the filter. The difference in elevation between the water surface over the sand and that in the filtered water-tanks shows the effective head which causes the water to flow through the sand. The object of the controlling or regulating appliances is to keep that head as nearly constant as possible. Both the hand and automatic appliances preserve the value of that head by maintaining constant discharges through either vertical or horizontal orifices, the orifices themselves being movable. They may be rectangular or other orifices with horizontal lips or crests. If the control is automatic it is accomplished usually by a float which raises and lowers the orifice in such a way as to maintain a constant difference of level between the filtered and the unfiltered water. The figures illustrate both types of regulating appliances, the actions of which will be readily understood.

[Illustration: FIG. 8.—Ejector Sand-washer.]

[Illustration: FIG. 9.—Ball-float Regulator of Rate of Filtration.]

[Illustration: FIG. 10.—Regulator in Use in Zurich, Switzerland. M. Peter, Engineer.]

=242. Cost of Slow Sand Filters.=—The cost of both the open and covered slow sand filters will obviously vary according to the cost of labor and materials at their sites. The original cost of the Lawrence filter, about 2.44 acres in total area, was nearly $25,000 per acre. The cost of covered filters, so far as constructed in this country, varies from about $44,000 to nearly $51,000 per acre excluding the pipe, pumping plants, and sedimentation-basins. The Albany covered filters cost about $38,000 per acre including filtering materials, but excluding excavation, pumps, buildings, sedimentation-basins, piping, and sand-washing machinery, or nearly $46,000 per acre including those items except pumps and sedimentation-basins. The roof, included in the preceding

estimate, cost about $14,000 per acre. The smaller the filters the greater the cost per acre, as a rule, as would be expected. A single open filter at Poughkeepsie and three open filter-beds at Berwyn, Pa., cost respectively $42,000 and $36,000 per acre, the former being little less than .7 acre in area and the latter having an aggregate area of a little more than one half acre. A covered filter at Ashland, Wis., consisting of three beds of one sixth acre each, cost at the rate of about $70,000 per acre.

[Illustration: FIG. 11.—Regulating Apparatus Designed by Allen Hazen for the Albany Filters.]

[Illustration: FIG. 12.—Regulator of Rate of Filtration.]

=243. Cost of Operation of Albany Filter.=—The cost of operating the Albany filter, including only the costs of scraping, removing sand, refilling, incidentals, lost time, and washing the sand during seventeen months ending December 29, 1900, was $1.66 per million gallons filtered. The cost of removing the sand (excluding scraping), washing, and refilling was $1.21 per cubic yard. The total cost of operating the entire filter-plant, including all items, for the year 1900 was $4.52 per million gallons filtered. This covers all expenses, including pumping, superintendence, and laboratory, which can be charged to the operation of the filter-plant. The average removal of albuminoid ammonia at Albany for the year 1900 was 49 per cent and of the free ammonia 78 per cent of that in the raw water, while the average bacterial removal was over 99 per cent, running from 98.3 per cent to 99.6 per cent. The volume of water used in washing the sand was about twelve and a half times the volume of the sand. Each cubic yard of sand washed, therefore, required twelve and a half cubic yards of water.

[Illustration: FIG. 13.—Regulator Designed by W. H. Lindley for the Filters at Warsaw, Poland.]

=244. Operation and Cost of Operation of Lawrence Filter.=—It was originally intended that the Lawrence filter should be worked intermittently. The Merrimac River water, which is used by the city of Lawrence, was known to carry at certain periods of the year sufficient typhoid germs received from the city of Lowell to produce at least mild epidemics. The intermittent operation was considered necessary to furnish the filter with the requisite oxygen to destroy beyond a doubt all pathogenic bacteria. The increasing demands of water consumption during the years that have elapsed since filtration began in 1894 have seriously modified these conditions, so that the intermittent feature of operation of the filter is no longer very prominent. During 1898, for instance, the filter was drained only four to thirteen times per month, with an average of eight monthly drainings. In 1899 the drainings were more frequent, varying from five to fourteen per month and averaging eleven times. Finally, in 1900, the monthly drainings ranged from three to thirteen, with an average of eight. It may be considered, therefore, that the Lawrence filter occupies a kind of intermediate position between intermittent and continuous operation.

The total cost of operating the filter at Lawrence, including scraping and washing of sand, refilling, removal of snow and ice, and general items in the period from 1895 to 1900, both inclusive, varied from a minimum of $7.70 per million gallons to $9.00 per million gallons. If the removal of snow and ice be omitted, these amounts will be reduced to $5.10 and $6.90 respectively. The cost of washing the sand only in the Lawrence filter during the same period varied from 45 to 67 cents per cubic yard. The volume of water required for that washing varied from ten to fourteen times the volume of sand.

=245. Sanitary Results of Operation of Lawrence and Albany Filters.=—The average number of bacteria in the Merrimac River water applied to the filter during the period 1894 to 1899, both inclusive, varied from about 1900 per cubic centimeter to 34,900, and the percentage of reduction attained by passing the water through the filter varied in the same period generally from 97 to 99.8 per cent, with an average of about 99.1 per cent.

In the city of Lawrence the average number of cases of typhoid fever per 10,000 of population has been about one third, since the introduction of filtered water, of the number of cases which existed prior to the installation of the filters, and less than one fourth as many deaths. A large number of the cases of typhoid occurring after the installation of the filter have been traced to the use of unfiltered water, and it is probable that all or nearly all could be similarly accounted for.

In the city of Albany the experience had been quite similar. The average number of deaths per year from typhoid fever for ten years before the introduction of filtered water was 84, while in 1900, with the filter in operation, the total number of deaths was 39. These figures are sufficient to show the marked beneficial effect of filtered water on the public health.

[Illustration: Jewell Filter.]

=246. Rapid Filtration with Coagulants.=—It has been seen that the rate of filtration through open sand filters does not usually exceed 2 to 4 million gallons per acre per day under ordinary circumstances. Much greater rates would clog the sand and produce

less efficient results. Experience has also shown that such methods cannot be depended upon to remove from water coloring matter of a vegetable origin or very finely divided sediment. In order to accomplish these ends it is necessary to employ suitable chemicals which, acting as coagulants, may accomplish results impracticable in the open filter. Resort has therefore been made first to the adoption of suitable coagulants and then to such increased heads or pressures as to force the water through the sand at rates from 25 to 30 or even 50 times as great as practicable in slow sand filtration. These rapid sand filters are called mechanical filters. If the water is forced through them under pressure, they consist of closed tanks in which sand is placed so as to leave sufficient volume above it for the influent water and, supported upon a platform carrying perforated pipes, strainers, or equivalent details through which the filtered water may flow into a suitable system of effluent pipes in the lower part of the filter. If water is forced through the sand by the required head, the upper part of the filter may be open, but of sufficient height to accommodate it. The same filtering material, clean sand, is used as in the slow filters; the only differences, aside from the higher rate of filtration, are the greater head and the introduction of a coagulant to the water. The depth of sand used may vary from 2 to 4 feet. The thickness of a relatively fine sand may be less than that of a coarser sand.

=247. Operation of Coagulants.=—The coagulant which has been found to give the best results is ordinary alum or sulphate of aluminum. If sulphate of aluminum is dissolved in water containing a little lime or magnesia, aluminum hydrate and sulphuric acid are formed. The aluminum hydrate is a sticky gelatinous substance which gathers together in a flocculent mass the particles of suspended matter in the water, and it also adheres to the grains of sand when those masses have settled to the bottom. This flocculent, gelatinous mass covers the sand and passes into its voids. As the water is forced through it the bacteria and suspended matter are held, leaving a clear effluent to pass through. Other coagulants are used, such as the hydrate of iron, but it costs more than alum and is not so effective in removing color, although it is an excellent coagulant for removing turbidity. Physicians have made objection to the use of alum for this purpose, on the ground that any excess might pass into distribution-pipes and so be consumed by the water-users to the detriment of health. While it is possible that further experience may show that there is material ground for this objection, it has thus far not been found to be so. It is, however, essential that only the necessary amount of alum should be used and that there may be a sufficient amount of alkali to combine with the sulphuric acid. Otherwise the acidulated water may attack the iron and lead pipes and so injure the water and produce serious trouble. It can only be stated that the method and operation of these mechanical filters have thus far been sufficiently successful to avoid any of these difficulties.

[Illustration: The Jewell Filter-plant at Norristown, Penn.]

=248. Principal Parts of Mechanical Filter-plant—Coagulation and Subsidence.=—The principal parts of a complete mechanical filter-plant in the order of their succession are a solution-tank, a measuring-tank, a sedimentation-basin, and a filter. In case of great turbidity the sedimentation may be completed in two stages, the first in a settling-basin prior to receiving the coagulant, and the second in another basin subsequent to the coagulation. The tanks are usually of wood, although they may be of steel. The solution-tank is a comparatively small vessel in which the alum is dissolved. The solution is then run into the measuring-tank, from which it flows into the water at a constant rate maintained by suitable regulating apparatus. It is imperative for the successful working of the mechanical filter-plant that the coagulant be introduced to the water at a uniform rate. This rate will obviously depend upon the character of the water. The coagulating solution runs from the measuring-tank into the pipe through which the water to be filtered flows and in which it first receives the alum. The water and the coagulating solution are thus thoroughly mixed and flow into the sedimentation-basin. The subsidence which is provided for in this basin may be omitted in very clear waters which carry little solid matter, but the operation of the filter itself will be more satisfactorily accomplished if as much work as feasible is done before reaching it. The mixture must remain in this basin a sufficient length of time to allow such subsidence as can reasonably be attained.

It appears from experience in this part of the work that it is not well to introduce the coagulant too long before the water enters the filter, especially if the water be fairly clear. In the case of the presence of finely divided solid matter, however, sufficient time must be permitted for the necessary settlement. A period ranging in length from ½ hour to 6 or 8 hours may be advantageously assigned to this part of the operation, the shorter period for clear waters and the longer for very turbid waters. It has been suggested that two applications of the coagulant might be beneficial, the principal portion being given to the water before entering the sedimentation-basin and the other just before the waters enters the filter. The work of the filter, especially with turbid waters, may be much reduced by simple subsidence for a period of perhaps 24 hours before receiving the coagulant, the secondary subsidence taking place in the settling-basin in the manner already described. Duplicate solution- and measuring-tanks will be required in order that the process may be continuous while one set is out of use. In this process it is absolutely essential also that the coagulant should be of the best quality, inferior grades having been found to be unsatisfactory in their operation.

=249. Amount of Coagulant—Advantageous Effect of Alum on Organic Matter.=—The amount of sulphate of alumina will vary largely with the quality of water. In the investigation made by Mr. Fuller in connection with the Ohio River supply for the city of Cincinnati, he found that with very slight turbidity only ¾ grain was required per gallon of water, but that a high degree of turbidity required as much as 4.4 grains per gallon, with intermediate amounts for intermediate degrees of turbidity. It was estimated that these quantities would correspond to an average annual amount of about 1.6 grains per gallon. In case there should be a period of three days of subsidence preliminary to filtration, he estimated that for the greater part of the time the amount of alum would vary from 1 to 3 grains per gallon. Occasionally more and sometimes less would be required.

Alum has some specially valuable qualities in connection with this class of purification work. It combines with coloring matter, particularly that which has been acquired from contact of the water with vegetation, and precipitates it. It seems to combine also, to some extent, with the organic matter carried by the water and thus enhances the efficiency of filtration.

=250. High Heads and Rates for Rapid Filtration.=—The principal work of investigation of filtration in mechanical or pressure filters has been made for the cities of Pittsburg, Cincinnati, Louisville, and Providence, R. I. In the experimental work of those investigations rates of filtration ranging from 46 million to 170 million gallons per acre per day have been employed with essentially the same efficiency. This is a practical result of great importance, particularly if in the continued use of these filters on a large scale a satisfactorily high efficiency can be reached and maintained. It was observed that the number of bacteria in the effluent varied with that in the raw water. It was also noticed that similarly to the operation of slow sand filters the rate of filtration should not be changed suddenly, as that is likely to cause breaks in the sand and militate against continued efficiency.

In his experimental work at Cincinnati Mr. Fuller found that with fine sand an available head on the filter of 12 feet gave economical results. He also states that "high rates are more economical than low ones, and that the full head which can be economically used should be provided. Just where the economical limit of the rate of filtration is can only be determined from practical experience with a wider range of conditions than exist here, but there seem to be no indications that the capacity of a plant originally constructed on a medium rate basis (100 million to 125 million gallons per acre daily) could not readily and economically be increased, as the consumption demanded, to rates at least as high as the highest tried here (170 million gallons per acre daily), provided the full economical increase in loss of head could be obtained."

=251. Types and General Arrangement of Mechanical Filters.=—These mechanical or pressure (by gravity) filters have until lately been constructed by companies owning patents either on the process or on the different parts of the filters. The fundamental patent, however, protecting rapid sand filters with the continuous application of a coagulant has expired and the city of Louisville, Ky., is now constructing rapid sand filters different in design from those heretofore used. The types that have been most common heretofore are the Jewell subsidence gravity filter, the Continental gravity filter, the New York sectional-wash gravity filter, and others. They all possess the main feature of accelerating the rate of filtration by pressure, either in a closed tank (rarely) with comparatively small water volume above the sand or by an open filter with sufficient head of water above the sand to accomplish the high rate desired. This latter method is that now generally used, as by it the requisite steadiness of head or pressure can be secured. The closed type is subject to objectionable sudden changes of pressure which prevent or break uniform rates of filtration. The sand is supported upon a platform with a suitable system of pipes fitted with valves or gates for the withdrawal of the filtered water, the space below the platform forming a small sedimentation-chamber. They are usually constructed in comparatively small circular units, so that one or more of a group may be withdrawn from operation for the purposes of cleaning or repairs without interfering with the operation of the others. This system of small units, gives some marked practical advantages, as housing is readily accomplished, and if necessary the plant may be easily removed from one point to another.

[Illustration: Continental Filter.]

It is obvious that with the large amount of water forced through a given area of filter-bed the sand will become clogged within a comparatively short time, requiring washing and replacing. Mr. Fuller found at Cincinnati that the periods between washings when fine sand was used in the filters ranged from 8 to 24 hours, with an average of 15, but with coarse sand the average became 20, with a range of from 6 to 36 hours. The time required for washing the sand at Cincinnati was 20 minutes for coarse or 30 minutes for fine. At Providence Mr. Weston found that the average time of washing was about 11 minutes. The cleaning is accomplished partially by stirring the sand with revolving arms, as shown in the accompanying figures, but generally by forcing the water in a reverse direction through the sand and allowing the wash-water either to run to waste or to be again purified. The filters are designed for the purpose of cleaning by the reversal of the direction of the flow of water. Latterly the sand has been cleaned by forcing compressed air at a low pressure through it and the superimposed water. The passage of the air or water upward through

the sand produces such a commotion among the grains that they rub against each other and clean themselves of the adhering material, allowing it to be carried off by the water above the sand. Both methods are much used and are satisfactorily effective for the purpose.

It was found at Cincinnati that 4 to 9 per cent, with an average of 5 per cent, of filtered water was required for washing the fine sand, and only 2 to 6 per cent, with an average of 3 per cent, for the coarse sand of the mechanical filters used in Mr. Fuller's experiments. Mr. Weston has found about the same figures in his experimental work at Providence. The wash-water need not be wasted at all if it is pumped back into the subsidence-tanks.

It has been found in some cases that the efficiency of the filters after washing is not quite normal, and that possibly 2 or 3 per cent of the water must be wasted unless it is allowed to run back into the subsidence-tanks and again pass through the filter. Under such circumstances it has required 20 to 30 minutes of operation of the filter after washing to regain its normal efficiency.

=252. Cost of Mechanical Filters.=—The cost of these mechanical filters has been found to range as high as a rate of $500,000 per acre, which is probably about ten times as much as the rate of cost for the slow sand filters. On the other hand, the efficiency of the mechanical filters may be as high as the other class, with a rate of filtration from thirty to fifty times as great, and with a cost of operation less than that of the slow sand filters. The cost of the filters per million gallons of filtered water may, therefore, be reduced to perhaps one fourth of that of the slow sand type.

=253. Relative Features of Slow and Rapid Filtration.=—It is premature, even unnecessary, to make a comparison between the slow and rapid sand filters. The former are well adapted to a large class of potable waters in which there is not too much or too finely divided solid matter and in which the coloring from organic origin is not serious. They have the advantage of requiring no chemicals and are capable of attaining a high degree of efficiency. The average rate of filtration may be taken about 3,000,000 gallons per acre per day. The rapid sand filter, on the contrary, requires the application of a coagulant, but has thirty to fifty times the capacity of the other class. It is better adapted to the removal of turbidity and color, and when properly operated it gives a high efficiency. A sufficiently extended experience has not yet, however, been attained to enable a complete statement to be made as to the entire field to which they may be adapted. They have certainly been shown to possess valuable qualities in a number of respects, and they are undoubtedly destined to play an important part in the purification of waters.

PART IV.

SOME FEATURES OF RAILROAD ENGINEERING.

CHAPTER XXI.

=254. Introductory.=—The first step toward the construction of a railroad is the location of the line, which requires as an initiative a careful ocular examination of the general vicinity of the proposed road, supplemented by simple and approximate instrumental work rapidly performed. Following this reconnaissance, as it is called, more complete surveys and examinations are made both in the field and on the maps plotted from the data of the field-work. The prosecution of this series of operations produces the final location, together with the accumulation of such maps, profiles, and other data as may be required in the construction of the road-bed, bridges, and other structures constituting the complete railroad line with its ballast and track in place ready for traffic.

The ultimate purpose of any railroad line is the transportation of passengers and freight under conditions, including those of a physical nature connected with the road as well as the rates received, leading to profitable returns. Competition or other circumstances attending the traffic of a given road will fix the maximum rates to be charged for transportation. It is the business, first, of the civil engineer so to locate and design the road and, second, of the manager so to conduct the transportation as to make the margin of profits the greatest possible. It will be the purpose of this lecture to consider in a general way only some of the features of a railroad and its operation which are related directly to civil-engineering.

[Illustration: The Royal Gorge.]

=255. Train Resistances.=—It is a fact confirmed by constant daily experience that, however nicely the machine impelling the railroad train or the tracks supporting the cars may be built, considerable frictional and other resistance is offered to the movement of the train when the latter passes over a perfectly level and straight track.

A considerable portion of the cost of transportation is expended in overcoming this resistance. When the line fails to be either level or straight other resistances of magnitude are developed; they are called the resistances of grades and curves: and it is the business of the civil engineer so to design the railroad as to reduce these two classes of resistance to an absolute minimum, in view of certain other conditions which must be concurrently maintained.

=256. Grades.=—The grade of a railroad is expressed usually in this country by the number of feet through which 100 feet of length of line rises or falls, or by some expression equivalent to that. If, for instance, the line rises 1.5 or 2 feet in 100, it is said to have an ascending grade of 1.5 or 2 per cent. Or if the line falls the same amount in the same length, it is said to have a descending grade of 1.5 or 2 per cent. It is evident that a grade which descends in one direction would be an ascending grade for trains moving in the opposite direction, so that grades favoring traffic in one direction oppose it in the other. Hence, other things being equal, that road is the most advantageous for the movement of trains which has the least grade. The grades of railroads seldom exceed 2 or 2.5 per cent, although, as will presently be shown, there are some striking exceptions to that general observation. The actual angles of inclination of railroad tracks from a horizontal line are therefore as angles very small, but their disadvantages for traffic increase rapidly.

A simple principle in mechanics shows that if the railroad train with a weight _W_ moves up a 2 per cent grade, one component of the train weight acts directly against the tractive force of the locomotive or other motive power. If _a_ is the angle of inclination of the track to a horizontal line, this opposing component will have the value _W_ sin _a_. When angles are small their sines are essentially equal to their tangents. Hence, in this case, sin _a_ would have the value .02 or 1/■■ of the train weight. If the weight of the train were 500 tons, which is a rather light train for the present time, this opposing force would be 10 tons, or 20,000 pounds, which, as we shall see later on, is more than one half of the total tractive force of any but the heaviest locomotives built at the present day. This simple instance shows the advantage of keeping railroad grades down to the lowest practicable values.

One of the most economical freight-carrying roads in the United States is the Lake Shore and Michigan Southern of the New York Central system, running from Buffalo to Chicago. Its maximum grade is 0.4 of 1 per cent. The maximum grade of the N. Y. C. & H. R. R. R. is 0.75 of 1 per cent between New York City and Albany and between Albany and Buffalo, 1.74 per cent at Albany, 1.12 per cent at Schenectady, and 1 per cent at Batavia. Pushers or assistant locomotives are used for heavy trains at the three latter points. The maximum grade of the Pennsylvania R. R. on the famous Horseshoe Curve between Altoona and Cresson is 1.8 per cent. It is advantageous, whereever practicable, to concentrate heavy grades within a short distance, as in the case of the New York Central at Albany, and use auxiliary engines, called pushers or assistants. Some of the heaviest grades used in this country are found on the trans-continental lines where they pass the summits of the Rocky Mountains or the Sierras. In one portion of its line over a stretch of 25.4 miles the Southern Pacific R. R. rises 2674 feet with a maximum grade of 2.2 per cent; also approaching the Tehacipi Pass in California the maximum grade is about 2.4 per cent. At the Marshall Pass on the Denver & Rio Grande R. R. there is a rise of 3675 feet in 25 miles with a maximum grade of 4 per cent. The Central Pacific R. R. (now a part of the Southern Pacific system) rises 992 feet in 13 miles with a maximum grade of 2 per cent. The Northern Pacific R. R. rises at one place 1668 feet in an air-line distance of 13 miles with a maximum grade of 2.2 per cent. Probably the heaviest grade in the world on an ordinary steam railroad is that of the Calumet Mine branch of the Denver & Rio Grande R. R., which makes an elevation of 2700 feet in 7 miles on an 8 per cent grade and with 25° curves as maximum curvature. These instances are sufficient to illustrate maximum railroad grades found in the United States.

=257. Curves.=—Civil engineers in different parts of the world have rather peculiar classifications of curves. In this country the railroad curve is indicated by the number of degrees in it which subtend a chord 100 feet in length. Evidently the smaller the radius or the sharper the curvature the greater will be the number of degrees between the radii drawn from the centre of a circle to the extremities of a 100-feet chord. American civil engineers use this system for the reason that the usual tape or chain used in railroad surveying is 100 feet long. A very simple and elementary trigonometric analysis shows that under this system the radius of any curve will be equal to 50 divided by the sine of one half of the angle between the two radii drawn to the extremities of the 100-feet chord. In other words, it is equal to 50 divided by the sine of one half the degree of curvature. The application of this simple formula will give the following tabular values of the radii for the curves indicated:

Curve. Radius in Feet.

1° 5729.65 2° 2864.93 3° 1910.08 4° 1432.69 5° 1146.28 6° 955.36 7° 819.02 8° 716.78 9° 637.27 10° 573.69 12° 478.74 15° 383.06 20° 287.91

=258. Resistance of Curves and Compensation in Grades.=—Inasmuch as the resistance offered to hauling the train around a curve increases quite rapidly as the radius of curvature decreases, it is obvious that in constructing a railroad the degree of each curve should be kept as low as practicable, and that there should be no more curves than necessary. While no definite rule can be given as to such matters, curves as sharp as 10° (573.69 feet radius) should be avoided wherever practicable. It is not advisable to run trains at the highest attainable speeds around such curves, nor is it done. Inasmuch as curve resistance has considerable magnitude, as well as the resistance of grades, it is natural that wherever curves occur grades should be less than would be permissible on straight lines or, as they are called, tangents. If a maximum gradient is prescribed in the construction of a railroad, that gradient will determine the maximum weight of train which can be hauled on the straight portions or tangents of the road. If one of these grades should occur on a curve, a less weight of train could be handled by the same engine than on a tangent. Hence it is customary to reduce grades by a small amount for each degree of curvature of a curve. This operation of modifying the grades on curves so as to enable a locomotive to haul the same train around them as up the maximum grade on a tangent is called compensating the curves for grade. There is no regular rule prescribed for this purpose, because the combination may necessarily vary between rather wide limits in view of speed, condition of track, and other influencing elements. The compensation, however, has perhaps frequently been taken as lying between .03 and .05 per cent of grade for each degree of curvature. In other words, for a 5° curve the grade would be .15 to .25 per cent less than on a tangent. This compensation for grades is carefully considered in each case by civil engineers in view of experience and such data as special investigations and general railroad operation have shown to be expedient.

[Illustration: FIG. 1. GRAVEL BALLAST]

[Illustration: FIG. 2. STONE BALLAST

NEW YORK CENTRAL & HUDSON RIVER RY.]

[Illustration: FIG. 3. PENNSYLVANIA RY.]

=259. Transition Curves.=—High speeds for which modern railroads are constructed have made it necessary not only to protect road-beds, but also to make the passage from tangents to curves as easy and smooth as possible. This is accomplished by introducing between the curve and the tangent at each end what is called a "transition" curve. This is a compound curve, i.e., a curve with varying radius. At the point where the tangent or straight line ceases the radius of the transition curve is infinitely great, and it is gradually reduced to the radius of the actual curve at the point where it meets the latter. By means of such gradual change of curvature the trucks of a rapidly moving train do not suddenly pass from the tangent to the curve proper, but they pass gradually from motion in a straight line to the sharpest curvature over the transition curve. The rate of transition is fixed by the character of the curves, which have been subjected to careful analysis by civil engineers, and they can be found fully discussed in standard works on railroad location.

[Illustration: FIG. 4.—Baltimore Belt-line Tunnel, B. & O. Ry.]

=260. Road-bed, including Ties.=—Not only the high rates of speed of modern railroad trains but the great weights of locomotives and cars have demanded a remarkable degree of perfection in the construction of the road-bed and in the manufacture of rails. The favorite ballast at the present time for the best types of road-beds is generally broken stone, although gravel is used. The first requisites are a solid foundation and perfect drainage whether in cuts or fills. Figs. 1, 2, 3, and 4 show two or three types of road-bed used by the New York Central and Hudson River R. R., the Pennsylvania R. R., and a special type adopted by the B. & O. for the belt-line tunnel at Baltimore. These sections show all main dimensions and the provision made for drainage. The general depth of ballast is about 18 inches, including the drainage layer at the bottom. The total width of road-bed for a double-track line varies frequently between 24 and 25 feet, while the width of a single-track line may be found between 13 and 14 feet. In the cross-sections shown the requirements for drainage are found to be admirably met. Timber ties are almost invariably used at the present time in this country, although some experimental steel ties have been laid at various points. Fig. 5 shows the steel tie adopted for experiment on the N. Y. C. & H. R. R. R. within the city limits of New York. The time will undoubtedly come when some substitute for timber must be found, but the additional cost of steel ties at the present time does not indicate their early adoption.

[Illustration: FIG. 5.]

[Illustration: FIG. 6.]

[Illustration: Cañon of the Rio Las Animas, near Rockwood.]

=261. Mountain Locations of Railroad Lines.=—The skill of the civil engineer is sometimes severely taxed in making mountain locations of railroads. Probably no more skilful engineering work of this kind has ever been done than in the crossings of the Rocky Mountains and the Sierras in this country by trans-continental railroad lines, although more striking examples of railroad location for short distances may perhaps be found in Europe or other countries. The main problem in such

cases is the making of distance in order to attain a desired elevation without exceeding maximum grades, such as those which have already been given. Most interesting engineering expedients must sometimes be resorted to. One of the oldest of these is the switchback plan shown in Fig. 6. This is probably the simplest procedure in order to make distance in attaining elevation. The line is run up the side of a mountain at its maximum grade as far in one direction as it may be desirable to go. It then runs back on itself a short distance before being diverted so as to pass up another grade in the reverse direction. This zigzagging of alignment may obviously be made to attain any desired elevation and so overcome the summit of a mountain range. The old switchback coal road near Mauch Chunk, Pa., is one of the oldest and more famous instances of the method, which has many times been employed in other locations.

[Illustration: FIG. 7.]

A more striking method, perhaps, is that of loops by which the direction of a line or motion of a train on it is continuous. Distance is made by a judicious use of the topography of the locality so as to run the line as far up the side of the valley as practicable and then turn as much as a semicircle or more, sometimes over a bridge structure and sometimes in tunnel, so as to give further elevation by running either on the opposite side of the valley or on the same. A succession of loops or other curves suitably located will give the distance desired in order to reach the summit.

=262. The Georgetown Loop.=—Fig. 7 shows one of these spiral or loop locations on the Georgetown branch of the Union Pacific Railroad in Colorado. It is a well-known and prominent instance of railroad location of this kind. On the higher portion of this loop system included in the figure there is a viaduct on a curve which crosses the line 75 feet above the rail below it and 90 feet above the water. This location is a specimen of excellent railroad engineering. The length of line shown in the figure, including the spiral, is 8½ miles, and it cost $265,000 per mile exclusive of the bridges.

=263. Tunnel-loop Location, Rhætian Railways, Switzerland.=—In Figs. 8 and 9 are shown two portions of the Albula branch of the Rhætian Railways, Canton Graubünden, southeastern Switzerland. The line connects the valleys of the Albula and the Inn, the former being one of the branches of the Rhine and the latter of the Danube; it therefore cuts the divide between the watersheds of those two rivers. It is a 3.28-feet gauge single-track road, and is built largely for tourist traffic, as the scenic properties of the line are remarkable.

The maximum grade on this line is 3.5 per cent. Over one portion of the line 7.8 miles long one third of that distance is in tunnel and 15 per cent of it on viaducts. The radii of the centre lines of the tunnels are 460 and 394 feet, while the lengths of the tunnels range from 1591 to 2250 feet, with a maximum grade in them of 3 per cent. The weight of rails used is 50 pounds per yard on grades of 2.5 per cent or less, but for heavier grades 55-pound rails are employed. The cross-ties are of mild steel and weigh 80 pounds each except in the long Albula tunnel, where treated oak ties are used as being better adapted to the special conditions existing there. It will be observed that in each case the line rises from the left-hand portion of the figure toward the right.

[Illustration: FIG. 8.]

[Illustration: FIG. 9.]

The tunnels are represented by broken lines, and they are in every instance on circular curves. Fig. 9 represents the line running from a point on the east side of the Albula River through a heavy cut and then across the valley of the Albula into a tunnel 2250 feet long. The line then runs chiefly in cuts to a point where there are two tunnels, one over the other; indeed the line over-laps itself in loops and tunnels a number of times in that vicinity. That portion of the road shown in Fig. 8 is less remarkable than the other, although it exhibits extraordinary alignment. This example of railroad location is one of the most striking among those yet completed. It would appear to indicate that no topographical difficulties are too great to be overcome by the civil engineer in railroad location in a most rugged and precipitous country. Obviously such a line could not be economically operated for heavy freight traffic.

Railroad lines frequently lead through mountainous regions affording some of the grandest scenery in the world accessible to the travelling public. In this country the Canadian Pacific, the Northern Pacific, the Great Northern, and the Rio Grande Western

probably exhibit the most remarkable instances of this kind.

CHAPTER XXII.

=264. Railroad Signalling.=—The birth of the art of railroad signalling was probably coexistent with that of the railroad. At the very outset of the movement of railroad trains it became imperative to insure to a given train the sole use of the single track at schedule periods. Both head-to-head and rear-end collisions were liable to occur on main tracks, as well as false meetings at branches and cross-overs.

=265. The Pilot Guard.=—One of the earliest if not the earliest of systematic procedures in England to accomplish the safe use of a railroad track involved the employment of the "pilot guard" on single-track roads. The pilot was an employé whose duty it was to accompany every train over a stated section of the line. The authority to start trains was lodged in him. When it became necessary to start two or three trains from the same point and in the same direction, it was also his duty to issue to each train conductor what was called a pilot ticket, equivalent to a modern train order to run the train over the section under his control. In that case he was obliged to accompany the last train to the other end of his section, and no more trains could move over that section in the same direction until his return to his first station. As no train could pass over the section without either him or his pilot ticket, it is clear that the system could prevent head-to-head collisions, but in itself it is not sufficient to eliminate rear-end collisions. This system is still employed in Great Britain on some short branch lines.

=266. The Train-Staff.=—Another method nearly as old as the preceding is that of the train-staff, used in an improved form at the present time on some single-track roads. No train under this system can pass over any given section of the line unless it carries the staff belonging to that section, the staff being a piece of wood or metal 1 to 1¼ inches in diameter and 18 to 20 inches long. In order to cover the case of two or more trains starting in the same direction at one end of a section before running a train in the opposite direction, tickets were issued, the staff being taken by the last train. The proper operation of this method, like that of the preceding, would prevent head-to-head collisions, but is not sufficient in itself to prevent one train running into the rear of another while both are proceeding in the same direction in the same section.

=267. First Basis of Railroad Signalling.=—These and other similar systems answered fairly well the more simple requirements of early railroad operation. Strictly speaking they are not methods of signalling, although it may be said that each train is a signal in itself. With the development of railroad business it was found that other methods better adapted to a more efficient and rapid movement of trains were imperative. It was in response to the advancing requirements of the railroad business that the first approach to what is now so well known as the block system of signalling was made in 1842. An English engineer, subsequently, Sir W. F. Cooke, stated the following sound principles as to the basis of efficient railroad signalling:

"Every point of a line is a dangerous point which ought to be covered by signals. The whole distance ought to be divided into sections, and at the end as well as at the beginning of them there ought to be a signal, by means of which the entrance to the section is open to each train when we are sure that it is free. As these sections are too long to be worked by a traction rod, they ought to be worked by electricity."

The main features of railroad signalling, as thus set forth, have continued to characterize the development of the block system from that early day to the present. The electrical application to which reference is made in the preceding quotation was that of the needle, which by its varying position could indicate either "line clear" or "line blocked." In 1851 electric bells were used in railroad signalling on the Southeastern Railway of England. Various other developments were completed from time to time in Great Britain until the Sykes system of block signalling was patented in 1875. One of the main features of the system, and perhaps the most prominent, was the control of the track signals at the entrance end of the block by the signalman at the advance end. He exerted this control by electrically operated locks. About 1876 the Pennsylvania Railroad introduced the block system into the United States, which has since been greatly developed in a number of different forms, and its use has been widely extended over many if not most of the great railroad systems of the country. It is not only used for the movement of trains, but also for the protection of such special danger-points as switches, cross-overs, junctions, drawbridges, heavy descending grades, sharp curves, and other points needing the protection which a well-designed block system affords.

=268. Code of American Railway Association.=—The code of the American Railway Association gives the following definitions among others pertaining to the block system:

Block.—A length of track of defined limits, the use of which by trains is controlled by block signals.

Block Station.—The office from which block signals are operated.

Block Signal.—A fixed signal controlling the use of a block.

Home Block Signal.—A fixed signal at the entrance of a block to control trains in entering and using said block.

Distant Block Signal.—A fixed signal of distinctive character used in connection with a home block signal to regulate the approach thereto.

Advance Block Signal.—A fixed signal placed in advance of a home block signal to provide a supplementary block between the home block signal and the advance block signal.

Block System.—A series of consecutive blocks controlled by block signals.

Telegraph Block System.—One in which the signals are operated manually upon telegraphic information.

Controlled-Manual Block System.—One in which the signals are operated manually, and by its construction requires the co-operation of a signalman at both ends of the block to display a clear signal.

Automatic Block System.—One in which the signals are operated by electric, pneumatic, or other agency, actuated by a train or by certain conditions affecting the use of a block.

=268a. The Block.=—It is seen by these definitions that what may be called the unit in railroad signalling is the "block"; it may be of almost any length from a few hundred feet to 6 or 8 miles, or even more. On a single-track railroad it may evidently extend from one side track or passing-place to another. Over portions of lines carrying heavy traffic it may be a half-mile or less. The length of block will depend, then, upon the intensity and kind of traffic, the physical features of the line, such as curvature, grade, sidings, cross-overs, and other similar features, the location, whether in cities, towns, or open country, as well as upon other elements affecting conditions of operation which it is desirable to attain.

=269. Three Classes of Railroad Signals—The Disc.=—The signals used in railroad operation may mainly be divided into three classes: semaphores, banners, and discs. In general they may convey information by form, position, and color. The disc is used by causing it to appear and disappear before an aperture, usually a little larger than itself, in a case standing perhaps 10 or 12 feet high alongside the track, and is admirably typified in the Hall electric signal. On account of its shape, the case in which the disc is operated is frequently called the banjo, as it is quite similar in shape to that musical instrument placed in a vertical position, the key end resting on the ground.

=270. The Banner Signal.=—The banner signal is usually operated by rotation about a vertical axis, frequently in connection with switches. Its full face painted red, exposed with its plane at right angles to the track, indicates "danger" or "stop." With its face turned parallel to the track, showing only its edge to approaching trains, a "clear" line or "safety" is indicated.

In the present development of railroad signalling the banner and disc patterns have a comparatively limited application, although, on the whole, they are largely used. The banner signal is mostly employed in the manual operation of switches, turn-outs, and cross-overs, and for other local purposes, particularly on lines of light traffic.

[Illustration: FIG. 10.—Semaphore Signals.]

=271. The Semaphore.=—The semaphore is now mainly used in connection with block signalling. Like many other appliances in railroad signalling it was first used in England, by Mr. C. H. Gregory, about 1841. Its name is derived from the combination of two Greek words signifying a sign-bearer. It consists of a post varying in height from about 3 to 35 or 40 feet, carrying an arm at its top from 3 to 5 feet long, pivoted within a foot or 18 inches of one end, the long end suitably shaped and painted and the other arranged with a lens so that when operated at night in connection with a lamp it may exhibit a properly colored light. The post of the semaphore is placed alongside the track so as to be on the right-hand side of an approaching train, the long arm rising and falling as a signal away from the track and in a plane at right angles to it. The other arm of the semaphore signal may be connected by wires or rods and light chains running over pulleys with suitable levers and weights operated either in a near-by signal cabin or by a signalman stationed near the semaphore itself; or it may be operated by electric or pneumatic power, as in many of the later installations. The semaphore may, therefore, be operated at the post or by suitable appliances at a distance.

[Illustration: Semaphore on Pennsylvania Railroad.]

=272. Colors for Signalling.=—The colors used either for painted signals for daylight exposure or for coloring lenses for night signalling are red, white, and green, as ordinarily employed in this country; red signifying "danger" or "stop," white signifying "safety" or "clear track," and green signifying "caution" or "proceed with train under control," indicating that a train may go forward cautiously, expecting to find an obstruction or occupied track. In England green is largely employed to indicate "safety" or "clear track," on the ground that a white light is so similar to any other in its vicinity that the latter may too easily be mistaken for a signal. While there is some diversity of views in this country on that point, the consensus of engineering opinion seems to favor the retention of the white for the track safety signal.

=273. Indications of the Semaphore.=—It is evident that a semaphore affords facilities of form, position, and color in its use for the purpose of signalling. The horizontal position is the most striking for the semaphore arm, as it then extends at right angles to the post and to the right or away from the track; this position is, therefore, taken to indicate "danger" or "stop." No train may, therefore, proceed against a horizontal semaphore arm.

It might at first sight appear that the vertical position of the semaphore arm close against the post could be taken to indicate "safety" or "clear track" or "proceed," but experience has shown that such a position may be injudicious, except under special conditions where it has lately been employed to make that indication. If the semaphore arm should be knocked or blown from the ordinary post, the engineman of an approaching train probably would not be able to detect the actual condition of things and might accept the appearance of the semaphore as indicating a clear line, thus justifying himself in proceeding at full speed, while the signalman in his cabin might have placed the signal at "danger." A position of the semaphore arm, therefore, at an angle of 65° or 70° below the horizontal is usually taken as a safety signal. This position is in marked contrast to the horizontal arm and at the same time makes the absence of the semaphore arm impossible without immediate detection from an approaching locomotive. After dark the semaphore in a position of danger exhibits a red light through the lens in its short arm when the long arm is at the "danger" position or horizontal. Similarly, when the long arm is in the safety position a white light is exhibited through the lens in the shorter arm, so that the respective conditions of clear or obstructed track are made evident to the engineman as well by night as by day on his approach to the semaphore.

In some of the latest signal work three positions of the semaphore arm on one post, known as three-position block signalling, have been employed. In this system a special post, frequently on a signal bridge over the track, permits the vertical position of the semaphore arm to indicate "clear track," while the diagonal or inclined position below the horizontal indicates "caution." In the Mozier three-position signal a diagonal or inclined position above the horizontal indicates "caution" an addition to the two usual positions of "stop" and "clear."

These are the elements, so to speak, of railroad signalling at the present day. They are combined with various appliances and in various sequences, so as to express all the varied conditions of the track structure which affect the operation of the road or the movement of trains upon it. These combinations and the appliances employed in them are more or less involved in their principal features and complicated in their details, although the main principles and salient points are simple and may easily be exhibited as to their mode of operation and general results. In this treatment of the subject it will only be possible to accomplish these general purposes without attempting to set forth the mechanical details by which the main purposes of railroad signalling are accomplished.

=274. General Character of Block System.=—It is evident from what has already been stated that the block system of signalling involves the use of fixed signals located so as to convey promptly to approaching trains certain information as to the condition of points of danger approached. Furthermore, this system of signals is designed and operated on the assumption that every point is to be considered as a danger-point until information is given that a condition of safety exists. The usual position of signals, or what may be called the normal position, is that of "danger," and no position of "safety" is to be given to any signal except to permit a train to pass into a block whose condition of safety or clear track is absolutely assured. These are the ground principles on which the signal systems to be considered are designed and operated, although there are some conditions under which the normal signal position may be that of safety.

=275. Block Systems in Use.=—The block systems now in general use are:

The Manual, in which the signals at each end of each block are wholly controlled and operated by the signalman at each signal point.

The Controlled-Manual, in which the signals at the entrance to each block are controlled either electrically or in some other manner by the signalman at the other extremity of that block, but are operated subject to that control by the signalman at the entrance of the

block.

The Auto-Manual, in which the signals are generally operated and controlled as in the Manual or Controlled-Manual, except that they are automatically returned to the danger position as the rear car of a moving train passes them.

The Automatic, in which the operation of the signals is wholly automatic and generally by electricity, or by a combination of electric and pneumatic mechanism. In this system no signalmen are required.

The Machine, which is a controlled block system for single-track operation and in which machines operated electrically with detachable parts, as staffs, are employed in connection with other fixed signals alongside the track.

The main features of these various systems of blocking are, in respect to their signalling, the same, but the means for actuating or manipulating the signals and the conditions under which moving trains receive the necessary instructions are different. They all have the same main objects in view of improving railroad operation by enhancing both safety and facility of train movement.

"Absolute" blocking is that system of block signalling which absolutely prevents one train passing into a block until the preceding train is entirely out of it, or, in other words, until the block is absolutely clear.

"Permissive" blocking is, strictly speaking, the violation of the true block system of signalling, since under it a train may under certain precautionary conditions enter a block before the preceding train has passed out of it.

=276. Locations of Signals.=—In proceeding to locate signals along a railroad line it is imperative to recognize the preceding purposes as controlling motives. Signals must be seen readily and clearly in order to be of the greatest service to the enginemen of approaching trains, and their positions must be selected with that end in view. Locations of switches, cross-overs, junctions, and other similar track features will control the locations of the signals which are to protect them. The main or home signal in these special cases may usually be placed from 50 to 200 feet from the point which is to be governed, the so-called "distant" signal being placed about 2000 feet for level track back of the main or home signal.

=277. Home, Distant, and Advance Signals.=—A complete system of signals employed in blocking includes first of all the so-called "home" signal at each extremity of a block, then at a distance of 2000 to 2500 feet back from the home signal is placed the "distant" signal. The latter is thus approached and passed before reaching the home signal. On the other side of the "home" signal at least a maximum train length into a block about to be entered by a moving train is placed the "advance" signal. The distance of the advance signal from the home signal may be 1500 to 2500 feet. As a moving train approaches the end of a block it first meets the distant signal, the purpose of which is to indicate what the engineman may expect to find at the home signal. If the distant signal is in the danger position, he will pass it with caution and place his train under control so as to be able to stop at the home signal. If he finds the distant signal in a safety position, indicating the same position of the home signal, he may approach the latter without reducing speed, confident that the next section is clear and ready for him. The advance signal forms a kind of secondary or supplementary block into which the train, under certain conditions, may enter when the block in which it is found is obstructed, but no train may pass the advance signal unless the entire block is clear except when, under permissive working, the train proceeds with caution, expecting to find the track either obstructed or occupied. This group of three signals—the distant, the home, and the advance—taken in the order in which the moving train finds them, is located at each extremity of the block. Although the home signal is said to control the movement of trains in a block at the entrance to which it is found, as a matter of fact it appears that the advance signal in the final event holds that control.

=278. Typical Working of Auto-Controlled Manual System.=—The mode of employing these signals can be illustrated in a typical way by the diagrams, Figs, 11, 12, and 13, which exhibit in a skeleton manner Pattenall's improved Sykes system which belongs to the Auto-Controlled Manual class. In these figures the end of block 1, the whole of blocks 2 and 3, and the beginning of block 4 are shown. Stations _A_, _B_, and _C_ indicate the extremities of blocks. The signals _S_, _S■_, and _S″_ are the home signals, while _D_, _D■_, and _D″_ indicate distant signals, and _A_, _A■_, and _A″_ advance signals. As the diagrams indicate, the stretch of double-track road is represented with east- and west-bound tracks. In order to simplify the diagrams, signals and stations are shown for one track only; they would simply be duplicated for the other track. The signal cabin is supposed to be located at each station, and at that cabin are found the levers and other appliances for working the signals operated there, the signals themselves being exposed alongside the track. In each signal cabin there is an indicator, as shown at _I_, _I■_, and _I″_. On the face of each indicator there are two slots, shown opposite the lines _E_ and _F_. In the upper of these slots appears either the word "Clear" or "Blocked." In the lower slot appears either the word "Passed" or "On." The significance of these words will appear

presently. On this indicator face at _P_, _P■_, and _P″_ are located electric push-buttons called plungers. The operation of the levers indicated at _L_, the counterweights _d_, and the locking detail _I_ are evident from an inspection of the figure, and need no special explanation. It is only necessary to state that the locking-device _I_ holds the bar _bc_ until it is released at the proper time, and that the counterweight may then return the lever from its extreme leftward position to that at the extreme right, at the same time placing the semaphore arm _S_ in the position of danger. It is particularly important to bear in mind this last observation. The counterweight is the feature of the system which always holds the semaphore arm in the position of danger, making that its normal position, except when it is put to safety for the passing of a train.

[Illustration: FIG. 11.]

[Illustration: FIG. 12.]

[Illustration: FIG. 13.]

If a westward train is represented in Fig. 11 at _T_ as approaching station _A_ to enter the block 2, both the distant signal _D_ and the home signal _S_ being at danger, the system is so arranged that the signalman at station _A_ cannot change those signals, i.e., to a position of safety, until the signalman at station _B_ permits him to do so. If the signalman at station _A_ desires to open block 2 for the entrance of the train _T_, he asks the signalman at station _B_ by wire to release the lock _I_ to enable him to do so. If there is no train in block 2, the signalman at station _B_ pushes the button _P′_ or "plunges" it. This raises the lock _I_ at station _A_ and the signalman immediately pulls the lever _L_ to its extreme leftward position, throwing both the signals _S_ and _D_ to the position of safety or clear, indicated by the dotted lines at _S_². At the same time the indicator _E_ at station _A_ shows the words "Clear to _B_," while the slot _F■_ at _B_ shows the words "On from _A_." The signals at stations _B_ and _C_ are supposed to be in their normal position of danger, and the indicator _E′_ at station _B_ shows the words "Blocked to _C_." The home and distant signals _S■_ and _D■_ are now at danger, but the train _T_ may enter block 2 and proceeds to do so, it being remembered that the signalman at station _A_ cannot move the lever _L_, as it has passed out of his control; not even the signalman at station _B_ can give him power to do so. The train _T_ now passes station _A_ into block 2. As the last car passes over the point _G_ its wheels strike what is called a track-treadle, an appliance having electrical connection with the lock _I_. The effect of the wheels of the last car of the train passing over the treadle at _G_ is to release lock _I_, enabling the signalman at station _A_ immediately to raise the arms _S_ and _D_ to the position of danger. It is to be observed that he cannot do this until the entire train has passed into block 2; nor, since his plunger is locked by the same treadle at _G_, can he signal "Safety" or "Clear" to the entrance of block 1. Hence no train can enter block 1 to collide with the rear end of the train just entering block 2. When the signalman at station _A_ has raised his signal _S_ to danger, it again passes out of his control, indeed out of both his control and that of the signalman at _B_, until the last car of the train passes over the treadle _G■_ at the entrance of block 3.

The train has now passed into block 2 and is approaching station _B_. The signalman at _B_ asks _C_ by wire to release the lever _L■_, and if block 3 is clear, _C_ plunges at _P″_.

_C_ then throws his lever _L■_ so as to place the home and distant signals _S■_ and _D■_ at safety. The condition of things will then be shown by Fig. 12. As soon as the last car of the train has passed over the treadle at _G■_ his lever _L■_ will be released and he can then throw the lever to the danger position, raising the home and distant signals _S■_ and _D■_ to the horizontal. After the danger position is assumed by the home signal _S■_, as well as the distant signal _D■_, he has no power over them until the signalman at station _C_ confers it on him by plunging the button _P″_.

While the train has been in block 2, the indicator _I■_ has shown "Blocked to _C_" and "Train on from _A_," but as the train passes _B_ the indicator reads "Blocked to _C_" and "Train passed from _A_," while the indicator _I″_ at _C_ reads "Blocked to _D_" and "Train on from _B_." This condition of the signals and trains is shown by Fig. 13. Also, when the last car passes over the treadle _G■_, but not till then, _B_ may permit _A_ to admit a train to enter block 2 should _A_ so desire. Finally, when the train approaches _C_, the signalman at that point asks _D_ to enable him to permit the train to enter block 4, and _C_ confers the power by plunging if that block is clear. Fig. 13 exhibits the corresponding signals at _C_.

This sequence of operations is typical of what takes place in this particular block signal system at the limits of every successive block, and differs only in details characteristic of this system from those which are performed in any other block signal system.

=279. General Results.=—It is seen first that no signalman can operate a signal until the condition in the block ahead of him is such as to make it proper for him to do so, and then he can only indicate what is necessary for the safe entrance of the train into that

block. Furthermore, immediately on the passage of the train past his home signal he must put the latter to danger or the counterweight may do it for him, the train itself when in a safe position having conferred the requisite power upon him. The signalman at the advance end of the block always knows when the train is about to enter it, for he is obliged to give his permission for that entrance. His indicator shows this result, and will continue to show it until the train passes out of the block. It is to be observed that the upper openings marked _E_ on the indicator give information of the condition of the block in advance, while the lower openings give information of the block in the rear.

It is particularly important to notice that after the signalman at the advance end of a block has "plunged" his plunger remains locked and it cannot be released until the train admitted to the block covered by the plunger has completely passed out of that block, permitting the track-treadle at the entrance to the next block to unlock the plunger. This feature makes it impossible for one train to enter a block until the preceding train has passed out of it.

If the permissive system of using a block be employed, in which the train is permitted to enter that block before a preceding train leaves it, the treadle gives no protection against a rear-end collision with the first train. In such an exigency other devices must be used or the following train must proceed cautiously, expecting to find the track occupied.

=280. Distant Signals.=—Thus far the distant signals have been treated incidentally only. They may be operated concurrently with or independently of the home signal in such a way that if danger is indicated, the distant signal gives its indication prior to that of the home signal. In this manner protection is given to the rear of a train approaching a block against the home signal set at "danger." After the obstruction is removed and the block cleared, the home signal is set at "safety" before the distant signal is cleared.

=281. Function of Advance Signals.=—The advance signals are used when for any purpose it is desired to form a short block in a regular block. If, for instance, block 3 in Fig. 11 were obstructed by a train stopped by some failure of a locomotive detail, a train approaching station _B_ in section 2 against the home signal _S■_ set at "danger" would be obliged to stop before entering block 3. It might then be permitted to enter the latter block, to be stopped by the advance signal _A■_ set at "danger" or under instructions to pass it cautiously, expecting to find the track obstructed. It is thus seen that the advance signal creates what may be called an emergency block, and in reality finally controls the movement of trains in the block in which it is located. It would never be cleared unless the home signal were first cleared, nor would it be set at "danger" unless the home signal gave the same indication.

The preceding operation of the block system of signalling controls the movement of trains along a double-track line.

[Illustration: FIG. 14.]

=282. Signalling at a Single-track Crossing.=—A somewhat similar sequence of signal operations controls train movements at a crossing, whether single- or double-track. Fig. 14 illustrates the use of signals required for the safe movement of trains at a single-track railroad crossing, which is supposed to be that of a north-and-south line crossing obliquely an east-and-west line. Precisely the same arrangement of signals operated in the same manner would be required if the crossing were at the angle of 90°. The signal cabin is placed, as shown, as near as practicable to the actual intersection of tracks. Trains may pass in either direction on either track, but in every case they would be governed by the signals at the right-hand side of the track as seen by the engineman. There will therefore be a set of signals on both sides of each track, each set governing the movement of trains in its own direction. Each home signal may be placed about 350 feet from the actual intersection, and each distant signal 1200 to 1500 feet from the home signal, or 1550 feet to 1800 feet from the intersection. Each advance signal must be at least as far in advance of the home signal as the maximum length of train, since it may be used to stop a train, the rear car of which should completely pass the home signal. In their normal positions every home signal should be set at "danger," carrying with them the distant signals giving the same indication. The advance signals must also indicate "danger" with the home signal. No train can then pass the crossing until the home and distant signals indicate a clear line for it, the other signals at the crossing, except possibly the advance signal, being set at "danger." If for any reason it is desired to hold the train after it is entirely free of the crossing, the advance signal would also indicate "danger."

It is thus seen that if the signals are properly set and obeyed, it is impossible for two trains to attempt a crossing at the same time. It is not an uncommon occurrence, however, for an engineman to run his train against the danger signal, and in order to make it impossible for the train to reach the crossing even under these circumstances a derailing device is used. This derailing arrangement is shown in Fig. 14, about 300 feet from the crossing, although it may be placed from 300 to 500 feet from that point. Its purpose is to derail any train attempting to make the crossing against the danger signal. The operation of the derail is evident from the skeleton lines of the figure. When the home signal is at danger the movable part of the derailing device is at this point

turned so as to catch the flanges of the wheels as they attempt to pass it. The train is thus thrown upon the cross-ties at such a distance from the crossing as will produce a stop before reaching it. When the home signal is at safety the derail operated with the signal is closed and the line is continuous. This combination of signals and derail coacting serves efficiently to prevent collisions at crossings, although trains may be occasionally derailed in accomplishing that end. The preceding explanations of the use of signals and derail apply to a train that may approach the crossing in either direction on either track, as is obvious from an inspection of the diagram itself.

=283. Signalling at a Double-track Crossing.=—In the case of a double-track crossing, the arrangement of signals and derails is precisely the same as for a single-track crossing, each set of signals shown in Fig. 15 covering one track. In other words, the line of single track is to take the place of each rail with its set of signals in that figure. There will be but four derails, one for each track only on the approach to the crossing. The working of the signals with the derails is precisely the same as has already been explained for the single-track crossing.

[Illustration: FIG. 15.]

[Illustration: FIG. 16.]

=284. Signalling for Double-track Junction and Cross-over.=—Fig. 16 represents a skeleton diagram of signals required for a junction of two double-track roads and a cross-over. This arrangement covers the use of switches. The location of signals and signal cabin as shown is self-explanatory, after what has already been stated in connection with single- and double-track crossings. It will be observed that the home signals for both the west-bound main and branch tracks are identical in location, and are shown by the solid double flag, the distant signal being shown by its notched end at a considerable distance back of the double home signal. It will, furthermore, be observed that at each home signal there is a derailing-switch interlocked, in the lock-and-block system presently to be explained, with the home signals operated simultaneously with them. If, therefore, an engineman attempts to run his train past a home signal set at danger, the result will be the derailment of his train, thus brought to rest before it can make any collision with another. It is obvious in this case that if the switches from the main to the branch tracks or at the extremities of the cross-over are worked independently, they must be operated directly in connection with the signals. For complete protection they should be interlocked with the signals so that it would be impossible to clear any signal without simultaneously setting the switches consistently with those signals. The diagram exhibits clearly the indications which must be made in order to effect any desired train movement at such a junction of tracks.

=285. General Observations.=—Similar arrangements of signals, derails, or switches must be made wherever switches, cross-overs, and junctions are found, the detailed variations of those signals and switches being made to meet the individual requirements of each local case. The combinations of switches and switch-signals frequently become very complicated in yards where the tracks are numerous and the combinations exceedingly varied, in order to meet the conditions created by the movement of trains into and out of the yard.

The preceding explanations are intended only to give a clear idea of the main features of signalling, in order to secure the highest degree of safety and facility in the movement of trains over a modern railroad. While they exhibit the external or apparent combinations of signals for that purpose, they do not touch in detail and scarcely in general upon the mechanical appliances found in the signal cabin and along the tracks required to accomplish the necessary signal movements. The considerations in detail of those appliances would cover extended examinations of purely mechanical, electrical, pneumatic, and electro-pneumatic combinations too involved to be set forth in any but the most extended and careful study. They have at the present time been brought to a wonderful degree of mechanical perfection and afford a field of most interesting and profitable study, into which, however, it is not possible in these general statements of the subject to enter.

[Illustration: FIG. 17.]

=286. Interlocking-machines.=—The earliest machine perfected for use in this department of railroad signalling was the Saxby and Farmer interlocking-machine, first brought out in England and subsequently introduced in this country between 1874 and 1876. This machine has been much improved since and has been widely used. Other interlocking-machines have also been devised and used in this country in connection with the most improved systems of signalling, until at the present time a high degree of mechanical excellence has been reached.

The interlocking-machine in what is called the lock-and-block system of signalling is designed to operate signals, or signals in connection with switches, derailing-points, or other dangerous track features, so as to make it impossible for a signalman to make a wrong combination, that is, a combination in which the signals will induce the engineman to run his train into danger. The signals and switches or other track details are so connected and interlocked with each other as to form certain desired combinations by the movement of designated levers in the signal cabin or tower. These combinations are predetermined in the design and connections of the appliances used, and they cannot be changed when once made except by design or by breakage of the parts; they cannot be deranged by any action of the signalman. He may delay trains by awkward or even wrong movement of levers, but he cannot actually clear his signals for the movement of a train without simultaneously giving that train a clear and safe track. As has been stated, he cannot organize an accident. Figs. 17 and 18 show banks or series of levers belonging to interlocking-machines. As is evident from these figures, the levers are numerous if the machine operates the switches and signals of a large yard, for the simple reason that a great many combinations must be made in order to meet the requirements of train movements in such a yard. The signalman, however, makes himself acquainted with the various combinations requisite for outgoing and incoming trains and the possible movements required for the shifting or hauling out of empty trains. He has before him diagrams showing in full the lever movements which must be made for the accomplishment of any or of all these movements, and he simply follows the directions of the diagrams and his instructions in the performance of his duty. He cannot derange the combinations, although he may be slow in reaching them. The locking-frame which compels him to make a clear track whenever his signals give a clear indication to the engineman lies below the lower end of the levers seen in the figures. The short arms of the levers carry tappets with notches in their edges into which fit pointed pieces of metal or dogs; the arrangement of these notches and dogs is such as to make the desired combinations and no others. It will be observed that a spring-latch handle projects from a point near the upper end of each lever where the latter is grasped in operating the machine. This spring-latch handle must be pressed close to the lever before the latter can be moved. The pressing of the spring-latch handle against the lever effects a suitable train of unlocking before which the lever cannot be moved and after which it is thrown over to the full limit and locked there. The desired combination for the movement of the train through any number of switches may require a similar movement of a number of levers, but the entire movement of that set, as required, must be completely effected before the signals are cleared, and when they are so cleared the right combination forming a clear track for the train, and that one only, is secured. These meagre and superficial statements indicate in a general way, however imperfectly, the ends attained in a modern interlocking-machine. They secure for railroad traffic as nearly as possible an absolutely safe track. They eliminate, as far as it is possible to do so, the inefficiency of human nature, the erratic, indifferent, or wilfully negligent features of human agency, and substitute therefor the certainty of efficient mechanical appliances. In some and perhaps many States grade crossings are required by statute to adopt measures that are equivalent to the most advanced lock-and-block system of signalling. So vast has become railroad traffic upon the great trunk lines of the country that it would be impossible to operate them at all without the perfected modern systems of railroad signalling. They constitute the means by which all train movements are controlled, and without such systems great modern railroads could not be operated.

[Illustration: FIG. 18.]

The swiftly moving “limited” express passenger trains, equipped with practically every luxury of modern life, speed their way so swiftly and smoothly over many hundreds of miles without the incident of an interruption, and in such a regular and matter-of-fact way, that the suggestion of an intricate system of signalling governing its movements is never thought of. Yet such a train moves not a yard over its track without the saving authority of its block signals. If the engineman were to neglect even for a mile the indication of the semaphore, he would place in fatal peril the safety of his train and of every life in it.

=287. Methods of Applying Power in Systems of Signalling.=—The mechanical appliances used in accomplishing these ends are among the most efficient in character and delicate yet certain in motive power which engineering science has yet produced. The electric circuit formed by the rails of the track plays a most important part, particularly in securing the safety of the rear of the train in making it absolutely certain whether even rear cars that may have broken away have either passed out of the block or are still in it. The electric circuit in one application or another was among the earliest means used in railroad signalling. Electric power is also used in connection with compressed air for the working of signals. Among the latest and perhaps the most advanced types of lock-and-block signalling is that which is actuated by low-pressure compressed air, the maximum pressure being 15 pounds only per square inch. The compressed air is supplied by a simple compressor, and it is communicated from the signal cabin to the most remote signal or switch by pipes and suitable cylinders fitted with pistons controlled by valves, thus effecting the final signal or switch movements. It has been successfully applied at the yard of the Grand Central Station in New York City and at many other similar points. In this connection it is interesting to observe that while the original Saxby and Farmer interlocking-machine was installed from England in this country, as has already been observed, about 1875, American engineers have within a year

reciprocated the favor by furnishing and putting in place most successfully in one of the great railroad yards of London the first low-pressure pneumatic lock-and-block system[8] found in Great Britain.

[8] By Standard Railroad Signal Company of Troy, N. Y.

=288. Train-staff Signalling.=—The lock-and-block system gives the highest degree of security attainable at the present time for double-track railroad traffic, but the simpler character of the single-track railroad business can be advantageously controlled by a somewhat simpler and less expensive system, which is a modification of the old train-staff method. It is one of the "machine" methods of signalling. The type which has been used widely in England, Australia and India, and to some extent in this country is called the Webb and Thompson train-staff machine, shown in Fig. 19. It will be observed that the machine contains ten staffs (18 to 20 inches long and 1 to 1¼ inches in diameter), but as many as fifteen are sometimes used. These staffs can be removed from the machine at one end of a section of the road at which a train is to enter, only by permission from the operator at the farther end of the section. If the station at the entrance to that section is called _A_, and the station at the farther end _X_, the following description of the operation of the instrument is given by Mr. Charles Hansel in a very concise and excellent manner:

[Illustration: FIG. 19.—Webb and Thompson Train-staff Machine.]

"When a train is ready to move from _A_ to _X_ the operator at _A_ presses down the lever which is seen at the bottom of the right-hand dial, sounding one bell at _X_, which is for the purpose of calling the attention of the operator at _X_ to the fact that _A_ desires to send a train forward. The operator at _X_ acknowledges the call by pressing the lever on his instrument, sounding a bell in the tower at _A_. The operator at _A_ then asks permission from _X_ to withdraw staff by pressing down the lever before mentioned three times, giving three rings on the bell at _X_, and immediately turns his right-hand pointer to the left, leaving it in the horizontal position pointing to the words 'For staff,' indicating that he desires operator at _X_ to release his instrument so that he can take a staff or train order from it. If there is no train or any portion of a train between _A_ and _X_, the holding down of the lever at _X_ closes the circuit in the lock magnets at _A_, which enables the operator at _A_ to withdraw a staff. As soon as this staff is removed from _A_, _A_ turns the left-hand pointer to the words 'Staff out,' and in removing this staff from the instrument _A_ the galvanometer needle which is seen in the centre of the instrument between the two dials vibrates, indicating to the operator at _X_ that _A_ has withdrawn his staff. _X_ then releases the lever which he has held down in order that _A_ might withdraw a staff and turns his left-hand indicator to 'Staff out,' and with this position of the instrument a staff cannot be withdrawn from either one.

"The first method of delivering this staff to the engineer as a train order was to place it in a staff-crane, which crane was located on the platform outside of the block station. With the staff in this position it has been found in actual practice that the engineman can pick it up while his train is running at a speed of 30 miles per hour. A second staff cannot be removed from _A_ nor a staff removed from _X_ until this staff which was taken by the engineman in going from _A_ to _X_ is placed in the staff instrument at _X_; consequently the delivering of a staff from _A_ to the engineman gives him absolute control of the section between _A_ and _X_.

"This train order staff also controls all switches leading from the main line between _A_ and _X_, for with the style of switch-stand which we have designed for the purpose the trainman cannot open the switch until he has secured the staff from the engineman and inserted it in the switch-stand, and as soon as he throws the switch-lever and opens the switch he fastens the train-staff in the switch-stand, and it cannot be removed until the switchman has closed and locked the switch for the main line. When this is done he may remove the train-staff and return it to the engineman. It will thus be seen that this train order, in the shape of a staff, gives the engineman absolute control over the section, and also insures that all switches from the main line are set properly before he can deliver the train-staff to the instrument at _X_.

"In order that the operator at _X_ may be assured that the entire train has passed his station, we may divide the staff in two and deliver one half to the engineman and the other half to the trainman on the caboose or rear end of the train, and it will be necessary for the operator at _X_ to have the two halves so that he may complete the staff in order to insert it into the staff instrument at _X_, as it is impossible to insert a portion of the staff; it must be entirely complete before it can be returned to the staff instrument."

Instead of using the entire staff as a whole or in two parts, Mr. Hansel suggests that one or more rings on the body of the staff be removed from the latter and given to the engineman or other trainman to be placed upon a corresponding staff at the extreme end of the section. This would answer the purpose, for no staff can be inserted in a machine unless all the rings are in their proper positions. These rings can be taken up by a train moving at any speed from a suitable crane at any point alongside the track.

For a rapid movement of trains on a single-track railroad under this staff system an engineman must know before he approaches the end of the section whether the staff is ready for delivery to him. In order to accomplish that purpose the usual distant and home signals may readily be employed. The distant signal would show him what to expect, so that he would approach the entrance to the section either at full speed or with his train under control according to the indication. Similarly, electric circuits may be employed in connection with the staff or rings in the control of signals which it may be desired to employ.

The electric train-staff may also be used in a permissive block system, the section of the track between stations _A_ and _X_ constituting the block. In Fig. 19, showing the machine, a horizontal arm is seen to extend across its face and to the right. This is the permissive attachment which must be operated by the special staff shown on the left half of the machine about midway of its height. If it is desired to run two or three trains or two or three sections of the same train from _A_ before admitting a train at _X_ in the opposite direction, the operator at _A_ so advises the operator at _X_. The latter then permits _A_ to remove the special staff with which the extreme right-hand end of the permissive attachment is unlocked and a tablet taken out. This tablet is equivalent to a train order and is given to the train immediately starting from _A_. A second tablet is given in a similar manner to the second section or train, and a third to the third section. The last section of train or train itself starting from _A_ takes all the remaining tablets and the special staff for insertion in the machine at _X_. In this manner head-to-head collisions are prevented when a number of trains are passing through the block in the same direction before the entrance of a train in the opposite direction. This system has been found to work satisfactorily where it has been used in this country, although its use has been quite limited. Evidently, in itself, it is not sufficient to prevent rear-end collisions in a block between trains moving in the same direction. In order to avoid such collisions where a train falls behind its schedule time or for any reason is stopped in a block, prompt use must be made of rear flagmen or other means to stop or to control the movement of the first following train.

[Illustration: FIG. 20.]

The most improved form of high-speed train-staff machine is shown in Fig. 20, as made and installed by the Union Switch and Signal Company and used by a number of the largest railroad systems of the United States. In these machines the staffs are but a few ounces in weight.

CHAPTER XXIII.

=289. Evolution of the Locomotive.=—The evolution of the steam locomotive may be called the most spectacular portion of the development of railroad engineering. The enormous engines used at the present time for hauling both heavy freight and fast passenger trains possess little in common, in respect of their principal features, with the crude machines, awkward in appearance and of little hauling capacity, which were used in the early part of the nineteenth century in the beginning of railroad operation. The primitive and ill-proportioned machine, ungainly in the highest degree, designed and built by Trevithick as far back as 1803, was a true progenitor of the modern locomotive, although the family resemblance is not at first very evident. Several such locomotive machines were designed and operated between 1800 and 1829 when Stevenson's Rocket was brought out. The water was carried in a boiler on a wagon immediately behind the engine, and the steam-cylinder in those early machines was placed almost anywhere but where it now seems to belong. The Rocket has some general features of resemblance to the machines built seventy years later, but when placed side by side it might easily be supposed that seven hundred years rather than seventy had elapsed between the two productions of the shop.

After the famous locomotive trial in which Robert Stevenson distanced his competitors, the design of the locomotive advanced rapidly, and it was but a few years later when the modern locomotive began to be accurately foreshadowed in the machines then constructed. This was true both in England and the United States.

The first steam locomotive in this country is believed to be the machine built by John Stevens at Hoboken, N. J., in 1825 and operated in 1825-27. This locomotive has practically the arrangement of boiler and cylinder which is found upon the modern contractors' engines used for pile-driving, hoisting, and similar operations. It would certainly be difficult to imagine that it had any relation to the great express and freight locomotives of the present day. The rectilinear motions of the piston were transformed into the rotary motion of the wheels by means of gearing consisting of a simple arrangement of cog-wheels. About the same time a model of an English locomotive called the Stockton and Darlington No. 1 was brought to the United States by Mr. William Strickland of Philadelphia. The next important step in American locomotive development was the construction of the locomotive "John Bull" for the Camden and Amboy Railroad Company in the English shops of Stevenson & Company in the years 1830-31. This machine has the general features, although not the large dimensions, of many modern locomotives. The cow-catcher is a little more elaborate in

design and far-reaching in its proportions than the similar appendage of the present day, but the general arrangement of the fire-box and boiler, the steam-cylinders, the driving-wheels and smoke-stack is quite similar to a modern American locomotive. This machine, "John Bull," and train made the trip from New York City to Chicago and return under its own steam in 1893. It was one of the prominent features of the World's Columbian Exposition. It rests in the National Museum at Washington, where it is one of the most interesting early remains of mechanical engineering in this country. One of the cars used in this train was the original used on the Camden and Amboy Road about 1836. Its body was used as a chicken-coop at South Amboy, N. J., for many years, and was rescued from this condition of degradation for the purpose of the Exposition trip in 1893. The original driving-wheels had locust spokes and felloes, the hubs and tires being of iron.

The locomotive "George Washington" was built, as a considerable number have been since, with one driving-axle, and was designed to be used on heavy grades. This machine was built by William Norris & Sons of Philadelphia, who were the progenitors of the present great establishment of the Baldwin Locomotive Works. While the development of the locomotive was subjected to many vicissitudes in principles, general arrangement, and size in order to meet the varying requirements of different roads as well as the fancies or more rational ideas of the designers, its advance was rapid. As early as 1846 we find practically the modern consolidation type, followed in 1851 by the ordinary eight-wheel engine of which thousands have been constructed within the past fifty years. The first Mogul built by the Baldwin Locomotive Works was almost if not quite as early in the field. Both these types of machines carry the principal portion of their weight upon the driving-wheels and were calculated to yield a high tractive capacity, especially as the weights of the engines increased. The weight of the little "John Bull" was but 22,425 pounds, while that of the great modern machine may be as much as 267,800 pounds, with 53,500 pounds on a single driving-axle.

=290. Increase of Locomotive Weight and Rate of Combustion of Fuel.=—The development of railroad business in the United States has been so rapid as to create rigorous exactions of every feature of a locomotive calculated to increase its tractive force. Any enhancement of train-load without increasing the costs of the train force or other cost of movement will obviously lead to economy in transportation. In order that the locomotive may yield the correspondingly augmented tractive force the weight resting upon the drivers must be increased, which means a greater machine and at the same time higher working pressures of steam. This demands greater boiler capacity and strength and a proportionately increased rate of combustion, so as to move the locomotive and train by the stored-up energy of the fuel transformed in the engine through steam pressure. The higher that pressure the greater the amount of energy stored up in a unit of weight of the steam and the greater will be the capacity of a given amount of water to perform the work of hauling a train. The greater the weight of train moved and the greater its speed the more energy must be supplied by the steam, and, again, that can only be done with a correspondingly greater consumption of fuel. In the early days of the small and crude machines to which allusion has already been made the simplest fuel was sufficiently effective. As the duties performed by the locomotive became more intense a higher grade of fuel, i.e., one in which a greater amount of heat energy is stored per unit of weight, was required. Both anthracite and bituminous coal have admirably filled these requirements. The movement of a great modern locomotive and its train at an average rate of 30 to 60 miles per hour requires the combustion of fuel at a high rate and the rapid evaporation of steam at pressures of 180 to 225 or more pounds per square inch. The consumption of coal by such a locomotive may reach 100 pounds per minute, and two barrels of water may be evaporated in the same time. This latter rate would require over a gallon of water per second to be ejected through the stack as exhaust steam. Some of the most marked improvements in locomotive practice have been made practically within the past six or seven years in order to meet these exacting requirements.

While the operations of locomotives will obviously depend largely upon quality of fuel, speed, and other conditions, the investigations of Prof. W. F. M. Goss and others appear to indicate that 12 to 14 pounds of water per hour may be evaporated by a good locomotive boiler per square foot of heating surface, and that 25 to 30 pounds of steam will be required per indicated horse-power per hour.

=291. Principal Parts of a Modern Locomotive.=—The principal features of a modern locomotive are the boiler with the smoke-stack placed on the front end and the fire-box or furnace at the rear, the tubes, about 2 inches in diameter, through which the hot gases of combustion pass from the furnace to the smoke-stack, the steam-cylinders with their fittings of valves and valve movements, and the driving-wheels. These features must all be designed more or less in reference to each other, and whatever improvements have been made are indicated almost entirely by the relative or absolute dimensions of those main features. The boiler must be of sufficient size so that the water contained in it may afford a free steam production, requiring in turn a corresponding furnace capacity with the resulting heating surface. The latter is that aggregate surface of the interior chambers of the boiler through which the heat produced by combustion finds its way to the water evaporated in steam; it is composed almost

entirely of the surfaces of the steel plates of the fire-box and of the numerous tubes running through the boiler and parallel to its centre, exposed to the hot gases of combustion and in contact with the water on the opposite sides of those plates. Evidently an increase in size of the fire-box with the correspondingly increased combustion will furnish a proportionally larger amount of steam at the desired high pressure, but an increase in the size of the fire-box is limited both in length and in width. It is found that it is essentially impracticable for a fireman to serve a fire-box more than about 10 feet in length. The maximum width of the locomotive limits the width of the fire-box.

[Illustration: FIG. 21.]

=292. The Wootten Fire-box and Boiler.=—As the demand arose for an enlarged furnace the width of the latter was restricted by the width between the driving-wheel tires, less than 4 feet 6 inches. That difficulty was overcome by what is known as the Wootten fire-box, which was brought out by John E. Wootten of the Philadelphia and Reading Railroad about 1877, and has since been developed and greatly improved by others. The Wootten boiler with its sloping top and great width extending out over the rear driving-wheels presented a rather curious appearance and was a distinct departure in locomotive boiler design. Fig. 21 shows an elevation and two sections of the original Wootten type of boiler. It will be noticed that in front of the fire-box there is a combustion-chamber of considerable length, 2½ to 3 feet long. This boiler was first designed to burn the poorer grades of fuel, such as coal-slack, in which the combustion-chamber to complete the combustion of the fuel was thought essential. By Wootten's device, i.e., extending the boiler out over the driving-wheels, a much greater width of fire-box was secured, but the height of the locomotive was considerably increased. It cannot be definitely stated just how high the centre of the locomotive boiler may be placed above the track without prejudice to safety in running at high speeds, but it has not generally been thought best to lift that centre more than about 9½ feet above the tops of rails, and this matter has been held clearly in view in the development of the wide fire-box type of locomotive boilers.

Like every other new form of machine, the Wootten boiler developed some weak features, although there was no disappointment in its steaming capacity. It will be noticed in the figure that the plates forming that part of the boiler over the fire-box show abrupt changes in curvature which induced ruptures of the stay-bolts and resulted in other weaknesses. This boiler passed through various stages of development, till at the present time Figs. 22 and 23 show its most advanced form, which is satisfactory in almost or quite every detail. The sudden changes in direction of the plates in the first Wootten example have been displaced by more gradual and easy shapes. Indeed there are few features other than those which characterize simple and easy boiler construction. The enormous grate area is evident from the horizontal dimensions of the fire-box, which are about 120 inches in length by about 106 inches in breadth. The boiler has over 4000 square feet of heating surface and carries about 200 pounds per square inch pressure of steam. The combustion-chamber in front of the fire-box has been reduced to a length of about 6 inches, just enough for the protection of the expanded ends of the tubes. The barrel of the boiler in front of the fire-box has a diameter of 80 inches and a length of about 15 feet. The grate area is not far from 100 square feet. The improvements which have culminated in the production of this boiler are due largely to Mr. Samuel Higgins of the Lehigh Valley Road.

[Illustration: FIG. 22.]

[Illustration: FIG. 23.]

=293. Locomotives with Wootten Boilers.=—Fig. 24 exhibits a consolidation freight locomotive of the Lehigh Valley Railroad, having the boiler shown in Figs. 22 and 23. This machine is one of the most efficient and powerful locomotives produced at the present time. The locomotive shown in Fig. 25 has a record. It is one used on the fast Reading express service between Philadelphia and Atlantic City during the season of the latter resort. It has run one of the fastest schedule trains in the world and has attracted attention in this country and abroad. Its type is called the Atlantic and, as the view shows, it is fitted with the Wootten improved type of boiler. It will be noticed that the wide fire-box does not reach out over the rear drivers, but over the small trailing-wheels immediately behind them. This is a feature of wide locomotive fire-box practice at the present time to which recourse is frequently had. There is no special significance attached to the presence of the small trailing-wheels except as a support for the rear end of the boiler, their diameters being small enough to allow the extension of the fire-box over them without unduly elevating the centre of the boiler.

[Illustration: FIG. 24.]

The cylinders of these and many other locomotives are known as the Vauclain compound. In other words, it is a compound locomotive, there being two cylinders, one immediately over the other, on each side. The diameter of the upper cylinder is much

less than that of the lower. The steam is first admitted into the small upper cylinder and after doing its work there passes into the lower or larger cylinder, where it does its work a second time with greater expansion. By means of this compound or double-cylinder use of the steam a higher rate of expansion is secured and a more uniform pull is exerted upon the train, the first generally contributing to a more economical employment of the steam, which in turn means a less amount of fuel burned for a given amount of tractive work performed.

[Illustration: FIG. 25.]

In the early part of November, 1901, an engine of this type hauling a train composed of five cars and weighing 235 tons made a run of 55.5 miles between Philadelphia and Atlantic City at the rate of 71.6 miles per hour, the fastest single mile being made at a rate of a little less than 86 miles per hour.

The power being developed by these engines runs as high as 1400 H.P. at high speeds and 2000 H.P. at the lower speeds of freight trains.

The chief economic advantage of these wide fire-box machines lies in the fact that very indifferent grades of fuel may be consumed. Indeed there are cases where fuel so poor as to be unmarketable has been used most satisfactorily. With a narrow and small fire-box a desired high rate of combustion sometimes demands a draft strong enough to raise the fuel over the grate-bars. This difficulty is avoided in the large fire-box, where sufficient combustion for rapid steaming is produced with less intensity of blast.

=294. Recent Improvements in Locomotive Design.=—Concurrently with the development of the Wootten type of boiler, other wide fire-box types have been brought to a high state of excellence. In reality general locomotive progress within the past few years has been summed up by Mr. F. J. Cole as follows:

(_a_) The general introduction of the wide fire-box for burning bituminous coal.

(_b_) The use of flues of largely increased length.

(_c_) The improvements in the design of piston-valves and their introduction into general use.

(_d_) The recent progress made in the use of tandem compound cylinders.

[Illustration: FIG. 26.]

The piston-valve, to which reference is made, is a valve in the shape of two pistons connected by an enlarged stem or pipe the entire length of the double piston, the arrangement depending upon the length of steam-cylinder or stroke; it may be 31 or 32 inches. This piston-valve is placed between the steam-cylinder and the boiler, and is so moved by eccentrics attached to the driving-wheel axles through the medium of rocking levers and valve-stems as to admit steam to the cylinder at the beginning of the stroke and allow it to escape after the stroke is completed. Fig. 26 shows a section through the centre of one of these piston-valves. It will be noticed that the live steam is admitted around a central portion of the valve, and that the steam escapes through the exhaust-passages at each end of the piston-valve. This type of valve is advantageous with high steam pressures for the reason that its "blast," i.e., the steam pressure, does not press it against its bearings as is the case with the old type of slide-valve, the wear of which with modern high steam pressures would be excessive, although under more recent slide-valve design this objection does not hold.

[Illustration: FIG. 27.]

=295. Compound Locomotives with Tandem Cylinders.=—The tandem compound locomotive, as recently built, is a locomotive in which the high-pressure cylinder is placed immediately in front of the low-pressure cylinder and in line with it. In the Vauclain type it is necessary to have a piston-rod for each of the two cylinders, one above the other, each taking hold of the same cross-head. In the tandem arrangement with the two cylinders each in line, but one piston-rod is required. An example of a locomotive with this tandem arrangement of compound cylinders will be shown farther on.

[Illustration: FIG. 28.]

Figs. 27 and 28 show two sections, one transverse and one longitudinal, of a type of large fire-box boiler built by the American Locomotive Works at Schenectady. The diameter of the barrel of the boiler in front of the fire-box is about 5 feet 8 inches, while the clear greatest width of the fire-box is 5 feet 4½ inches. The length of the latter is 8 feet 7 inches, making a total grate area in this

particular instance of over 45 square feet. There are 338 2-inch tubes, each 16 feet in length. The total length over all of the boiler is 31 feet ½ inch. The result of such a design is an arrangement by which a large grate area is secured and a corresponding high rate of combustion without a too violent draft. In designing locomotive boilers for bituminous coal one square foot of grate area is sometimes provided for each 60 to 70 square feet of heating surface in the tubes.

[Illustration: FIG. 29.]

=296. Evaporative Efficiency of Different Rates of Combustion.=—In the development of this particular class of locomotive boilers it is to be remembered that as a rule the highest rates of combustion frequently mean a decreased evaporation of water at boiler pressure per pound of fuel. Modern locomotives may burn over 200 pounds of coal per square foot of grate area per hour, and in doing so the evaporation may be less than 5 pounds of water per pound of fuel. On the other hand, when the coal burned does not exceed 50 pounds per square foot of grate area per hour, as much as 8 pounds of water may be evaporated for each pound of coal. It is judicious, therefore, to have large grate area, other things being equal, in order that the highest attainable efficiency in evaporation may be reached.

=296a. Tractive Force of a Locomotive.=—The tractive force of a locomotive arises from the fact that one solid body cannot be moved over another, however smooth the surface of contact may be, without developing the force called resistance of friction. This resistance is measured by what is called the coefficient of friction, determined only by experiment. The resistance of friction and this coefficient will depend both upon the degree of smoothness of the surface of contact and on its character. If surfaces are lubricated, as in the moving parts of machinery, the force of friction is very much decreased, but in the absence of that lubricant it will have a much higher value. The coefficient of friction is a ratio which denotes the part of the weight of the body moved which must be applied as a force to that body in order to put it in motion against the resistance of friction. In the case of lubricated surfaces this ratio may be as small as a few hundredths. In the case of locomotive driving-wheels and the track on which they rest this value is usually taken at .2 to .25.

There are times when it is desirable to increase the resistance of friction between locomotive drivers and the rails. For this purpose a simple device, called the sand-box, is frequently placed on the top of a locomotive boiler with pipes running down from it so as to discharge the sand on the rails immediately in front of the drivers. The sand is crushed under the wheels and offers an increased resistance to their slipping.

The tractive force of a locomotive may also be computed from the pressure of steam against the pistons in the steam-cylinders. If the indicated horse-power in the cylinder be represented by H.P., and if all frictional or other resistance between the cylinder and the draw-bar be neglected, the following equality will hold:

Draw-bar pull × speed of train in miles } per hour × 5280 } = H.P. × 33,000 × 60.

If _S_ = speed in miles per hour, and if _T_ = draw-bar pull, then the preceding equality gives

$$375 \times \text{H.P.} \quad _T_ = \frac{\quad}{_S_}$$

This value of the "pull" must be diminished by the friction of the locomotive as a machine, by the rolling resistance of the trucks and tender, and by the atmospheric resistance of the locomotive as the head of the train. Prof. Goss proposes the following approximate values for these resistances in a paper read before the New England Railroad Club in December, 1901.

A number of tests have shown that a steam pressure of 3.8 pounds per square inch on the piston is required to overcome the machine friction of the locomotive. Hence if _d_ is the diameter of the piston in inches, _L_ the piston-stroke in feet, and _D_ the diameter of driver in feet, while _f_ is that part of the draw-bar pull required to overcome machine friction, the following equation will hold:

$$\pi _d_^2 _f_ . \pi _D_ = 3.8 \frac{\quad}{\quad} \times 2 _L_ \times 2.4$$

$$_d^2 L_ \therefore _f_ = 3.8 \frac{\quad}{\quad} . _D_$$

Again, if _W_ be the rolling load in tons on tender and trucks (excluding that on drivers), and if _r_ be that part of the draw-bar pull required to overcome the rolling resistance due to _W_, then experience indicates that approximately, in pounds,

$$\left(\frac{_S_}{\quad} \right) _r_ = \left(2 + \frac{\quad}{\quad} \right) _W_ . \quad (6)$$

As before, _S_ is the speed in miles per hour.

Finally, if _h_ be that part of the draw-bar pull in pounds required to overcome the head resistance (atmospheric) of the locomotive, there may be written approximately

$$h = .11 S^2.$$

The actual draw-bar pull in pounds available for moving the train will then be

$$t = T - f - r - h = \frac{375 \text{ H.P.}}{S} - 3.8 - W\left(2 + \frac{d^2 L}{S}\right) - .11 S^2. \quad (6)$$

The maximum value of _t_ should be taken as one fourth the greatest weight on drivers.

If _H_ is the total heating surface in square feet, and if 12 pounds of water be evaporated per square foot per hour, while 28 pounds of steam are required per horse-power per hour, then

$$\frac{12 H}{28} = \frac{375 \text{H.P.}}{S} \text{ and } \frac{161 H}{S} = \text{H.P.}$$

Hence

$$t = \frac{161 H d^2 L}{S} - 3.8 - W\left(2 + \frac{d^2 L}{S}\right) - .11 S^2. \quad (6)$$

The actual draw-bar pull in pounds may then be computed by this formula.

Some recent tests of actual trains (both heavy and light) on the N. Y. C. & H. R. R. R. between Mott Haven Junction and the Grand Central Station, New York City, a distance of 5.3 miles, by M. Bion J. Arnold, by means of a dynamometer-car, gave the actual average draw-bar pull per ton of 2000 pounds as ranging from 12 to 25 pounds going in one direction and 12.1 to 24 pounds in the opposite direction. There were eight tests in each direction, and the greatest speed did not exceed 30 miles per hour.

As the diameter of the driver appears in the preceding formulæ, it may be well to state that an approximate rule for that diameter is to make it as many inches as the desired maximum speed in miles per hour, i.e., 70 inches for 70 miles, or 80 inches for 80 miles, per hour.

=297. Central Atlantic Type of Locomotive.=—Fig. 29 represents what is termed the Central Atlantic type (single cylinder) of engine, which is used for hauling most of the fast passenger trains on the New York Central and Hudson River Railroad. The characteristics of boiler and fire-box are such as are shown in Figs. 27 and 28.

The cylinders are 21 inches internal diameter, and the stroke is 26 inches. The total grate area is 50 square feet, and the total heating surface 3500 square feet. The total weight of the locomotive is 176,000 pounds, with 95,000 on the drivers. It will be observed that the total weight of locomotive per square foot of heating surface is scarcely more than 650 pounds, which is a low value. The boiler pressure carried may be 200 pounds per square inch or more. The tractive force of this locomotive may be taken at 24,700 pounds. There is supplied to these engines, among others, what is called a traction-increasing device. This traction-increaser is nothing more nor less than a compressed-air cylinder secured to the boiler, so that as its piston is pressed outward, i.e., downward, it carries with it a lever, the fulcrum of which is on the equalizing-lever of the locomotive frame, the other or short end of the lever being attached to the main bar of the frame itself. This operation redistributes the boiler-load on the frame, so as to increase that portion which is carried by the drivers. This has been found to be a convenient device in starting trains and on up grades. In the present instance the traction-increaser may be operated so as to increase the load on the drivers by about 12,000 pounds. It is not supposed to be used except when needed under the circumstances indicated.

[Illustration: FIG. 30.]

A number of indicator-cards taken from the steam-cylinders of these engines hauling the Empire State Express and other fast passenger trains on the Hudson River Division of the N. Y. C. & H. R. R. R., show that with a train weighing about 208 tons while running at a speed of 75 miles per hour 1323 H.P. was developed. Fig. 30 shows these indicator diagrams. With a train weighing 685 tons 1452 H.P. was indicated at a speed of 63 miles per hour.

=298. Consolidation Engine, N. Y. C. & H. R. R. R.=—One of the heaviest wide fire-box compound consolidation engines recently built for the New York Central freight service is shown in Fig. 31. It will be noticed that there is but one cylinder on each side of the locomotive, and that they are of different diameters. One of these cylinders, 23 inches inside diameter, is a high-pressure cylinder,

and the other, 35 inches inside diameter, is a low-pressure cylinder, the stroke in each case being 34 inches. The total grate area is 50.3 square feet, the fire-box being 8 feet long by 6 feet 3 inches wide. The total heating surface is 3480 square feet. The diameter of the barrel of the boiler at the front end is 72 inches, and the diameter of the drivers 63 inches. The pressure of steam in the boiler is 210 pounds per square inch. The total weight of the locomotive is 194,000 pounds, of which 167,000 rests upon the drivers. These engines afford a maximum tractive force of 37,900 pounds. This engine is typical of those used for the New York Central freight service. They have hauled trains weighing nearly 2200 tons over the New York Central road.

[Illustration: FIG. 31.]

=299. P., B. & L. E. Consolidation.=—The consolidation locomotive shown in Fig. 32 is a remarkable one in that it was for a time the heaviest constructed, but its weight has since been exceeded by at least two of the Decapod type built for the Sante Fé company. It was built at the Pittsburg works of the American Locomotive Company for the Pittsburg, Bessemer and Lake Erie Railroad to haul heavy trains of iron ore. The total weight is 250,300 pounds, of which the remarkable proportion of 225,200 is carried by the drivers. The tender carries 7500 gallons of water, and the weight of it when loaded is 141,100 pounds, so that the total weight of engine and tender is 391,400 pounds. The average weight of engine and tender therefore approaches 7000 pounds per lineal foot. This is not a compound locomotive, but each cylinder has 24 inches inside diameter and 32 inches stroke, the diameter of the driving-wheels being 54 inches. The boiler carries a pressure of 220 pounds, and the tractive force of the locomotive is 63,000 pounds.

[Illustration: FIG. 32.]

A noticeable feature of this design, and one which does not agree with modern views prompting the design of wide fire-boxes, is its great length of 11 feet and its small width of 3 feet 4¼ inches. There are in the boiler 406 2¼-inch tubes, each 15 feet long, the total heating surface being 3805 square feet.

=300. L. S. & M. S. Fast Passenger Engine.=—The locomotive shown in Fig. 33 is also a remarkable one in some of its features, chief among which is the 19 feet length of tubes. It was built at the Brooks works of the American Locomotive Company for the Lake Shore and Michigan Southern Railroad. The total weight of engine is 174,500 pounds, of which 130,000 pounds rests upon the drivers. The rear truck carries 23,000 pounds and the front truck 21,500 pounds. This is not a compound engine. The cylinders have each an inside diameter of 20½ inches, and 28 inches stroke. As this locomotive is for fast passenger traffic, the driving-wheels are each 80 inches in diameter, and the driving-wheel base is 14 feet. The fire-box is 85 × 84 inches, giving a grate area of 48½ square feet and a total heating surface of 3343 square feet. There are 285 2¼-inch flues, each 19 feet long. The tender carries 6000 gallons of water. Cast and compressed steel were used in this design to the greatest possible extent, and the result is shown in that the weight divided by the square feet of heating surface is 52.18 pounds.

[Illustration: FIG. 33.]

=301. Northern Pacific Tandem Compound Locomotive.=—The diagram shown in Fig. 34 exhibits the outlines and main features of a tandem compound locomotive to which allusion has already been made. It was built at Schenectady, New York, in 1900, for the Northern Pacific Railroad, and was intended for heavy service on the mining portions of that line.

The diameters of the high- and low-pressure cylinders are respectively each 15 and 28 inches, with a stroke of 34 inches, while the boiler pressure is 225 pounds per square inch. The total weight of the machine is 195,000 pounds and the weight on the drivers 170,000 pounds, the diameter of the drivers being 55 inches. As the figure shows, it belongs to the consolidation type. The fire-box is 10 feet long by 3.5 feet wide, giving a grate area of 35 square feet, with which is found a total heating surface of 3080 square feet. There are 388 2-inch tubes, each 14 feet 2 inches long. These engines are among the earliest compound-tandem type and have been very successful. Other locomotives of practically the same general type have been fitted with a wide fire-box, 8 feet 4 inches long by 6 feet 3 inches wide, with the grate area thus increased to 52.3 square feet.

[Illustration: FIG. 34.]

=302. Union Pacific Vauclain Compound Locomotive.=—The next example of modern locomotive is the Vauclain compound type used on the Union Pacific Railroad. It is a ten-wheel passenger engine and one of a large number in use. The weight on the drivers is 142,000 pounds, and the total weight of the locomotive is about 185,000 pounds. The high-pressure cylinder has an inside diameter of 15½ inches, while the low-pressure cylinder has a diameter of 26 inches. The stroke is 28 inches and the diameter of the driving-wheels 79 inches. On the Union Pacific Railroad the diameter of the driving-wheel varies somewhat with the grades of the divisions on which the engines run.

[Illustration: FIG. 35.]

In some portions of the country, as in Southern California, oil has come into quite extended use for locomotive fuel.

=303. Southern Pacific Mogul with Vanderbilt Boiler.=—The locomotive shown in Fig. 36 belongs to the Mogul type, having three pairs of driving-wheels and one pair of pilots. It is fitted with the Vanderbilt boiler adapted to the use of oil fuel. The locomotives of which this is an example were built for the Southern Pacific Company, and they have performed their work in a highly satisfactory manner. They are not particularly large locomotives as those matters go at the present day, as they carry about 135,000 pounds on the drivers and 22,000 pounds on the truck, giving a total weight of 157,000 pounds. The characteristic feature of the machine is its adaptation to the burning of oil, which requires practically no labor in firing, although the services of a fireman must still be retained.

[Illustration: FIG. 36.]

=304. The "Soo" Decapod Locomotive.=—It has been seen that the results of Trevethick's early efforts was a crude and simple machine, with what might be termed, in courtesy to that early attempt, a single pair of drivers. Subsequently, as locomotive evolution took place, two pairs of drivers coupled with the horizontal connecting-rod were employed. Then the Mogul with the three pairs of coupled drivers was used, and at or about the same time the consolidation type with four pairs of coupled drivers was found adapted in a high degree to the hauling of great freight trains. The last evolution in driving-wheel arrangement is exhibited in Fig. 37. It belongs to what is called the Decapod type. As a matter of fact, five pairs of coupled driving-wheels have been occasionally used for a considerable number of years, but this engine is the Decapod brought up to the highest point of modern excellence. As shown, it uses steam by the Vauclain compound system, the small or high-pressure cylinder being underneath the low-pressure cylinder. They have been built by the Baldwin Locomotive Works for the Minneapolis, St. Paul and Sault Ste. Marie Railroad Company, on what is called the "Soo Line." It has given so much satisfaction that more of this type but of greater weight are being built for the same company. This engine was limited to a total weight of 215,000 pounds, with 190,000 pounds on the drivers.

[Illustration: FIG. 37.]

[Illustration: FIG. 38.]

[Illustration: FIG. 39.]

[Illustration: FIG. 40.]

=305. The A., T. & S. F. Decapod, the Heaviest Locomotive yet Built.=—The heaviest locomotive yet constructed, consequently occupying the primacy in weight, is that shown in Fig. 38. It is a Decapod operated with others of its type by the A., T. & S. F. Company near Bakersfield, California. It is a tandem compound coal-burner, as shown by the illustration, the high-pressure cylinder being in front of the low-pressure. The dimensions of cylinders are 19 and 32 × 32 inches stroke, and the driving-wheels are 57 inches in diameter. The total height from the top of stack down to the rail is 15 feet 6 inches, while the height of the centre of the boiler above the rails is 9 feet 10 inches. Figs. 39 and 40 show some of the main boiler and fire-box dimensions. There are 463 2¼-inch tubes, each 19 feet long. The total heating surface is 5390 square feet, about one eighth of an acre, the length of the fire-box being 108 inches and the width 78 inches. The heating surface in the tubes is 5156 square feet, and in the fire-box 210.3 square feet; the grate surface having an area of 58.5 square feet. The boiler is designed to carry a working pressure of 225 pounds per square inch, the boiler-plates being ¹■/■■ inch, ■/■■ inch, and ■ inch thick, according to location. As shown by the illustrations, the boiler is what is termed an extended wagon-top with wide fire-box. The total weight of the locomotive itself is 267,800 pounds, while the weight on the driving-wheels is 237,800 pounds, making 47,560 pounds on each axle. The tractive force of this locomotive is estimated to be over 62,000 pounds.

=306. Comparison of Some of the Heaviest Locomotives in Use.=—The following table gives a comparison of the heaviest locomotives thus far built, as taken from the _Railroad Gazette_ for January 31, 1902, revised to September 1, 1902.

COMPARISON OF HEAVIEST LOCOMOTIVES.

---------- | Atchison, | Pittsburg, | Union | Topeka | Bessemer & | Railroad. | & Santa Fé. | Lake Erie. | ---------- Name of builder | Baldwin | Pittsburg | Pittsburg Size of cylinders |19 & 32 × 32 in.|24 × 32 in. |23 × 32 in. Total weight | 267,800 lbs. |250,300 lbs. |230,000 lbs. Weight on drivers | 237,800 lbs. |225,200 lbs. |208,000 lbs. Driving-wheels, diam.| 57 in. | 54 in. | 54 in. Heating surface | 5,390 sq. ft. |3,805 sq. ft.|3,322 sq. ft. Grate area | 58.5 sq. ft. |36.8 sq. ft. |33.5 sq. ft. ---------- | Illinois | Lehigh | Central. |

Valley. ----------+----------+---------- Name of builder | Brooks | Baldwin Size of cylinders | 23 × 30 in. | 18 & 30 × 30 in. Total weight | 232,200 lbs. | 225,082 lbs. Weight on drivers | 193,200 lbs. | 202,232 lbs. Driving-wheels, diam.| 57 in. | 55 in. Heating surface | 3,500 sq. ft. | 4,104 sq. ft. Grate area | 37.5 sq. ft. | 90 sq. ft. ----------+----------+----------

These instances of modern locomotive construction are impressive, especially when considered in contrast with the type of engine in use not more than fifty years ago. They indicate an almost incredible advance in railroad transportation, and they account for the fact that a bushel of wheat can be brought overland at the present time from Chicago to New York City, a distance of 900 miles, for about one third of the lowest charge for delivering a valise from the Grand Central Station in the city of New York to a residence within a mile of it.

PART V.

THE NICARAGUA ROUTE FOR A SHIP-CANAL.

=307. Feasibility of Nicaragua Route.=—The feasibility of a ship-canal between the two oceans across Nicaragua has been recognized almost since the discovery of Lake Nicaragua in 1522 by Gil Gonzales de Avila, who was sent out from Spain to succeed Balboa, after the execution of the latter by Pedro Arias de Avila at Acla on the Isthmus of Panama.

=308. Discovery of Lake Nicaragua.=—Gil Gonzales set sail from the Bay of Panama in January of that year northward along the Pacific coast as far as the Gulf of Fonseca. He landed there and proceeded to explore the country with one hundred men, and found what he considered a great inland sea, as we now know, about 14 miles from the Pacific Ocean at the place of least separation. The country was inhabited, and he found a native chief called Nicarao, who was settled with his people at or near the site of the present city of Rivas. As he found it a goodly country, fertile and abounding in precious metals, he immediately proceeded to take possession of it for his sovereign, but the Spanish explorer was sufficiently gracious to the friendly chief to name Lake Nicaragua after him. From that time the part of Nicaragua in the vicinity of the lake received much attention, and the Spaniards made conquest of it without delay. Among those who were the earliest visitors was a Captain Diego Machuca, who, with two hundred men under his command, explored Lake Nicaragua in 1529 and constructed boats on it, a brigantine among them. He seems to have been the first one who entered and sailed down the Desaguadero River, now called the San Juan, and one of the rapids in the upper portion of the river now bears his name. He pursued his course into the Caribbean Sea and sailed eastward to the Isthmus of Panama.

[Illustration: Map of American Isthmus, showing Proposed Canal Routes.]

=309. Early Maritime Commerce with Lake Nicaragua.=—Subsequently sea-going vessels passed through the San Juan River in both directions and maintained a maritime trade of some magnitude between the shores of Lake Nicaragua and Spain. Obviously these vessels must have been rather small for ocean-going craft, unless there was more water in the San Juan River in those early days than at present. There are some obscure traditions of earthquakes having disturbed the bed of the river and made its passage more difficult by reducing the depth of water in some of the rapids; but these reports are little more than traditionary and lack authoritative confirmation. It is certain, however, that the marine traffic, to which reference has been made, was maintained for a long period of years, its greatest activity existing at about the beginning of the seventeenth century. It was in connection with this traffic probably that the city of Granada at the northwestern extremity of the lake was established, perhaps before 1530.

=310. Early Examination of Nicaragua Route.=—Although the apparently easy connection between the Caribbean Sea and Lake Nicaragua, together with the proximity of the latter to the Pacific coast, at once indicated the possibility of a feasible water communication between the two oceans, probably no systematic investigation to determine a definite canal line was made until that undertaken by Manuel Galisteo in 1779 under the instruction of Charles III., who was then on the throne of Spain. Galisteo made a report in 1781 that Lake Nicaragua was 134 feet higher than the Pacific Ocean, and that high mountains intervened between the lake and the ocean, making it impracticable to establish a water communication between the two. In spite of the discouragement of this report a company was subsequently formed under the patronage of the crown to construct a canal from Lake Nicaragua along the Sanoa River to the Gulf of Nicoya, but nothing ever came of the project.

=311. English Invasion of Nicaragua.=—The country was invaded in 1780 by an English expedition sent out from Jamaica under Captain Horatio Nelson, who subsequently became the great admiral. He proceeded up the San Juan River, and after some fighting captured by assault Fort San Juan at Castillo Viejo. Nelson and his force, however, were ill qualified to take care of themselves in that tropical country where drenching rains were constantly falling, and he was therefore obliged to abandon his plan

of taking possession of Lake Nicaragua and returned instead to Jamaica. The tropical fevers induced by exposure reduced the crew of his own ship, two hundred in number, to only ten after his return to Jamaica, and he himself nearly lost his life by sickness.

=312. Atlantic and Pacific Ship-canal Company.=—Subsequently to this period the Nicaragua route attracted more or less attention until Mr. E. G. Squier, the first consul for the United States in Nicaragua, negotiated a treaty between the two countries for facilitating the traffic from the Atlantic to the Pacific Ocean by means of a ship-canal or railroad in the interest of the Atlantic and Pacific Ship-canal Company, composed of Cornelius Vanderbilt, Joseph L. White, Nathaniel Wolfe, and others. It was at this time that the Nicaragua route became prominent as a line of travel between New York and San Francisco. Ships carried passengers and freight from New York to Greytown, then trans-shipped them to river steamboats running up the San Juan River and across the southerly end of the lake to a small town called La Virgin, whence a good road for 14 miles overland led to the Pacific port of San Juan del Sur. Pacific coast steamships completed the trip between the latter port and San Francisco.

=313. Survey and Project of Col. O. W. Childs.=—This traffic stimulated the old idea of a ship-canal across the Central American isthmus on the Nicaragua route to such an extent that Col. O. W. Childs, an eminent civil engineer, was instructed by the American Atlantic and Pacific Ship-canal Company to make surveys and examinations for the project of a ship-canal on that route. The results of his surveys, made in 1850-52, have become classic in interoceanic canal literature. He concluded that the most feasible route lay up the San Juan River from Greytown to Lake Nicaragua, across that lake, and down the general course of the Rio Grande on the west side of Nicaragua to Brito on the Pacific coast. This is practically identical with the route adopted by the Isthmian Canal Commission now (1902) being discussed in Congress.

=314. The Project of the Maritime Canal Company.=—The project planned by Col. Childs, like those which preceded it, had no substantial issue, but the general subject of an isthmian canal across Nicaragua was, from that time, under almost constant agitation and consideration more or less active until the Maritime Canal Company of Nicaragua was organized in February, 1889, under concessions secured from the governments of Nicaragua and Costa Rica by Mr. A. G. Menocal. This company made a careful examination of all preceding proposed routes, and finally settled upon a plan radically different in some respects from any before considered. The Caribbean end of the canal was located on the Greytown Lagoon west of Greytown. From that point the line followed up the valley of the Deseado River and cut across the hills into the valley of the San Juan above its junction with the San Carlos. A dam was to be constructed across the San Juan River at Ochoa, below the mouth of the San Carlos, so as to bring the surface of Lake Nicaragua down to that point. From its junction with the San Juan River the canal line followed that river to the lake, across the latter to Las Lajas, and thence down the Rio Grande to the Pacific coast at Brito. It was contemplated under this plan to carry the lake level to a point called La Flor, 13.5 miles west of the lake, and drop down to the Pacific from that point by locks suitably located. After partially excavating the canal prism for about three quarters of a mile from the Greytown Lagoon, constructing a line of railroad up the Deseado valley, as well as a telegraph line, and doing certain other work preparatory to the actual work of construction, the Maritime Canal Company became involved in financial difficulties and suspended operations without again resuming them.

[Illustration: Breakwater of the Maritime Canal Company. The closed former entrance to Greytown harbor is shown on the left.]

=315. The Work of the Ludlow and Nicaragua Canal Commissions.=—In 1895 and again in 1897 two commissions were appointed by the President of the United States to consider the plans and estimates of the Maritime Canal Company in the one case, and the problem of a ship-canal on the Nicaragua route in the latter. Neither of these commissions, however, had the funds at its disposal requisite for a full and complete consideration of the problem. In 1899, therefore, the Isthmian Canal Commission was created by Act of Congress, and appointed by the President of the United States, to determine the most feasible and practical route across the Central American isthmus for a canal, together with the cost of constructing it and placing it under the control, management, and ownership of the United States. This commission consisted of nine members, and included civil and military engineers, an officer of the navy, an ex-senator of the United States, and a statistician. It was the province and duty of this commission to make examinations of the entire isthmus from the Atrato River in the northwestern corner of South America to the western limits of Nicaragua for the purpose of determining the most feasible and practical route for a ship-canal between those territorial limits. This brings the general consideration of the isthmian canal question to the Nicaragua route in particular, to which alone attention will be directed in this part.

=316. The Route of the Isthmian Canal Commission.=—The Isthmian Canal Commission adopted a route practically following the San Juan River from near Greytown to the lake, across the latter to Las Lajas on its westerly shore, and thence up the course of the Las Lajas River, across the continental divide into the Rio Grande valley, and down the latter to Brito at the mouth of the Rio

Grande on the Pacific coast. As has already been stated, this is practically the line adopted by Col. Childs almost exactly fifty years ago. It is also essentially the route adopted by the Nicaragua Canal Commission appointed in 1897, and which completed its operations immediately prior to the creation of the Isthmian Canal Commission. The amount of work performed in the field under the direction of the commission can be realized from the statement that twenty working parties were organized in Nicaragua with one hundred and fifty-nine civil engineers and other assistants, and four hundred and fifty-five laborers.

=317. Standard Dimensions of Canal Prism.=—By the Act of Congress creating it, the latter commission was instructed to consider plans and estimates for a canal of sufficient capacity to accommodate the largest ships afloat. In order to meet the requirements of those statutory instructions the commission decided to adopt 35 feet as the minimum depth of water in the canal throughout its entire length from the deep water of one ocean to that of the other, wherever the most feasible and practical route might be located, the investigations of the commission having shown that the final location to be selected must narrow down to a choice between the Panama and the Nicaragua routes. It was further decided by the commission that the standard width of excavation at the bottom of the canal should be 150 feet, with 500 feet for the ocean entrances to harbors, and 800 feet in those harbors. Greater widths than that of the bottom of standard excavations were also adopted for river and lake portions. The slopes of the sides of the excavation were determined to be 1 vertical on 1½ horizontal for firm earth, but as flat as 1 vertical on 3 or even 6 horizontal for soft mud or silt in marshy locations. In rock cutting below water the sides of the excavation would be vertical, but as steep as 4 vertical on 1 horizontal above water.

[Illustration]

[Illustration: Standard Sections adopted by the Isthmian Canal Commission.]

The longest ship afloat at the present time (1902) is the Oceanic of the White Star Line, and its length is about 704 feet. The widest ships, i.e., the ships having the greatest beam, are naval vessels, and at the present time none has a greater beam than about 77 feet. In order to afford accommodation for further development in both length and beam of ships without leading to extravagant dimensions, the commission decided to provide locks having a usable length of 740 feet with a clear width of 84 feet. These general dimensions meet fully the requirements of the law, and were adopted for plans and estimates on both the Panama and Nicaragua routes.

=318. The San Juan Delta.=—The entire Central American isthmus is volcanic in character, and this is particularly true of the country along the Nicaragua route with the exception of the lowlands immediately back of the ocean shore line in the vicinity of Greytown. From the latter point to Fort San Carlos, where the San Juan River leaves the lake, is approximately 100 miles. With the exception of the 15 miles nearest to the seacoast the San Juan River runs mostly through a rugged country with high hills densely wooded on either side. The soil is mostly heavy clay, although the bottom of the valley immediately adjacent to the river is largely of sandy silt with some mixture of clay. Between the hills back of Greytown and the seacoast the country is almost a continuous morass covered with coarse grasses and other dense tropical vegetation, but with a number of small isolated hills projecting up like islands in the surrounding marsh, and interspersed with numerous lagoons. All this flat country has the appearance of forming a delta through which a number of mouths of the San Juan River find their way. One of these, called the Lower San Juan, empties into the Greytown Lagoon, but the main mouth of the San Juan, called the Colorado, branches from the main river at the point where the Lower San Juan begins, about 13 or 14 miles from the ocean. The Colorado itself is composed of two branches, and at the place where it empties into the sea there are a number of long narrow lagoons parallel to the seashore, appearing to indicate comparatively recent shore formation. Again, a small river called the Rio San Juanillo leaves the main river 3 or 4 miles above the junction of the lower San Juan and the Colorado, and pursues a meandering course through the low marshy grounds back of Greytown, and finally again joins the Lower San Juan near the town. This marshy lowland is underlaid by and formed largely of dark-colored sand brought down mostly from the volcanic mountains of Costa Rica by two rivers, the San Carlos and the Serapiqui, the former joining the San Juan about 44 miles and the latter about 23 miles from the sea.

[Illustration: Greytown Lagoon (formerly Greytown Harbor), showing Greytown in the Distance.]

=319. The San Carlos and Serapiqui Rivers.=—Both those Costa Rican rivers are subject to sudden and violent floods, and they bring down large quantities of this volcanic sand, the specific gravity of which is rather low. The San Carlos bears the greater burden of this kind. In fact its bed, even when not in a state of flood, is at many points at least composed of moving sands. Both rivers are clear-water streams except in high water stages. Below the junction of the San Carlos the San Juan is necessarily in times of floods a large bearer of silt and sand, but above that point it carries little or no sediment. There are no streams of

magnitude which join the San Juan between the lake and the San Carlos.

=320. The Rapids and Castillo Viejo.=—About 54 miles from the ocean are the Machuca Rapids, and from that point to a distance of about 75 miles from the ocean other rapids are found, the principal of which are the Castillo and the Toro. The Castillo Rapids are at the point called Castillo Viejo, where there is located an old Spanish fort on the top of the high hill around the base of which the river flows. The town of Castillo Viejo has a small population of perhaps 500 to 600 people. It is a place with historical associations, to which reference has already been made. It was here that Captain (afterwards Admiral) Nelson captured the Spanish fort in 1780. It is a place of some importance in connection with the river traffic in consequence of necessary transhipment of freight and passengers to overcome the rapids.

=321. The Upper San Juan.=—The upper reaches of the San Juan within about 20 miles of the lake are bordered with considerable marshy ground. In the vicinity of its exit from the lake there is a wide strip of soft marshy country around the entire southeastern shore.

=322. The Rainfall from Greytown to the Lake.=—The entire country between Greytown and the lake is intensely tropical, and the vegetation is characteristically dense. It is particularly so at Greytown, where the total annual rainfall sometimes reaches as much as 300 inches. It rains many times in a day, and nearly every day in the year. The strong easterly and northeasterly trade winds, heavy-laden with the evaporation from the tropical sea, meet the high ground in the vicinity of Greytown and precipitate their watery contents in frequent and heavy showers. The general course of the San Juan valley is a little north of west or south of east, and the trade winds appear to follow the course of the valley to the lake. The rainfall steadily decreases as the seashore is left behind, so that at Fort San Carlos, the point of exit of the river from the lake, the annual precipitation may vary from 75 to 100 inches. There is no so-called dry season between the lake and the Caribbean Sea, although at Fort San Carlos the rainfall is so small between the middle of December and the middle of May that that period may perhaps be considered, relatively speaking, a dry season. It is evident, therefore, that all the conditions are favorable to luxuriant tropical growths over this entire eastern portion of the canal route, and the coarse grasses, palms, and other tropical vegetation found in it are indescribably dense. The same general observation is applicable to the forest and undergrowth throughout the entire course of the river from Greytown to Fort San Carlos. All of the high ground is heavily timbered, with undergrowth so dense that no survey line can be run until it is first completely cut out. That observation holds with added force throughout the swampy country adjacent to the seashore. All the heavy forest growth carries dense vines and innumerable orchids, which so cover the trunks and branches of trees as in many places completely to obscure them.

[Illustration: The Maritime Canal Company's Canal Cut leading out of Greytown Lagoon.]

=323. Lake-surface Elevation and Slope of the River.=—The lake surface has an area of about 3000 square miles and varies in elevation with the amount of rainfall in its basin from about 97 or 98 to perhaps 110 feet above the ocean. The average elevation can probably be taken at about 104 feet above the sea. The length of the lake is about 103 miles, with a greatest width of 45 miles. The area of its watershed is about 12,000 square miles. Inasmuch as the length of the San Juan River from the ocean to the lake is but a little more than 100 miles, its average fall is seen to be about 1 foot per mile. The greatest slope of the river surface is at Castillo Rapids, where it falls about 6 feet in ■ of a mile. At the Machuca Rapids it falls about 4 feet in 1 mile. Fro

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THE BOOK OF WONDERS

[Illustration: HOW MAN BURROWS UNDER THE WATER

This is a picture of a section of one of the world's greatest tunnels, showing how man has learned to construct great tubes of steel beneath the surface of the water and land, in which to run the swiftly moving trains which carry him rapidly from place to place.]

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Edited and Arranged by RUDOLPH J. BODMER

Fully Indexed

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Introduction

No truly great book needs an explanation of its aim and purpose. A great book just grows, as has this Book of Wonders.

It began with the attempt of a father to answer the natural questions of the active mind of a growing boy. It developed into a nightly search for plain, understandable answers to such questions as "What makes it night?" "Where does the wind begin?" "Why is the sky blue?" "Why does it hurt when I cut my finger?" "Why doesn't it hurt when I cut my hair?" "Why does wood float?" "Why does iron sink?" "Why doesn't an iron ship sink?" on through the maze of thousands of puzzling questions which occur to the child's mind. It has grown until the answers to the mere questions cover practically the entire range of every-day knowledge, and has been arranged in such a form that any child may now find the answer to his own inquiries.

As the mind of the child matures, the questions naturally drift toward the things which the genius of man has provided for his comfort and pleasure. We have become so accustomed to the use and benefits of these wonders produced by man that we generally leave out of our books the stories of our great industries, and yet the mind of the child wonders and inquires about them. We have so long worn clothes made of wool or cotton, that we have forgotten the wonder there is in making a bolt of cloth. Every industry has a fascinating story equal to that of the silkworm, which moves its head sixty-five times a minute while spinning his thousand yards of silk.

Can you tell What happens when we telephone? How a telegram gets there? What makes an automobile go? How man learned to tell time? How a moving-picture is made? How a camera takes a picture? How rope is made? How the light gets into the electric bulb? How glass is made? How the music gets into the piano? and hundreds of others that embrace the captivating tales of how man has made use of the wonders of nature and turned them to his advantage and comfort? The Book of Wonders does this with illuminating pictures which stimulate the mind and give a bird's-eye view of each subject step by step.

Where shall such a book begin? Shall it begin with the Story of How Man Learned to Light a Fire--he could not cook his food, see at night, or keep warm without a fire; or should it begin with How Man Learned to Shoot--he could not protect himself against the beasts of the forest, and, therefore, could not move about, till the soil or obtain food to cook until he knew how to shoot or destroy.

What was the vital thing for man to know before he could really become civilized? Some means, of course, by which the things he learned--the knowledge he had acquired--could be handed down to those who came after him so that they might go on with the intelligence handed down to them. This required some means of recording his knowledge. Man had to learn to write. Without writing there could be no Book of Wonders, and the book, then, begins naturally with the Story of Mow Man Learned to Write.

THE EDITOR.

[Illustration: WRITING BY MEXICAN INDIANS THOUGHT TO BE MORE THAN TEN THOUSAND YEARS OLD.]

How Man Learned to Write

It is a long time between the day of the cave-dwellers, with their instruments of chipped stone, and the present day of the pen. Yet wide apart as are these points of time, the trend of development can with but few obstacles be traced.

The story of the pen is a natural sequence of ideas between the first piece of rock scratched upon rock by prehistoric man, and the bit of metal which now so smoothly records our thoughts.

There was a time in the unwritten history of man when necessity prompted the invention of weapons, and the minds of these primitive men were concentrated upon this point. But the arts of war did not take up their entire time; some time must have been given to other pursuits. As the mind developed, and as an aid to memory, we find them carving, engraving, incising upon the rocks their hieroglyphics, which took the form of figures of men, habitations, weapons, and the animals of their period.

[Illustration: THE STYLUS]

How Did Writing First Come About?

An apparently difficult question to answer, since without writing there can be no record of its origin, and without records no facts; yet the deduction is so clear that the answer is simple. Somewhere far, far back in the dawn of the world, back in the beginning of human history, in the epoch which we have now named the Quaternary Period, man lived in a dense wilderness surrounded by the wildest and most ferocious beasts. His home was a cave, exposed to the dangers incidental to that time and his surroundings, and he was of necessity compelled to look about for means of defense. With this idea in mind, he found that by striking one stone against another he knocked off chips, which chips could be used as arrow-heads, spears and axes. Following along these lines he discovered that by rubbing one of these chips against another there was left a mark, which was the first imitation of writing; that the sharper the edge of the chip, the deeper was the scratch, and consequently the more distinct the mark.

[Illustration: EARLIEST WAYS OF WRITING

THE FIRST IMITATION OF WRITING]

Next it was discovered that certain stones, such as flint, serpentine and chalcedony, marked more readily than others; that the elongated chip was handled with more facility; that by rubbing one stone against another the finest possible points and edges might be obtained. Thus in the Age of Stone was the long, tapering instrument of stone, the first pen, the Stylus, originated.

Then came the time, known as the Bronze Age, when men learned to hammer metal into shapes, and metal having many advantages over stone, the stylus of stone gave way to one of iron. So we find that in the time of the Egyptians, about fourteen or fifteen centuries B.C., an iron stylus was in use for marking on soapstone, limestone and waxed surfaces. An improvement in this metal stylus was that the blunt end was convex and smooth, the purpose of which was to erase and smooth over irregularities. In

some cases it was pointed with diamonds, which gave it greater cutting properties. The iron stylus was also used by the Egyptians of that period, as well as in later times, with a mallet, after the manner of the modern chisel (which indeed it resembled) for cutting out inscriptions on their monuments.

[Illustration: THE BRUSH]

~WRITING FLUIDS HELPED DEVELOPMENT~

In course of time a marking fluid was discovered, and this made necessary a writing instrument which could spread characters on parchment, tree-bark, etc. Thus it was found that by putting together a small bunch of hairs, arranging them in the shape of an acute cone, and fastening them together in some manner, an instrument could be made which would carry fluid in its path, and thus make a mark of the desired shape. The hair best adapted for the purpose was found to be camel's hair, while that of the badger and sable was also used. A tube cut from a stalk of grass answered for a holder. The hairs were held together by a piece of thread which was then drawn through the tube, thus making the first writing instrument to be used in conjunction with ink, the Brush.

[Illustration: HOW THE CHINESE IMPROVED METHODS]

Just when the Brush came into existence is not definitely known, but with this instrument the great Chinese philosopher Confucius wrote his marvelous philosophy. The Brush as a writing instrument is generally associated with the Chinese, because the Chinese use this instrument even to the present day, it being especially adapted to their letters and mode of writing. We have now a pen (brush), as well as an ink, but the material upon which the people of that age wrote, in lieu of paper, was still very crude, parchment and tree-bark being most commonly used.

[Illustration: THE QUILL]

~THE EARLIEST FORMS OF PAPER~

Just as the discovery of an ink wrought a change from the Stylus to the Brush, so the advent of papyrus, a paper made from the papyrus plant, which was much finer and more economical than parchment, brought with it a pen better adapted for this material. It was found that the Reed, or Calamo, as it was called, which grew on the marshes on the shores of Egypt, Armenia and the Persian Gulf, if cut into short lengths and trimmed down to a point, made an admirable pen for this newly discovered paper. This was the true ancient representative and precursor of the modern pen. The use of the Reed can be traced to a remote antiquity among the civilized nations of the East, where Reeds are in use now as instruments for writing.

[Illustration: HOW THE MONKS DID THEIR WRITING]

The introduction of a finer paper rendered necessary a finer instrument of writing, and the quill of the goose, swan, and, for very fine writing, of the crow, was found to be well adapted. Immense flocks of geese were raised, chiefly for their quills. The earliest specific allusion to the quill occurs in the writings of St. Isadore de Seville, seventh century, although it is believed to have been in use at an earlier period. The quill was used for many centuries. Most of the writing during its reign was done in the monasteries by the monks, and in the eighteenth century, when quill-making became quite an art, every monk and every teacher was expected to be proficient in the art of making a pen from a quill. The preliminary process of preparing the quills was first to sort them according to their quality, dry in the hot sand, then clean them of the outer skin, and harden by dipping in a boiling solution of alum and diluted nitric acid. During the last century many efforts were made to improve the quill, its great defect being speedy injury from use. Ruby points were fitted to the nib, but this was found impracticable on account of the delicacy of the work. Joseph Bramah devised, in 1809, a machine for cutting the quill into separate nibs for use in holders, thus making several pens from one quill and anticipating the form of the modern pen.

[Illustration: THE STEEL TUBE PEN]

[Illustration: THE FIRST STEEL PEN]

The quill held sway as writing instrument for many years, and with it the greatest masterpieces in literature have been written. Many attempts, however, had been made to supersede the quill by a pen not so easily injured by use, but it was not until about 1780 that, after much experimenting and numerous failures, Mr. Samuel Harrison introduced the first metallic pen.

~THE INVENTION OF THE PEN~

This pen was made as follows:

A sheet of steel was rolled in the form of a tube. One end was cut and trimmed to a point after the manner of the quill, the seam where both edges of the tube met forming the slit of the pen. This was soon after improved upon by cutting a rough blank out of a thin sheet of steel, which blank was filed into form about the nib, rounded, and with a sharp chisel marked inside where the slit was to be in the finished pen. After tempering, the nib was ground and shaped to a point suitable for fine or broad writing, as required.

[Illustration: THE MODERN STEEL PEN]

[Illustration: THE MODERN WRITING PEN]

Once started, the steel pen made rapid strides in improvement. Mr. James Perry, in 1824, started in England the manufacture of pens on a large scale, and to him as well as Gillott is due the many improvements which followed.

Perry was the first to manufacture “slip” steel pens, up to this time the pen and holder being one piece.

“In times of yore, when each man cut his quill With little Perryian skill; What horrid, awkward, bungling tools of trade Appeared the writing instruments, home made!”

~THE MODERN WAY OF WRITING~

The steel pen of the present day has reached the pinnacle of perfection, and the method of manufacture of this little but mighty instrument of writing, though of extreme interest, is practically unknown by the general public. To explain in detail the development from the rough steel to the finished pen would needs make a book in itself. And as it has been our intention to dwell, not upon the manufacture of the pen, but to trace its history and development from its most crude form, the Stylus, to the perfect and smooth-writing steel pen of to-day, we will close our story with the well-worn epigram of old, grim Cardinal Richelieu:

“Beneath the rule of men entirely great, The Pen is mightier than the Sword!”

How a Steel Pen is Made

In the picture on the following page, we see the various processes required in making a steel pen, together with a description of each process:

[Illustration: HOW A STEEL PEN IS MADE

N^o. 1. ROLLED STEEL.

N^o. 2. SCRAP.

N^o. 3. BLANKS.

N^o. 4. MARKING.

N^o. 5. PIERCING.

N^o. 6. ANNEALING.

N^o. 7. RAISING.

N^o. 8. HARDENING.

N^o. 9. TEMPERING.

N^o. 10. SCOURING.

N^o. 11. GRINDING.

N^o. 12. SLITTING.

N^o. 13. No. 1. COLLEGE PEN No. 5. SCHOOL PEN. (FINISHED PENS.) COLORING AND VARNISHING.

The pictures herewith printed are by the courtesy of the Spencerian Pen Company

Raw Material.--The sheet steel is cut into strips of a convenient length and width, and then rolled cold to the exact gauge necessary, according to the pen to be manufactured.

Cutting the Blank.--This is a mechanical operation, and is effected with the aid of a screw press, in which a pair of tools corresponding with the shape of the pen has been fixed. On pulling a lever the screw descends, driving the punch into the bed, which cuts a blank with a scissors-like action, from the strip of steel.

Marking the Name.--This is done by means of a punch fixed in the hammer of a stamp, worked by the foot. The blanks are rapidly introduced between guides fixed on the bed of the stamp, and as soon as the hammer has fallen the blank is thrown out and a new one introduced.

Piercing.--The tools for this operation are of a delicate character. The blanks are fed by hand, as above explained, and the hole punched by a screw press. This is a most important process; the pierce hole and slide slits determine the elasticity and regulate the flow of the ink on the pen.

Annealing or Softening.--The blanks are still moderately hard and before raising, it is necessary to soften them by heating to a dull red, and allowing them to gradually cool.

Raising.--The operator places one of the soft blanks on a die to which guides are affixed to keep it in position; then by moving the handle of the press, the screw descends, forcing a die which rounds the blank into the form of a pen.

Hardening.--The pen is now too soft, and is hardened by heating and the immersing in oil while hot, after which it is thoroughly cleansed from all grease.

Tempering.--The pens are now hard but very brittle, and in order to correct this defect they are placed in an iron cylinder, and kept revolving over a gas or charcoal fire until they acquire a proper temper.

Scouring.--After soaking in diluted sulphuric acid, the pens are placed in iron cylinders containing fine stone and water, or fine sand, and revolved for several hours. When taken from these cylinders they are bright and smooth.

Grinding.--This is a process performed by hand on a "bob," or wooden wheel covered with leather and dressed with emory, revolving at high speed. A light touch on the emory wheel grinds off the surface between the pierce hole and the point, to obtain proper action and to assist the flow of ink.

Slitting.--This is a hand process performed with a press, the cutters being as sharp as razors. The pen is placed in position by means of guides, and must be cut with utmost precision from the pierce hole to the point, the point must be divided exactly in the middle, the least variation making the pen defective.

Coloring and Varnishing.--The pens having been polished to a bright silver color are placed in an iron cylinder and kept revolving over a gas or charcoal fire until the tint required is produced. They are then immersed in a bath of shellac varnish, and afterwards dried in an oven.

Examination.--Every steel pen passing through the factory is most carefully examined before being boxed, and should the least fault be found, it is at once rejected.]

Why Does a Pencil Write?

You can use a pencil to write with or to make marks, because the pencil wears off if you are scratching it on a surface that is rough enough to make it do so. Writing, you know, is only a way of making marks in such a manner as to make them mean something. You cannot write with a pencil on a pane of glass, because the glass is so smooth that when you move the pencil over its surface, the pencil will not wear off. To prove to yourself that the tip of the pencil constantly wears off when you write, you have only to recall that when you write with it a pencil keeps getting shorter and shorter. A slate-pencil will wear down short by merely writing with it, but a lead-pencil must be sharpened--that is, you must keep cutting away the wood in order to get at the lead inside.

Why Can't I Write on Paper With a Slate-pencil?

You cannot do so, because it takes something with a rougher surface than paper to wear off the point of a slate-pencil. A slate is used to write on with slate-pencils, because slate wears off the end of the pencil easily, and also because you can rub out the

writing on a slate with water. Lead-pencils are used for writing on paper, but you must have a rough surface on the paper to write on even with a lead-pencil. Some kinds of papers have such a smooth surface that you cannot write on them with a lead-pencil.

How Does a Pen Write?

Writing with a pen, however, is quite different from writing with any kind of pencil, because in writing with ink we do not wear off the end of the pen, but have the ink flow from the pen. For this purpose we must have a surface that will absorb the ink from the pen, and draw the ink down off the pen and make it flow. A slate has no power of absorption and therefore cannot draw the ink. A piece of blotting paper is the best kind of paper for absorbing ink, but it is too much so for writing purposes. For writing with ink we need a comparatively hard surfaced paper that has absorbent qualities, but not too absorbent.

How Does a Blotter Take Up the Ink of a Blot?

It is because the blotter has a very excellent ability to absorb some liquids. The thinner the liquid the more easily the blotter will absorb it. Ink is thin--being mostly water--the blotter is of a loose texture and has a rough surface. This gives the blotter the ability to pick up the ink, just as a sponge would do. A sponge has what is called the power of capillary attraction and so has the blotter.

Where Does Chalk Come From?

Deposits of chalk are found on some shores of the sea. A piece of chalk such as the teacher uses to illustrate something on the blackboard at school consists of the remains of thousands of tiny creatures that at one time lived in the sea. All of their bodies excepting the chalk--called carbonate of lime in scientific language--has disappeared and the chalk that was left was piled up where it fell at the bottom of the ocean, each particle pressing against the other with the water pressing over it all until it became almost solid. It took thousands of years to make these chalk deposits of the thickness in which they are found. Later on, through changes in the earth's surface, the mountain of chalk was raised until it stood out of the water and thus became accessible to man and school teachers.

How Did Men Learn to Talk?

Talking and the words used came into being through the desire of men to communicate with each other. Before words became known and used man talked to those about him by the use of signs, gestures and other movements of the body. Even to-day when men meet who cannot talk the same language they will be seen trying to come to an understanding by the use of signs and gestures and generally with fair results. The need of more signs and gestures to express a constantly increasing number of objects and thoughts led to the introduction of sounds or combination of sounds made with the vocal cords to accompany certain signs and gestures. In this way man eventually developed a very considerable faculty for expressing himself. Sign by sign, gesture by gesture and sound by sound language was slowly developed. A man would be trying to explain something to another by sign or gesture and to make it more clear would make a sound or combination of sounds to put more expression into his efforts. Finally the other man would understand what was meant and he would tell some one else, using the same signs, gestures and sounds. Later on it would develop that to express thus any certain thought, act or the name of a thing, all of the people in the community would make this same combination of sounds, signs and gestures to express the same thing. Finally the gestures and signs would be dropped and it was found that people understood perfectly what was meant when only the sound or combination of sounds was produced. That made a word. All the other words were made in the same way, one at a time, until we had enough words to express all the ordinary things and the combination of words became a language. The children learned the language by hearing their parents talk it, and that is how men learned to talk.

How Did Shaking the Head Come to Mean "No"?

The origin of this method of indicating "No" is found in the result of the mother's efforts in the animal kingdom of trying to feed her young. A mother animal would be trying to get her young to accept the food she brought them and tried to put it in their mouths. Perhaps, however, the young animal had had sufficient food or did not fancy the kind of food offered. The natural thing to do under the circumstances would be to close the mouth tight and shake the head from side to side to prevent the mother from forcing the food into the mouth. Thus we get the closed lips and the shaking the head from side to side to mean "No." In other words, that kind of a way of saying "No" came from an effort to say "I don't want any."

How Did a Nod Come to Mean "Yes"?

The idea of nodding to mean "Yes" comes from the opposite of the action which, as just described, indicates a "No."

When the young animal was anxious to accept the offered food, it made an effort to get at the food quickly. Hence, the pushing forward of the head and the open mouth (always more or less opened when you nod to indicate "Yes") and an expression of gladness. You will notice if you see anyone nod the head to indicate "Yes" that the lips are open rather than closed, and that there is always a smile or an indication of a smile to accompany it. In other words, the nod to mean "Yes" is only another way of saying "I shall be pleased."

Why Do We Count in Tens?

When man even in his uncivilized state found it necessary to count, the only implements at hand were his fingers and toes, and as he had ten toes and ten fingers, he naturally began counting in tens, and has been doing so ever since.

When we to-day count on our fingers we confine ourselves to our fingers leaving our toes stay in our shoes, where they naturally belong. But the first men who counted used both fingers and toes, and so he was able to count twenty before he had to begin over again, while little children to-day, when they count with their fingers, must begin where they started after they reach ten.

What Does Man Mean by Counting Himself?

The expression "counting himself" was originated by the first man who counted. Such a man would count all of his fingers and toes and the result would be twenty. Then, so that he would remember the number of times he had counted himself, he made a mark some place each time he reached twenty. The mark he made was a mere scratch in the dirt or on a hoe or something else. To make a scratch you merely, of course, score the surface of whatever you happen to be scratching on, and that is how it happened that the word "score" in our language to-day means as a term in counting, twenty.

There has been a great effort made to change our system of counting in tens to one where you count in twelves. That would fit in very well with our system of measuring which is based on the foot of twelve inches, and of our calendar for recording the passage of time which has twelve months. There are many arguments in favor of this change, among the principal of which is the fact that it would make our problems of division much easier, for our ten can be evenly divided by but two of our single figures, two and five, whereas twelve can be evenly divided by four of our single figures, viz., two, three, four and six. It is believed that sooner or later the system of counting by twelve instead of ten will be adopted by the entire world for counting everything. As it is now we do part of our counting by one system and part of it by another.

Where Did All the Names of People Originate?

There is no scientific plan by which people get their names. There is not much except curious interest to be gleaned from the study of how people got their names.

In the earliest days of the world, or at least as soon as men had learned to speak by sounds, all known persons, places and groups of human beings must have had names by which they could be spoken of or to, and by which they were recognized. The study of these names and of their survival in civilization enables us in certain instances to tell what tribes inhabited certain parts of the earth now peopled by descendants of an entirely different race and of another speech altogether. We learn such things from the names of mountains and other things, for instance, which still cling to them.

The story of personal names is very complex, but comes from very simple beginnings. The oldest personal names were those which indicated a group of people rather than individuals who may have been actually related to each other or even bound together for reasons of protection or other convenience. In the races of Asia, Africa, Australia and America examination shows that groups of people who considered themselves to be of the same relationship, attached to themselves the name of some animal or other object, whether animate or inanimate, from which they claimed to be descended. This animal or object was called the "totem," and thus the earliest and most widely spread class and family names are totemistic. Such groups called themselves by names from wolves, turtles, bears, suns, moons, birds, and other objects, and these people wore badges with pictures of the animal or object from which they took their names to identify them to other people.

When, then, we come to investigate the giving of personal names among the tribes, we see that most uncivilized races gave a name to each new-born infant derived from some object or incident. So a new-born member of the "Sun" tribe would be named "Dawn," and would be known as "Dawn" of the "Sun" tribe; or perhaps a new-born son of the tribe of "Wolf" would be called "Hungry," and be known as "Hungry Wolf." A member of the "Cloud" tribe would be named "Morning," because he was born in the morning. He would always be known as "Morning Cloud."

Later, as society became more established and paternity became recognized, we find the totem name give way to a gentile name. Among the Greeks and Romans the system was early adopted and proved satisfactory. Thus we have Caius Julius Caesar. Caius indicates that he is Roman; Julius is the gentile name given him and the Caesar a sort of hereditary nickname. On the other hand, the early Greeks began the system of introducing a local name instead of the gentile name. Thus Thucydides (obtained from the grandfather), the son of Olorus, of the Deme (township) of Halimusia.

~HOW DIFFERENT NAMES ORIGINATED~

This was all right and suited the purposes of the Greeks and Romans, who had plenty of time to give full explanations in this way. But in Europe, for instance, civilization demanded more speed, and the increase of population demanded more names, so that nicknames and names indicating personal descriptions and peculiarities came into use. Such names as Long, Short, Small, Brown, White, Green and others of the same kind came from this source, and as families grew these surnames stuck to the family and parents gave their children Christian names to further distinguish them as individuals. Other surnames such as Fowler, Sadler, Smith, Farmer, etc., became attached to people because of the occupations in which they were engaged, and yet other names were derived from places. The owner of an extensive estate would be designated by a Christian name which might be George (after his King) and then to indicate his landownership, von (meaning of) Wood, making the combination of George von Wood, meaning George, the owner of the place called Wood. On the other hand, he might have working for him a laborer who lived at the place and, if his name was Hiram, they would, to indicate where he belonged, put the Wood after the Hiram; but, lest there be confusion as to his class, they would put an At before the Wood and make him Hiram Atwood, indicating his Christian name, where he worked and the fact that he was not a landowner.

Many other names were invented in similar manner. When Adams became so common that there would likely be confusion on account of there being so many of them, a son of one of the Adams family would add to the name the fact that he was a son by writing his name Adamson, and thus start a new family name. Thus, in the same way also came Willson, Clarkson, and other names of that kind.

For a long time the Jews had only one word for a name, such as Isaac, Jacob, Moses, etc. They became so numerous that it was impossible to distinguish them, and so a commission was named to give surnames to all the Jews in addition to their other names. As the race was then, as now, held in derision by the rulers of many nations into which the tribe had become scattered, the people who had charge of the naming of the Jews took advantage of the opportunity to make sport of them, and gave them such names as

Rosenstock (Rose bush),

Rosenszweig (Rose twig),

Rosenbaum (Rose tree),

Blumenstock (Flower bush),

Blumenthal (Flower valley),

etc., etc.

Our Christian names are from similar sources, and while many of them are well selected because of their beautiful meanings, there are many of them which mean nothing as words as they were only invented for the purpose of giving a new name to a new child.

Why Can You Blow Out a Candle?

When you light a candle it burns, because the lighted wick heats the wax sufficiently to turn it into gases, which mix with the oxygen in the air and produce fire in the form of light. You know it is not easy to light a candle quickly. You must hold the lighted match to the wick until the wax begins to melt and change to gases. As long as the wax continues hot enough to melt and turn to gas the

candle will burn until all burned up; but if there is a break in the continuous process of changing the wax to gas, the light will go out. Now, when you blow at the lighted candle, you blow the gases which feed the flame away from the lighted wick, and this makes a break in the continuous flow of gas from the wax to taper, and the light goes out.

[Illustration]

The Story in a Photograph

How Does a Camera Take a Picture?

When we look upon the surface of a mirror we see the image of ourself and our surroundings. The extent of the view depends upon the size of the mirror and the distance we are standing from it.

If we hold the mirror close to our face we see only the face, or perhaps but a portion of it, and the farther away we are the more the mirror will reflect, only, of course, the various images will be smaller. The mirror reflecting exactly what the eye sees, without doubt had a great influence in inducing the experiments that resulted in the process we call photography.

The taking of a photograph with a camera may in a way be compared with the action of your eyes, when you gaze upon your reflection in a mirror, or look at any object or view. Any object in a light strong enough to render it visible will reflect rays of light from every point.

Now, the eye contains a lens very similar in form to that used in a camera. This lens collects the rays of light reflected from the object looked at and brings them to a focus in the back of the eye, forming an image or picture of whatever we see, just as the mirror collects the rays of light and reflects them back through the lens of the eye.

Certain nerves transmit the impression of the image so focused in the back of the eye to the brain and we experience the sensation of sight.

What Is the Eye of the Camera?

The lens is the eye of the camera, and the process we call photography is the method employed to make permanent the image the eye or lens of the camera presents to a sensitive surface within the camera.

Fig. 1 shows a simple form of camera, it being merely a light tight box with a lens fitted to the front, and a means for holding a sensitive plate at the back, the plate being placed at just the right distance to focus the rays of light admitted through the lens in exactly the same manner as the rays of light pass through the lens of the eye and come to a focus in the back part of the eye.

Now, if we could look inside the camera we would note that the image was inverted, or upside down.

Fig. 2 will explain this.

The rays of light from “A” pass in a straight line through the lens “B” until they are interrupted by “C,” upon which they strike, forming an upside down image of the object “A.” But, you exclaim, “we do not see things upside down.” No, we do not, because some mental process readjusts this during the passing of the impression from the eye to our brain.

Let us suppose we have our camera loaded with its sensitive plate or film. We select some object or view we wish to photograph, uncover the lens for an instant, and let the light impress the image upon the sensitive surface of the plate or film. Now, how are we going to make this image permanent?

If we were to examine the creamy yellow strip of film upon which the picture was taken there would seemingly be no difference between its present appearance and before the snapshot was made.

Now let us suppose that this strip of film is a little trundle bed, and in it tucked securely away from the light are many hundreds of little chaps called silver bromides, little roly-poly fellows lying just as close together as possible, and protected by a coverlet of pure white gelatine.

~HOW A PHOTOGRAPH IS DEVELOPED~

Until the sudden flash of light in their faces when the picture was taken, they have been content to lie still and sleep soundly. Now they are seized with a strange unrest, and each little atom is eager to do his part in showing your picture to the world. Alone they are powerless, but they have, all unbeknown to them, some powerful chemical friends, who, organized and aided by the photographer, will bring about their transformation. These chemicals, with the help of the photographer, form themselves into a society called the developer.

The photographer takes just so many of the tiny feathery crystals of pyro, just so many of the clear little atoms of sulphite of soda, and just so many little crystals of carbonate of soda, and tumbles them all into a beaker of clear cold water. Unaided by each other, any one of these chemicals would be powerless to help their little bromide of silver friends. The first of these chemicals to go to work is the carbonate of soda.

He tiptoes softly over to the trundle bed and gently begins turning back the gelatine covers over the little bromide of silver chaps, so that Pyro can find them in the dark.

It is Pyro's mission to transform the little silver bromides into silver metal, but he is rather an impulsive chap, so he is accompanied by sulphite of soda, who warns him not to be too rough, and whose sole mission is to strain his eagerness to help his friends.

"Go slow now," says Sulphite, "don't frighten the little silver bromides, or else you'll make them cuddle up in heaps, and the picture won't be as nice as if you wake them up gently and each little bromide stayed just where he belonged."

After all the little silver bromides that the light shone on have been transformed into metallic silver by the developer, another chemical friend has to step in and carry away all the little bromides that were not awakened by the flash of light.

This friend's name is "Hypo," and in a few minutes he has carried away all the little bromides that are still sleeping, so that the trundle bed with the now awakened and transformed silver bromides will, after washing and drying, be called a negative, and ready to print your pictures from.

If we take this negative, as it is called, and hold it up to the light, we will see that everything is reversed, not only from right to left, but also that whatever is white or light in color is dark in the negative, and that what would correspond to the darker parts of our picture are the lightest in the negative, and it is from these facts that we give it the name negative.

Now, to get our picture as it should be, we must place this negative in contact with a sheet of coated paper that is also sensitive to light.

So we place the negative and the sheet of sensitive paper in what is called a printing frame, with the negative uppermost, so that the light may shine through the negative, and impress the image upon the sheet of sensitive paper. Now, it stands to reason that if the lightest parts of our picture are the darkest in the negative that less light can pass through such portions of the negative in a given time, so that with the proper exposure to light the image upon the sheet of sensitive paper will be a correct picture of whatever the lens saw.

[Illustration: The swiftest thing that the human race has ever put into motion is the steel projectile of a twelve-inch gun. No human eye can follow its flight. Released at a pressure of forty thousand pounds to the square inch--in a heat at which diamonds melt and carbon boils--it hurls through the air at the rate of twenty-five miles a minute, and reaches the mark _ahead of its own sound_! (Pictures and story by courtesy of McClure's Magazine.)]

TWENTY-FIVE MILES A MINUTE

AN EXCLUSIVE STORY, ILLUSTRATED WITH A SERIES OF REMARKABLE PHOTOGRAPHS TAKEN WITH THE FASTEST CAMERA IN THE WORLD

BY CLEVELAND MOFFETT

~HOW SHOOTING SHELLS ARE PHOTOGRAPHED~

One of the most progressive branches of our military service is the Department of Coast Defenses, which, under the far-seeing guidance of General E. M. Weaver, holds our shores and harbors in a state of alert preparedness against foreign aggression. At Hampton Roads sits the Coast Artillery Board, composed of officers and consulting engineers to whom are referred all problems relating to coast artillery, and who have the responsibility of testing all new instruments proposed for artillery use. The purpose of

this article is to describe one among several notable achievements of the Hampton Roads Coast Artillery School, this particular work having been done by Captain F. J. Behr of the Coast Artillery Corps, who, after years of effort, has recently developed a system that makes it possible to take pictures of the swiftest moving bodies, the great steel projectiles of our biggest guns--to seize them with the camera's eye as they hurl through the air at enormous velocities or at the very moment of their emergence from the gun muzzles, and to preserve these images, never seen before, for military study and comparison. Captain Behr was ably assisted in this work by Engineer J. A. Wilson.

[Illustration: THE FASTEST CAMERA IN THE WORLD

The big gun, equipped with the fastest camera shutter in the world, about to be fired and the shell photographed.

For years a young officer of the Coast Artillery has been trying to devise a camera so incredibly swift that it will record every stage of this lightning flight from the gun-barrel to the target. At last he has succeeded. His photographs--some of them taken one hundred thousandth of a second apart--have revealed remarkable and unsuspected facts to the military world. The story of his invention had never before been told.]

Reckoning in Millionths of a Second.

Some of the increments and decrements of time involved in the series of photographs herewith published (several of them for the first time) are as small as one ten-thousandth part of a second. And Captain Behr has devised a method of taking photographs of projectiles as they arrive at a steel target and penetrate the target, inch by inch, that involves increments or decrements of time as small as the one hundred-thousandth part of a second. To the uninitiated it seems incredible that such infinitesimal divisions of time can be used in practical calculations; but every trained physicist knows that in wireless work scientists of to-day speak casually of experiments that take account of _two-tenths or one-tenth of a millionth part of a second_!

[Illustration: THE PROJECTILE EMERGING FROM MORTAR

In this photograph--the first of a remarkable series showing five stages of a moving projectile--the half-ton projectile seems to be standing still, but really it is traveling at the rate of 900 miles an hour. The gunners here work in concrete pits 34 feet high. Underneath the mounts are the powder magazines. Each pit has four mortars usually served by an entire Coast Artillery Company. The projectiles are the same as those used in the twelve-inch guns, but less powder is required because mortar projectiles are hurled high in the air, not straight at a vessel, and deliver their destructive blows downward from a great height.]

[Illustration: THE SMOKE RINGS WHICH APPEAR

This second photograph shows the projectile almost entirely out of the mortar. Its sharp nose may be seen above the "gas-ring" forming at its upper end. These "gas-rings," or "smoke-rings," come without warning, and only occasionally, perhaps once in eight or ten shots. They rise swiftly to the height of fifty or a hundred feet, growing larger and larger, and giving forth a weird, shrieking sound like a second projectile. Some insist that these "smoke-rings" are as hard as steel, owing to the enormous compression of their composing gases, and the story is told of a bird caught in the path of one of them and torn to pieces.]

What happened to the projectile after it leaves the gun, or after the discharge of the gun, and before the projectile has had time to issue from the gun-barrel? What is the action at the muzzle of gases generated? What shape do these gases assume as they leave the gun? What causes the much-discussed "gas-rings" that sometimes form when a mortar is fired, and oftener do not form? What phenomena attend the arrival of the projectile at a solid steel target? Is the steel actually fused by the heat of impact? Is it vaporized? Or what? These are some of the questions that Captain Behr set himself to solve, or to help in solving, as he worked out his methods of rapid photography. His aims were strictly military, but his results make fascinating appeal to the general imagination. Fancy doing anything in the one hundred-thousandth part of a second!

[Illustration: THE PROJECTILE HIDDEN BY THE SMOKE CONE

In the third photograph the smoke-cone is almost perfect and gives the famous "powder-puff" effect. It still hides the projectile, although the latter is traveling at a velocity that would take it from New York to Chicago in one hour. At night the "gas-rings" present a startling and fascinating appearance, burning with a reddish orange glow, and whirling with a complicated double motion, strange opalescent balls, like rings of Saturn. A study of these photographs--the first record ever made of the "gas-rings"--has led some experts to the conclusion that the cause of the rings is defective ramming of the projectile.]

[Illustration: THE PROJECTILE EMERGING FROM SMOKE CONE

The fourth photograph shows the projectile emerging from the smoke-cone about thirty feet above the muzzle of the mortar. The men who fire these mortars from the mortar-pits never see the distant target or vessel they are firing at, but point their mortars according to directions transmitted to them (usually by telephone) from observers at distant stations. And so great a degree of precision has been attained that, on certain practice occasions at Hampton Roads, a record of nine hits out of ten shots has been scored on a moving target five miles out in the ocean. This picture shows the smoke-cone as first seen by the human eye.]

Captain Behr's general idea was to utilize some phenomena connected with the discharge to actuate, by electrical connections, a mechanism that would work a rapid shutter in a properly placed camera. The phenomenon of concussion was tried first--the smash of air against a little swinging door; but this was much too slow. The projectile was hundreds of yards away before the camera had registered its picture. And that chance was gone!

[Illustration: THE PROJECTILE HIGH IN THE AIR

In the fifth photograph the projectile is seen entirely clear of the smoke-cone and well started on its long flight. Climbing into the sky at this steep angle, it will reach a height of from three to six miles before it begins to descend. There are harbors on our coasts guarded by so many guns and mortars that if these were fired simultaneously they could hurl against a given small area a converging rain of projectiles aggregating more than fifty tons in their combined mass. A minute later they could hurl another fifty tons against the same small area; and so on as long as the ammunition lasted.]

In the next trial, several months later, Captain Behr arranged to have the electrical connections made or broken by the movement of the gun-carriage itself in recoiling; but the result was unsatisfactory. Nor was he more fortunate at the succeeding target practice, when, having placed the apparatus farther forward on the parapet, he had the camera demolished by the force of the concussion and several blades of the rapid shutter broken. He was satisfied, now, that his effort to actuate the camera mechanism from the gun-carriage would never give the requisite precision in results, and he saw that he must work with a device functioning more reliably.

In the months that followed before the next target practice, the Captain did some experimenting, and finally determined making the projectile itself displace a length of piano-wire fixed across the muzzle of the gun, and thus actuate the electrical system and operate the shutter. In this way he eliminated troublesome variables of recoil, elasticity of the carriage, etc., leaving to determine only the time element of the electrical system to function. This result was admirable, and, after taking several similar pictures, the captain found that he could now operate with great precision--that is, he could get the same phase of the discharge with almost identical shapes of gas-cone and smoke-cloud, and he could get these every time.

In the fall of 1912 Captain Behr succeeded in obtaining a series of extremely rapid photographs showing a twelve-inch mortar battery in action. In taking these pictures the camera was placed on an elevation about ten feet above the concrete floor and about sixty feet back of the mortars. The electrical device for working the shutter was actuated by the mortar itself in its recoil. These pictures were taken in about one five-thousandth of a second--which is the more remarkable as the last two were taken in the shade after 4.30 A.M. The first three were taken about noon, in the sunshine, as the shadows show.

So great was the precision of the electrical device as to render possible the photographic recording of these mortar projectiles, moving at great velocities, in almost any desired position after the discharge, say two feet away from the muzzle, or six feet away, or twenty feet away, or right at the muzzle, as shown in the first mortar picture, where the great projectile has been caught in its flight half way out of the mortar.

Pictures Never Seen By the Human Eye.

~A CAMERA THAT IS FASTER THAN THE EYE~

It is interesting to note that of these five mortar pictures, representing five phases of the firing, only the last two are ever seen by the human eye. The far swifter camera, acting in about one five-thousandth of a second, has caught all these phases as reproduced here; but, to the ordinary observer standing by, the first visible impression after firing is that of the smoke-cone as developed in Number Four. The strange "powder-puff" effect shown in Number Three is never seen; nor the earlier effects in Numbers One and Two. Nor is any sound heard by an observer or by the gun crew until the third or fourth phase has been reached. This is a matter of simple calculation.

Sound travels through the air very slowly as compared with light, and in Numbers One, Two, and Three, although the crashing explosion has taken place and the projectile is already started on its long journey, the men (even the lanyard man, who is nearest), have heard nothing, since the sound-waves have not yet had time to reach their ears. Nor has the mortar itself had time to recoil, as it does presently, down into the well in the floor of the pit.

The men aboard the towing vessels that drag the floating targets during gun and mortar practice would seem to be in a dangerous position, since the tow-line is not more than two hundred yards long for guns and five hundred yards long for mortars, and a very slight error in aim or adjustment might cause a deviation of several hundred yards when the range is eight or ten thousand yards. As a matter of fact, such errors do not occur, and a gun-pointer who would make a right or left deviation from the target of ten yards, or at the most fifteen yards at a distance of five miles, would be considered unfit for his job. In one or two rare instances a towing vessel has been struck when a projectile has fallen short and then ricochetted to the right, as it invariably does owing to its rotation in that direction. The rifling of the gun-barrel causes this rotation.

[Illustration: This shows one of Captain Behr's earliest efforts to photograph the projectile from a twelve-inch gun. The man on the platform has been adjusting the electrical connections that actuate the camera mechanism. The halo effect at the muzzle of the gun is due to compressed air caused by the forward rush of the projectile. The projectile has not yet emerged from the muzzle of the gun. On the right is the place where the "Merrimac" and the "Monitor" had their famous fight.]

Sometimes these great projectiles ricochet several times, and go bounding over the water as a pebble skips along the surface of a mill-pond, only there may be the distance of a mile or more between these giant leaps.

The Projectile Travels Faster Than the Sound It Makes.

A strange phenomenon is witnessed by the observer on a towing vessel as he looks, rather uneasily perhaps, toward the distant shore battery, that seems to be firing straight at him. First there is a flash and a puff of smoke; then nothing for a period of seconds, while the projectile is on its way; then suddenly a great splash as the mass of iron strikes the water. Up to this moment there has been no sound of the discharge, no sound of the projectile, since it travels faster than the sound-waves; but now, _after_ it has buried itself in the ocean, is heard its own unmistakable voice, a low, buzzing _um-m-m-m_ approaching from the shore. The projectile itself has arrived _before_ the sound that it makes in transit, and the sound arrives afterward. Last of all is heard the boom of the discharge.

[Illustration: A GUN THAT PHOTOGRAPHED ITS OWN SHOT

In this beautiful picture the hurling projectile was itself the photographer: that is, in passing out of the gun-barrel, it broke a length of piano-wire stretched across the muzzle and thus automatically closed an electrical circuit that actuated the camera mechanism. And so rapid was the shutter that the great shot hurled forth in the discharge photographed here has not yet had time to issue from the smoke-cone, where it is still hidden.]

Owing to the great velocity of gun projectiles, it is almost impossible for an observer near the target to see them as they approach; but a trained eye can discern the slower moving mortar projectiles as they drop out of the sky, shrieking as they come, curving downward from a height of four or five miles, half a ton falling from a height of four or five miles.

[Illustration: EXPLODING A SUBMARINE MINE

This photograph illustrates another important form of coast defense--the submarine mine. A target about 5 by 5 feet, with a red flag at its apex, is towed across the mine-field, the mines being exploded electrically from a shore station several miles away. The methods of laying and exploding these mines are carefully kept secrets. In this case a charge of five hundred pounds of the newest explosive was used. Fragments of the shattered target and mine-buoy are seen at the right of the picture. Tons of water are hurled into the air by these explosions, and hundreds of fish are killed or stunned.]

It is difficult to realize what an enormous force is released when one of these twelve-inch guns is discharged. The pressure inside of the gun behind the projectile is between thirty-five and forty thousand pounds to the square inch. No engine or machine made by man produces anything like this pressure. The boiler pressure in steam-engines, or in big turbines driven by superheated steam, does not exceed two hundred or three hundred pounds to the square inch. The huge hydraulic presses that would crumple up a steel girder do not exert a pressure of more than one thousand pounds to the square inch. The only reason a gun-barrel can resist this pressure (forty thousand pounds to the square inch) is that it is built up in a series of concentric steel hoops or tubes shrunk

one over the other until there is a resistance capacity of from seventy thousand to ninety thousand pounds to the square inch. Even at rest, the barrels of these great guns are under such enormous compression, from being thus squeezed within these outer steel coverings, that, if the retaining steel jackets were suddenly cut, the tubes would blow themselves into pieces from the violent reaction of release.

Not only does this smokeless powder, burning inside these guns, produce enormous pressure, but it generates inconceivably great heat. Water boils at 100° Centigrade; iron melts at 1400°; platinum and the most resistant metals at 2900°; while the hottest thing on earth is the temperature of the electric arc, in which carbon boils. This temperature is between 3000° and 4000° Centigrade, and is believed to be the same as that of these great powder chambers when the gun is fired. Thus a diamond, the hardest substance known, would melt in the barrel of a twelve-inch gun at the moment of discharge. The consequence is that at each discharge of a big gun a thin skin of metal inside the barrel is literally fused, and this leads to rapid erosion of the softened surfaces under the tearing pressure of gases generated. The rifling is worn away; the band over the projectile becomes loose-fitting; and soon the huge gun, that has cost such a great sum, is rendered unfit for service. The life of a twelve-inch gun is only 450 rounds, that is, the gun would be worn out if fired every three minutes for a single day. After that a new life may be given it by boring out the inner tube and putting in a new steel lining.

A Secret for Which Foreign Governments Would Pay Millions.

A few words may be added about the formidable smokeless powder used in these great guns. This powder, in spite of its terrible power, is of innocent appearance, and a small stick of it may be held safely in the hand while it burns with a vivid yellowish flame. There is no danger of its exploding or detonating like gun-cotton, and yet it is made from gun-cotton, treated by a colloiding process that is one of our jealously guarded military secrets. There are foreign governments that would give millions to know exactly how this powder is made and how it is preserved for years without deterioration. The recent destruction of two ships of the French navy was due, it is believed, to deterioration of their smokeless powder.

[Illustration]

Why Do Some Eyes In a Picture Seem to Follow Us?

If a person's picture is taken with the eyes of the person looking directly into the lens or opening of the camera, then the eyes in the picture will always be directly on and appear to follow whoever is looking at it. This is also true of paintings. If a subject being painted is posed so as to look directly at the painter, and the artist paints the picture with the eyes so pointed, then the eyes of the picture will follow you. When you are looking at a picture of a person and the eyes do not follow you, you will know at once that he was not looking at the camera or artist when the picture was being taken or painted.

[Illustration]

Where Does a Light Go When It Goes Out?

~WHY YOU CAN BLOW OUT A CANDLE~

To understand the answer to this question fully you will first have to learn what light is, and particularly that it is not the flame from the gas jet or of the lamp or candle that is actually the light, but that light consists of rays or waves in the ether, which is constantly in all space and even in our bodies, coming from the something that is burning. This in the instance above mentioned would be the gas burning as it comes out of the gas jet, the oil in the lamp as it comes up through the wick or the flame of the candle. We are apt to call a lighted gas jet a lamp, or a candle, light, because it is steady. Really, however, there is no such thing as keeping light in a room in an actual sense, for rays of light travel from the substance which produces them faster than anything else we know of in the world. The first thing a light wave does when it is once created is to go some place, and it does this at the rate of 186,000 miles per second. If it cannot penetrate the walls of the room it is either reflected back in the direction from which it came or transformed by the objects which it strikes into some other kind of energy.

When you look at the rays coming from a gas jet, you do not see one ray for more than, say the millionth part of a second, but because these rays of light come so fast one after the other from the burning jet and spread in all directions, they seem to be continuous.

So you see that the rays of light are going away as fast as they are coming from the gas jet. They either go on as light or, as said above, are changed into other forms of energy when they strike things they cannot penetrate in the form of light, or rather one thing, which is heat. A large part of it goes into the air in the room in the form of heat, as you well know, now that it is called to your attention. Some of it goes into the furniture and some of it is changed into another form of heat, which, combining with the chemicals in other things it mixes with, changes their appearance and usefulness. As, for instance, the carpets and hangings in the room, the colors of which become faded when exposed to light rays too much. The heat from the light rays is responsible for the fading of colors in our garments as well.

When you "put out the light," as we say, or turn off the gas, you cut off the source of light. Really, then, our expression that "the light goes out" is only true while the gas is lighted, for from the flaming gas jet the light is going out all the time, whereas when the gas is turned off no light is being produced, and when you turn off the gas you do not turn out the light, but only that which makes light.

Why Does a Fire Go Out?

Fire will go out naturally when there is nothing left to burn, or it will go out if it cannot secure enough oxygen out of the air to keep it going. In the first case it dies what we might call a "natural death," and in the latter case the fire practically suffocates. The fire in the open fireplace, if it has plenty of air, will burn up everything burnable that it can reach. The stones of the fireplace or other parts of a stove will not burn, because they have already been burned, and you cannot burn anything a second time, if all of the oxygen in it was burned out of it the first time.

Now, then, to burn up a thing, you must first start a fire under it, and then keep a constant draft of air playing on it from beneath, or the fire will die out. The more difficult a thing is to burn, the more important it is that you have plenty of draft. If the ashes accumulate under the fire the air cannot go through them in sufficient quantity and the fire will go out. Other things which prevent the current of air from going up through the fire will cause it to go out. That is why we close the lower door of the furnace, to keep the fire from burning out. When we shut off the draft of air from below, the fire in the furnace burns slowly, i. e., it just hangs on, so to speak.

Why Does a Lamp Give a Better Light With the Chimney On?

When a lamp is burning without a chimney it generally smokes. That is because the oil which is coming up through the wick is being only partially burned. The carbon, which is about one-half of what the oil contains, is not being burned at all, and goes off into the air in little black specks with the gases which are thrown off. The reason the carbon is not burned when the chimney is off is that there is not sufficient oxygen from the air combining with it, as it is separated from the oil in the partial combustion that is going on. To make the carbon in the oil burn you must mix it with plenty of oxygen at a certain temperature, and this can only be done by forcing sufficient oxygen through the flame to bring the heat of the flame to the point where the carbon will combine with it and burn. When you put the chimney on the lamp you create a draft which forces more oxygen through the flame, brings the heat up to the proper temperature and enables the carbon to combine with it and burn. When you take the chimney off again the heat goes down, when the draft is shut off and the lamp smokes again.

The chimney also protects the flame of the lamp from drafts from the sides and above, and helps to make a brighter light, because a steady light is brighter than a flickering one.

The draft created by the chimney also forces the gases produced by the burning oil up and away from the flame. Some of these gases have a tendency to put out a light or a fire.

Does Light Weigh Anything?

To get at the answer to this question we must go back to the definition of light. Light is a wave in the ether and contains no particles of matter. It, therefore, does not weigh anything at all.

When men had studied light thoroughly, however, they came to the conclusion that it must have the power of pressure, which, from the standpoint of results, would amount to the same thing as having weight. They reasoned that if you had a perfect balance and let sunlight shine down on one of the sides of the balance, that side should go down under the pressure of light. In their first experiments along this line men failed to show that under such conditions the side of the balance on which the light shone did go

down, but by continuous experiments it was proved finally that the light did exert a sufficient pressure to cause the scales to go down, and in effect this is the same as having weight; but this has been found to be a common property of rays of various kinds, including heat, and we, therefore, do not speak of this quality as weight, but as the power of radiating pressure.

Why Does a Stick Seem to Bend When Put in Water?

When light passes from one medium to another, as for example from glass or water to air, or from air or glass to water, the rays of light change their course, thus making them seem to be bent or broken. The rays of light from the part of the stick in the water take a different direction from the rays from the part which is out of the water, giving the appearance of breaking or bending at the place where the air and water meet. It is, of course, the light rays which are bent and not the object itself.

This bending or changing of the path of light rays is called refraction. If you place a coin in a glass of water so that it may be viewed obliquely, you can apparently see two coins, a small one through the surface of the water and another apparently magnified through the side of the glass.

This is due only to the absolute principle that rays of light change their direction in passing from one thing to another, and on this principle of the rays of light our optical instruments, including the microscope, the telescope, the camera and eyeglasses are based.

What Makes the Stars Twinkle?

I might tell you, just to show how clever I am, that stars do not twinkle at all, and leave you with that for an answer. But since they really do seem to twinkle, and that is what causes your question, I will tell you. As we have already learned in our talks about the stars and the sky in general, the stars are suns which are constantly throwing off light, just as our sun gives us light, and when this light strikes the air which surrounds the earth it meets many objects--little particles of dust and other things always floating about in it. The light comes to us in the form of rays from the stars and some of these rays strike particles of various kinds in the air and are thus interfered with. If you are looking at a lighted window some distance away and there are a lot of boys and girls or men and women running past the window, one after the other, rapidly, it will make the light in the window appear to twinkle. The twinkling is due to the interference which the rays of light encounter while traveling toward the eye.

Why Does an Onion Make the Tears Come?

That is nature's way of protecting the eyes from the smarting which the onion would cause in your eyes if the tears did not come quickly and overcome the bad effect so produced. Tears are provided for washing the ball of your eyes. Every time you wink a little tear is released from under the eyelid, and the wink spreads it all over the eyeball. This washes down the front of the eyeball and cleanses it of all dust and other things that fly at the eye from the air. Then the tear runs along a little channel, much like a trough, at the lower part of the eye, and out through a little hole in the eye, and in this case the tear is really only an eye-wash. Many things, but more often sadness or injured feelings, start the tears coming so fast from under the eyelid that the little trough at the bottom and the hole in the corner of the eye are too small to hold them or carry them off, so they roll over the edge of the lower eyelid and down the face. These are what we call tears. Among other things that will cause tear-glands to cause an over-supply of eye-wash to come down, are onions. What they give off is very trying to the eyes, and so, just as soon as the something which an onion throws off hits the eyeball, the nerves of the eye telegraph the brain to turn on the tears quickly, and they come in a little deluge and counteract the bad effect of the onion.

[Illustration: SOME REMARKABLE PICTURES WITH A FAST CAMERA]

[Illustration]

[Illustration]

[Illustration]

[Illustration]

[Illustration: THE CAVE MAN OF PREHISTORIC TIMES WHO UNCONSCIOUSLY INVENTED AMMUNITION]

The First Missile

~HOW MAN LEARNED TO SHOOT~

A naked savage found himself in the greatest danger. A wild beast, hungry and fierce was about to attack him. Escape was impossible. Retreat was cut off. He must fight for his life--but how?

Should he bite, scratch or kick? Should he strike with his fist? These were the natural defences of his body, but what were they against the teeth, the claws and the tremendous muscles of his enemy? Should he wrench a dead branch from a tree and use it for a club? That would bring him within striking distance to be torn to pieces before he could deal a second blow.

There was but a moment in which to act. Swiftly he seized a jagged fragment of rock from the ground and hurled it with all his force at the blazing eyes before him; then another, and another, until the beast, dazed and bleeding from the unexpected blows, fell back and gave him a chance to escape. He knew that he had saved his life, but there was something else which his dull brain failed to realize.

He had invented arms and ammunition!

In other words, he had needed to strike a harder blow than the blow of his fist, at a greater distance than the length of his arm, and his brain showed him how to do it. After all, what is a modern rifle but a device which man has made with his brain permitting him to strike an enormously hard blow at a wonderful distance? Firearms are really but a more perfect form of stone-throwing, and this early Cave Man took the first step that has led down the ages.

This strange story of a development has been taking place slowly through thousands and thousands of years, so that today you are able to take a swift shot at distant game instead of merely throwing stones.

[Illustration: THE SLING MAN IN ACTION

PRACTICE DEVELOPED SOME WONDERFUL MARKSMEN AMONG THE USERS OF THIS PRIMITIVE WEAPON]

We do not know the name of the man who invented the sling. Possibly he did not even have a name, but in some way he hit upon a scheme for throwing stones farther, harder, and straighter than any of his ancestors.

The men and women in the Cave Colony suddenly found that one bright-eyed young fellow, with a little straighter forehead than the others, was beating them all at hunting. During weeks he had been going away mysteriously, for hours each day. Now, whenever he left the camp he was sure to bring home game, while the other men would straggle back for the most part empty-handed.

Was it witchcraft? They decided to investigate.

Accordingly, one morning several of them followed at a careful distance as he sought the shore of a stream where water-fowl might be found. Parting the leaves, they saw him pick up a pebble from the bank and then to their surprise, take off his girdle of skin and place the stone in its center, holding both ends with his right hand.

Stranger still, he whirled the girdle twice around his head, then released one end so that the leather strip flew out and the stone shot straight at a bird in the water.

The mystery was solved. They had seen the first slingman in action.

The new plan worked with great success, and a little practice made expert marksmen. We know that most of the early races used it for hunting and in war. We find it shown in pictures made many thousands of years ago in ancient Egypt and Assyria. We find it in the Roman Army where the slingman was called a “funditor.”

Surely, too, you remember the story of David and Goliath when the young shepherd “prevailed over the Philistine with a sling and with a stone.”

Yet slings had their drawbacks. A stone slung might kill a bird or even a man, but it was not very effective against big game.

What was wanted was a missile to pierce a thick hide.

Man had begun to make spears for use in a pinch, but would you like to tackle a husky bear or a well-horned stag with only a spear for a weapon?

No more did our undressed ancestors. The invention of the greatly desired arm probably came about in a most curious way.

Long ages ago man had learned to make fire by patiently rubbing two sticks together, or by twirling a round one between his hands with its point resting upon a flat piece of wood.

[Illustration: THE "LONG BOW" IN SHERWOOD FOREST

ONE OF ROBIN HOOD'S FAMOUS BAND ENCOUNTERS A SAVAGE TUSKER AT CLOSE RANGE]

In this way it could be made to smoke, and finally set fire to a tuft of dried moss, from which he might get a flame for cooking. This was such hard work that he bethought him to twist a string of sinew about the upright spindle and cause it to twirl by pulling alternately at the two string ends, as some savage races still do. From this it was a simple step to fasten the ends of the two strings to a bent piece of wood, another great advantage since now but one hand was needed to twirl the spindle, and the other could hold it in place. This was the "bow-drill" which also is used to this day.

But bent wood is apt to be springy. Suppose that while one were bearing on pretty hard with a well-tightened string, in order to bring fire quickly, the point of the spindle should slip from its block. Naturally, it would fly away with some force if the position were just right.

[Illustration: DEER STALKING WITH THE CROSSBOW

THIS COMPACT ARM WITH ITS SMALL BOLT AND GREAT POWER WAS POPULAR WITH MANY SPORTSMEN]

There was one man who stopped short when he lost his spindle, for a red-hot idea shot suddenly through his brain.

Once or twice he chuckled to himself softly. Thereupon he arose and began to experiment. He chose a longer, springier piece of wood, bent it into a bow, and strung it with a longer thong. He placed the end of a straight stick against the thong, drew it strongly back, and released it.

The shaft whizzed away with force enough to delight him, and lo, there was the first Bow-and-Arrow!

Armed with his bow-and-arrow, man now was lord of creation. No longer was it necessary for him to huddle with his fellows in some cave to avoid being eaten by prowling beasts. Instead he went where he would and boldly hunted the fiercest of them. In other words, his brain was beginning to tell, for though his body was still no match for the lion and the bear, he had thought out a way to conquer them.

Also he was better fed with a greater variety of game. And now, free to come and go wherever he might find it, he was able to spread into various lands and so to organize the tribes and nations which at last gave us civilization and history.

A new weapon now came about through warfare. Man has been a savage fighting animal through pretty much all his history, but while he tried to kill the other fellow, he objected to being killed himself.

Therefore he took to wearing armor. During the Middle Ages he piled on more and more, until at last one of the knights could hardly walk, and it took a strong horse to carry him. When such a one fell, he went over with a crash like a tin-peddler's wagon, and had to be picked up again by some of his men. Such armor would turn most of the arrows. Hence invention got at work again and produced the Crossbow and its bolt. We have already learned how the tough skin of animals brought about the bow; now we see that man's artificial iron skin caused the invention of the crossbow.

What was the Crossbow? It was the first real hand-shooting machine. It was another big step toward the day of the rifle. The idea was simple enough. Wooden bows had already been made as strong as the strongest man could pull, and they wished for still stronger ones--steel ones. How could they pull them? At first they mounted them upon a wooden frame and rested one end on the shoulder for a brace. Then they took to pressing the other end against the ground, and using both hands. Next, it was a bright idea to put a stirrup on this end, in order to hold it with the foot.

Still they were not satisfied. "Stronger, stronger!" they clamored; "give us bows which will kill the enemy farther away than he can shoot at us! If we cannot set such bows with both arms let us try our backs!" So they fastened "belt-claws" to their stout girdles and tugged the bow strings into place with their back and leg muscles.

Who First Discovered the Power of Gunpowder?

Probably the Chinese, although all authorities do not agree. Strange, is it not, that a race still using crossbows in its army should have known of explosives long before the Christian Era, and perhaps as far back as the time of Moses? Here is a passage from their ancient Gentoo Code of Laws: "The magistrate shall not make war with any deceitful machine, or with poisoned weapons, or with cannons or guns, or any kind of firearms." But China might as well have been Mars before the age of travel. Our civilization had to work out the problem for itself.

It all began through playing with fire. It was desired to throw fire on an enemy's buildings, or his ships, and so destroy them.

Burning torches were thrown by machines, made of cords and springs, over a city wall, and it became a great study to find the best burning compound with which to cover these torches. One was needed which would blaze with a great flame and was hard to put out.

Hence the early chemists made all possible mixtures of pitch, resin, naphtha, sulphur, saltpeter, etc.; "Greek fire" was one of the most famous.

Many of these were made in the monasteries. The monks were pretty much the only people in those days with time for study, and two of these shaven-headed scientists now had a chance to enter history. Roger Bacon was the first. One night he was working his diabolical mixture in the stone-walled laboratory, and watched, by the flickering lights, the progress of a certain interesting combination for which he had used pure instead of impure saltpeter.

Suddenly there was an explosion, shattering the chemical apparatus and probably alarming the whole building. That explosion proved the new combination was not fitted for use as a thrown fire; it also showed the existence of terrible forces far beyond the power of all bow-springs, even those made of steel.

Roger Bacon thus discovered what was practically gunpowder, as far back as the thirteenth century, and left writings in which he recorded mixing 11.2 parts of the saltpeter, 29.4 of charcoal, and 29 of sulphur. This was the formula developed as the result of his investigations.

Berthold Schwartz, a monk of Freiburg, studied Bacon's works and carried on dangerous experiments of his own, so that he is ranked with Bacon for the honor. He was also the first one to rouse the interest of Europe in the great discovery.

[Illustration: THE "KENTUCKY RIFLE" WITH ITS FLINT-LOCK WAS ACCURATE BUT MUST BE MUZZLE-CHARGED]

~THE FIRST REAL FIRE ARMS~

And then began the first crude, clumsy efforts at gunmaking. Firearms were born.

Hand bombards and culverins were among the early types. Some of these were so heavy that a forked support had to be driven into the ground, and two men were needed, one to hold and aim, the other to prime and fire.

Improvements kept coming, however. Guns were lightened and bettered in shape. Somebody thought of putting a flash pan, for the powder, by the side of the touch-hole, and now it was decided to fasten the slow-match in a movable cock upon the barrel, and ignite it with a trigger. These matches were fuses of some slow-burning fiber, like tow, which would keep a spark for a considerable time. Formerly they had to be carried separately, but the new arrangement was a great convenience and made the match-lock. The cock, being curved like a snake, was called the "serpentine."

About the time sportsmen were through wondering at the convenience of the match-lock, they began to realize its inconvenience. They found that they burned up a great deal of fuse, and were hard to keep lighted. Both statements were true, so inventors racked their brains again for something better. They all knew you could bring sparks with flint and steel, and that seemed an idea worth working on. A Nuremberg inventor, in 1515, hit on the wheel-lock. In this a notched steel wheel was wound up with a key like a clock. Flint or pyrite was held against the jagged edge of the wheel by the pressure of the serpentine. You pulled the trigger, then "whirr," the wheel revolved, a stream of sparks flew off into the flash-pan, and the gun was discharged.

[Illustration: WHEEL-LOCK RIFLE]

This gun worked beautifully, but it was expensive. Wealthy sportsmen could afford them, and so for the first time firearms began to be used for hunting. Some of these sixteenth and seventeenth century nabobs had such guns of beautiful workmanship, so wrought and carved and inlaid, that they must have cost a small fortune. You will find them in many large museums to this day.

But now the robbers had their turn. There are two stories of the invention of the flint-lock. Both deal with robbers, both have good authority, and both may be true, for inventions sometimes are made independently in different places.

One story runs that the flint-lock which was often styled "Lock à la Miquelet," from the Spanish word, "Miquelitos"--marauders--told its origin in its name. The other is, that the flint-lock was invented in Holland by gangs of thieves, whose principal business was to steal poultry.

In either case the explanation is easy. The match-lock showed its fire at night and wouldn't do for thieves, the wheel-lock was too expensive, so again necessity became the mother of a far-reaching invention.

Everybody knows what the flint-lock was like. You simply fastened a flake of flint in the cock and snapped it against a steel plate. This struck off sparks which fell into the flash-pan and fired the charge.

It was so practical that it became the form of gun for all uses; thus gunmaking began to be a big industry. Invented early in the seventeenth century, it was used by the hunters and soldiers of the next two hundred years. Old people remember when flint-locks were plentiful everywhere. In fact, they are still being manufactured and are sold in some parts of Africa and the Orient. One factory in Birmingham, England, is said to produce about twelve hundred weekly, and Belgium shares in their manufacture. Some of the Arabs use them to this day in the form of strange-looking guns with long, slender muzzles and very light, curved stocks.

There were freak inventors in the flint-lock period just as there are to-day. Some of them wrestled with the problem of repeating guns, and put together a number of barrels, even seven in the case of one carbine. Others tried revolving chambers, like our revolvers, and still others, magazine stocks. Pistols came into use in many interesting shapes, but these were too practical to be considered freaks.

~WHY WE CALL THEM PISTOLS~

Pistols, by the way, are named from the town of Pistola, Italy, where they are said to have been invented and first used.

We must not forget that rifling was invented about the time that the wheel-lock appeared, and had a great deal to do with the improvement of shooting. Austrians claim its invention for Casper Zollner, of Vienna, who cut straight grooves in the barrel's bore. His gun is said to have been used for the first time in 1498, but the Italians seem to have still better warrant as these significant words appear in old Latin Italian, under date of July 28th, 1476, in the inventory of the fortress of Guastalla: "Also one iron gun made with a twist like a snail shell." The rifling made the bullet spin like a top as it flew through the air, thus greatly improving its precision.

In the year 1807 the Rev. Alexander John Forsythe, LL.D., got his patent papers for something far better than even the steady old flint. He had invented the percussion system. In some form this has been used ever since. Which is to say that when the hammer of your gun falls, it doesn't explode the powder, although it seems to. Instead it sets off a tiny portion of a very sensitive chemical compound called the "primer," and the explosion of this "primer" makes the powder go off. Of course, the two explosions come so swiftly that your ear hears only a single bang.

Primers were tried in different forms called "detonators," but the familiar little copper cap was the most popular. No need to describe them. Millions are still made to be used on old-fashioned nipple guns, even in this day of fixed ammunition.

But now we come to another great development, the Breech-loader.

[Illustration: THE MODERN AUTOMATIC RIFLE

THE MODERN SPORTSMAN WITH HIS AUTOMATIC RIFLE IS PREPARED FOR ALL EMERGENCIES]

Perhaps you have had to handle an old muzzle-loader. It was all right so long as you knew of nothing better, but think of it now that you have your beautiful breech-loader. Do you remember how sometimes you overloaded, and the kick made your shoulder lame for a week? Or how, when you were excited you shot away your ramrod? The gun fouled too, and was hard to clean, the nipples broke off, the caps split, and the breeches rusted so that you had to take them to a gunsmith. Yes, in spite of the game it got, it was a lot of trouble, now you come to think of it. How different it all is now!

[Illustration: ASSEMBLING REPEATING SHOTGUNS AND RIFLES]

Breech-loaders were hardly new. King Henry VIII of England, he of the many wives, had a match-lock arquebus of this type dated 1537. Henry IV of France even invented one for his army, and others worked a little on the idea from time to time. But it wasn't until fixed ammunition came into use that the breech-loader really came to stay--and that was only the other day. You remember that the Civil War began with muzzle-loaders and ended with breech-loaders.

[Illustration: ASSEMBLING AUTO SHOTGUNS]

[Illustration: SOME OF THE SHOOTING TESTS]

Houiller, the French gunsmith, hit on the great idea of the cartridge. If you were going to use powder, ball and percussion primer to get your game, why not put them all into a neat, handy, gas-tight case?

THE FIRST AMERICAN MADE GUNS

~HOW THE FIRST AMERICAN GUN WAS MADE~

Two men, a smith and his son, both named Eliphalet Remington, in 1816, were working busily one day at their forge in beautiful Ilion Gorge, when, so tradition says, the son asked his father for money to buy a rifle, and met with a refusal. The request was natural for the surrounding hills were full of game. The father must have had his own reasons for refusing, but it started the manufacture of guns in America.

Eliphalet, Jr., closed his firm jaws tightly, and began collecting scrap iron on his own account. This he welded skillfully into a gun-barrel, walked fifteen miles to Utica to have it rifled, and finally had a weapon of which he might well be proud.

[Illustration: TYPES OF CARTRIDGES]

In reality, it was such a very good gun that soon the neighbors ordered others like it, and before long the Remington forge found itself hard at work to meet the increasing demand. Several times each week the stalwart young manufacturer packed a load of gun-barrels upon his back, and tramped all the way to Utica where a gunsmith rifled and finished them. At this time there were no real gun-factories in America, although gunsmiths were located in most of the larger towns. All gun-barrels were imported from England or Europe.

A VISIT TO A CARTRIDGE FACTORY

~HOW AMMUNITION IS MADE~

One of the first shocks you get when you start your visit through a cartridge factory is the matter-of-fact way in which the operatives, girls in many cases, handle the most terrible compounds. We stop, for example, where they are making primers to go in the head of your loaded shell, in order that it may not miss fire when the bunch of quail whirrs suddenly into the air from the sheltering grasses. That grayish pasty mass is wet fulminate of mercury. Suppose it should dry a trifle too rapidly. It would be the last thing you ever did suppose, for there is force enough in that double handful to blow its surroundings into fragments. You edge away a little, and no wonder, but the girl who handles it shows no fear as she deftly but carefully presses it into moulds which separate it into the proper sizes for primers. She knows that in its present moist condition it cannot explode.

[Illustration: INSPECTING METALLIC SHELLS]

[Illustration: EXAMINING PAPER SHELLS]

[Illustration: WEIGHING BULLETS]

Or, perhaps, we may be watching one of the many loading machines. There is a certain suggestiveness in the way the machines are separated by partitions. The man in charge takes a small carrier of powder from a case in the outside wall and shuts the door, then carefully empties it into the reservoir of his machine, and watches alertly while it packs the proper portions into the waiting shells. He looks like a careful man, and needs to be. You do not stand too close.

[Illustration: SHOOTING ROOM OF BALLISTICS DEPARTMENT]

[Illustration: CHRONOGRAPH FOR MEASURING]

The empty carrier then passes through a little door at the side of the building, and drops into the yawning mouth of an automatic tube. In the twinkling of an eye it appears in front of the operator in one of the distributing stations, where it is refilled, and returned to its proper loading machine, in order to keep the machine going at a perfectly uniform rate; while at the same time it allows but a minimum amount of powder to remain in the building at any moment. Each machine has but just sufficient powder in its hopper to run until a new supply can reach it. Greater precaution than this cannot be imagined, illustrating as it does that no effort has been spared to protect the lives of the operators.

[Illustration: PUTTING METAL HEADS ON PAPER SHOT SHELLS]

It is remarkable that, in an output of something like four million per day, every cartridge is perfect.

Such things are not accidental. The secret is, inspection.

~TESTING MATERIALS AND PRODUCTS~

Let us see what that means. It means laboratory tests to start with. Here are brought many samples of the body paper, wad paper, metals, waterproofing mixture, fulminate of mercury, sulphur, chlorate of potash, antimony sulphide, powder, wax, and other ingredients, and even the operating materials such as coal, grease, oil, and soaps. In the laboratory we see expert chemists and metallurgists with their test-tubes, scales, Bunsen burners, retorts, tensile machines, microscopes, and other scientific looking apparatus, busily hunting for defects.

For example, one marker is examining a supply of cupro-nickel, such as is used in jacketing certain bullets. A corner of each strip is first bent over at right angles, then back in the other direction until it is doubled, then straightened. It does not show the slightest sign of breaking or cracking, in spite of the severe treatment, therefore it is perfect. Let but the least flaw appear, and the shipment is rejected.

[Illustration: WHAT A SHOT TOWER LOOKS LIKE

SHOT TOWER--TALLEST BUILDING IN CONNECTICUT]

[Illustration:

LARGEST CARTRIDGE EQUALS MORE THAN 1,000,000 OF SMALLEST (HELD ON HAND)]

Two large iron cylinders descend in the center, coming down through the ceiling from above; we are invited to look through an open port in one of these.

We see nothing but the whitened opposite wall, against which a light burns.

It appears absolutely empty, though within it is raining such a swift shower of invisible metal that if we were to stretch our hands into the apparently vacant space they would be torn from our arms.

A large water tank below is churned into foam with the impact of the falling shot, and as we look downward we make out finally the haze of motion. It is so interesting that we take the elevator and rise ten stories to the source of the shower.

Here high in the air are the large caldrons where many pigs of lead, with the proper alloy, are melted into a sort of metallic soup. This is fed into small compartments containing sieves or screens, through the meshes of which the shining drops appear and then plunge swiftly downward.

But this only begins the process. Taken from the water tanks and hoisted up again, the shot pellets, in a second journey down, through complicated devices, are sorted, tumbled, polished, graded, coated with graphite, and finally stored.

The pictures shown in this story were prepared especially to illustrate this story of “How Man Learned to Shoot” by the Searchlight Library for the Remington Arms Company.

[Illustration: FORGING A MONSTER GUN

Photo by Bethlehem Steel Co.

This photograph shows gun ingots after being “stripped” and “cored.”]

[Illustration:

Photo by Bethlehem Steel Co.

This photograph shows a gun ingot in the process of being forged under forging press.]

[Illustration:

Photo by Bethlehem Steel Co.

This photograph shows a gun being fired at the Proving Grounds for test.]

The Parts of a Big Gun

~THINGS TO KNOW ABOUT A BIG GUN~

Before going into a description of the manufacture of a big gun it would be well to understand the following definitions:

The “breech” of a gun is its rear-end, or that end into which the projectile and powder charge are loaded.

The “muzzle” of a gun is its forward end.

By “calibre” is meant the inside diameter of the gun in inches. A 5-inch gun is one of “minor calibre,” and one of 14-inches a gun of “major calibre.”

The length of a gun is never expressed in inches or feet, but in the _number of times_ that its calibre is divisible into its length; thus, when we say a 12-inch 50-calibre gun, we mean a gun of 12 inches in diameter, and 12 times 50, or 600 inches long.

The “bore” is the hole extending through the center of the gun, from the rear face of the liner to its forward end.

The “powder chamber” is the rear part of the bore, and extends from the face of the breech plug when closed to the point where the “rifling” begins. The powder chamber is slightly larger in diameter than the rest of the bore.

The “rifling” is the name given to the spiral grooves which are cut into the surface of the bore of the gun, and give to the projectile its rotary motion when the gun is fired.

With the advent of “iron-clads” and heavily armored fortresses, it became necessary to increase the power of the guns in use, until to-day a 14-inch gun of 45 calibres fires a projectile weighing 1400 pounds, with an initial velocity of 2600 feet per second. An idea of this initial velocity may be better obtained by comparison when you realize that a train going sixty miles an hour is only traveling at the rate of 88 feet per second. Now, in order to produce such wonderful power in a gun, great pressure must be generated in the bore, and it was soon found that a one-piece gun, whether cast or forged, could not withstand such pressures.

To begin with, we may consider this one-piece gun, or any gun, as a tube which must withstand a great pressure from within, so that when a gun is designed care must be taken to see that the material from which it is constructed is strong enough to withstand this pressure. And not only must the gun be sufficiently strong, but it must not be too heavy, so that you see you cannot go on forever increasing the thickness of the walls of this tube. Besides, it is generally acknowledged that a simple tube or cylinder cannot be made with walls of sufficient thickness to withstand from within a _continued_ pressure per square inch greater than the tenacity of a square-inch bar of the same material; in other words, if the tensile strength of a metal is only twelve tons per square inch, no gun of that metal, however thick its walls, could withstand a pressure of twenty tons per square inch, and the modern big guns are tested at that great a pressure. And if we look further into this matter of pressures we find that when a gun is fired the pressure exerts itself in two ways; it tends to burst the gun longitudinally or down the middle, and it tends to pull the gun apart in the direction of its length. Of course, some method of strengthening this one-piece gun was sought after, with the result that to-day guns are either “_built-up_” or “_wire-wound_.”

A “built-up” gun is one made of several layers, each layer being separately constructed and then assembled together. The order of assemblage differs somewhat with the different calibres, but the method of assemblage is essentially the same, that is, the outside layers are heated and shrunk on the inner ones. This question will be treated at greater length later on.

A “wire-wound” gun is one in which the necessary additional strength is obtained by winding wire around an inner tube of steel, each layer being wound with a different tension of the wire; this type of gun has found great favor with foreign manufacturers. In this country, however, the “built-up” system is used almost exclusively, and so this description will deal with the manufacture of a “built-up” gun.

[Illustration: HOW A BIG GUN WOULD LOOK IF YOU WERE TO CUT IT IN TWO

Sketch Showing Construction of a Modern “Built-up” Gun.

_A_, HOOP; _B_, HOOP; _C_, JACKET; _D_, TUBE; _E_, LINER; _F_, HOOP.]

A modern “built-up” gun is composed of a _liner_, a _tube_, a _jacket_ and _hoops_.

The _liner_ is in one piece and extends the entire length of the bore and carries the “rifling” and the powder chamber.

The _tube_ is in one piece and envelops the liner for its entire length. Formerly the _tube_ carried the “rifling” and powder chamber, but due to the wearing out of the “rifling” with constant firing, a liner was decided on, so that now when the “rifling” becomes worn, the liner can be removed and a new one substituted.

The _jacket_ is usually in two pieces and is shrunk on the tube; it extends the entire length, and its rear end is threaded in the inside for the attachment of the “breech bushing.”

Hoops are shrunk on over the jacket and in a big gun are sometimes as many as six or seven in number.

The liner, tube, jacket and hoops are made of the finest quality of open hearth steel, and the steel must conform to specifications set by the government.

[Illustration:

Photo by Bethlehem Steel Co.

This photograph shows a mould for a gun ingot under hydraulic press for fluid compression.]

The chemical composition having been determined, the necessary elements are weighed out and the whole charged into an open hearth furnace. When the furnace is ready to be tapped the molten metal is run into a large ladle, which in turn is taken by a crane to the casting pit, where the mould is filled. The ingots for the large calibre guns run from 42-inch to 48-inch in diameter, and after being poured they are immediately run under a hydraulic press, where they are subjected to a pressure of about six tons per square inch to drive out the gases, and then lowered to about 1500 pounds pressure per square inch for a certain length of time during the cooling. This pressure tends to make the ingot solid, by expelling the gases, which would cause blow-holes, and by preventing “piping” and “segregation.” When a metal cools, the top and sides cool first, and this outer layer shrinks and pulls away from the centre, with the result that a cavity or “pipe” would be formed, but the hydraulic pressure forces fluid metal into this cavity and so prevents the “pipe.” The cooling also causes the various elements to solidify separately, and they tend to break away from the mass and collect at the centre; this is called “segregation,” and is also partially prevented by fluid compression. A solid ingot, however, is obtained, and this is absolutely necessary.

After the ingot has cooled sufficiently it is “_stripped_,” that is, it is removed from the mould, and then it is sent to the shop to have the “discard,” or extra length, cut off. When the ingot is cast, an extra amount of metal is poured into the mould to permit this discard, the theory being that the poorer metal, together with gases and other impurities, rise to the top. The government specifications require that there shall be a 20% discard from the upper end and a 3% discard from the lower end. The discard having been cut off, the ingot is “cored,” that is, its centre is bored out, the diameter of the hole depending on the size of the ingot.

[Illustration: TAKING THE BORE OF A BIG GUN

Photo by Bethlehem Steel Co.

This photograph shows gun ingot in boring mill being cored.]

The ingot is now ready for the “forge,” and on its receipt in the forge shop it is placed in a furnace to be heated; and here great care must be exercised to prevent setting up any additional strains in the ingot. When the ingot was cooling just after casting the metal tended to flow from the centre; the interior is still in a condition of strain, and if the cold ingot is now placed in a hot furnace, cracks

are apt to form in the centre, causing the forging to later break in service.

However, the ingot having been properly heated, it is ready for either the forging hammer or the press. The present-day practice, though, is to forge the ingot under a press forge, as the working of the metal causes a certain flow, and as a certain amount of time is necessary for this flow, the continued pressure and slow motion of the press allows the molecules of the metal to adjust themselves more easily, and a better and more homogeneous forged ingot is produced than if the forging had been done with a hammer.

When forging a hollow ingot, a mandrel, merely a cylindrical steel shaft, is placed through the hole in the ingot and the ingot forged on the mandrel, thereby not only is the outside diameter of the ingot decreased, but the length of the ingot is increased. The usual practice is to continue the forging until the original thickness of the walls of the ingot is decreased one-half and until the ingot is within two inches of the required finished diameters. The ingot is now known as a "forging," and the lower end of each ingot as cast will be the breech end of the forging that is made from it.

The next process is that of "annealing." This consists in heating the forging to a red heat and then allowing it to cool very slowly, and is usually done by hauling the fires in the furnace after the correct temperature has been attained and permitting both to cool off together. This process is to relieve the strains set up in the metal during forging, and further, it alters the molecular condition of the steel, making a finer and more homogeneous forging.

[Illustration: HOW THE GUN TUBE IS TEMPERED

Photo by Bethlehem Steel Co.

This photograph shows a gun tube ready to be lowered into oil bath for "oil tempering."]

After annealing, the forging is ready to go to the machine shop to be rough bored and turned. The forging is set in a lathe, the breech end being held by jaws on the face-plate and the muzzle end by a "pot-centre," a large iron ring having several radial arms screwed through it. The lathe can now be turned and the forging centered by screwing in or out on the jaws of the face-plate or the radial arms of the "pot-centre." When centered, several surfaces are turned on the forging for "steady rests" and then all is in readiness for the turning and boring.

In both operations of "turning" and "boring," the work revolves while the cutting tools are fed along. Turning is very simple and usually several tools are cutting at the same time, but boring is a more delicate operation, because the workman cannot see what he is doing. And in boring, either a "hog bit" or a "packed bit" is used; a "hog bit" is a half cylinder of cast iron fitted with one cutting tool and used for rough cuts, while a "packed bit" is a full cylinder of wood with metal framing and carrying two tools 180° apart and used for finishing cuts.

The forging, having been rough machined, is now ready to receive its heat treatment in order to give to the steel its required physical characteristics. Every piece of steel used in gun manufacture must conform to certain specifications as regard both its physical and chemical characteristics. The chemical analysis was made at the time the ingot was cast; now for the treatment of the forging, prior to the physical test as to its tensile strength, elastic limit, elongation and contraction.

The "tensile strength" of a metal is the unit-stress required to break that metal into parts. If a round bar ten inches in cross-section area will fracture under a strain of 120 tons, its tensile strength is 120 ÷ 10 or 12 tons per square inch. Tensile strength is usually expressed in pounds per square inch.

The "elastic limit" of a metal is the unit-stress required to first produce a permanent deformation of the metal. If a bar of metal be subjected to an increasing strain, up to a certain point that metal will be perfectly elastic, resuming its normal shape when the strain is removed; at the first permanent set or deformation, however, the elastic limit of that metal has been reached. Elastic limit is expressed in pounds per square inch.

By "elongation" is meant the increase in length in a bar when its tensile strength is reached. If a bar 10 inches long after rupture measures 11.8 inches, its elongation is 18%.

By "contraction" is meant the decrease in cross-section area in a bar when its tensile strength is reached. If a bar 1 square inch in area after rupture is only .75 of a square inch in area, its contraction is 25%.

These definitions being understood, a brief description of the heat treatment can be taken up, because it is after this treatment that standard bars are taken from the forgings to undergo the physical tests. The first step consists in "tempering" or hardening the metal. The piece to be tempered is placed in an upright position in a high furnace and uniformly heated to the required temperature. It is then lifted from the furnace through an opening in the top and carried by a crane to an oil tank of suitable depth and plunged into the oil. This rapid cooling or "tempering in oil" is facilitated by having the oil tank surrounded by a water bath, so arranged that a supply of cold water is constantly in circulation to carry the heat from the mass as quickly as possible. This operation produces exceeding toughness, increases the tensile strength and raises the elastic limit of the metal.

Now the forging is again annealed, so as to relieve any strains set up by tempering and to soften up the metal to the degree required by the specifications. It also increases materially the elongation and contraction. Great care must be exercised in the heat treatment, as the acceptance or rejection of the forging depends upon whether or not the test bars pass the required specifications.

The forging is now submitted for test and the test bars taken. In the manufacture of a big gun, four test bars are taken from the breech end and four from the muzzle end of each forging and these bars sent to the physical laboratory. Quite an elaborate testing machine is provided, and if the bars pass the required tests the forging is accepted and is sent to the machine shop for finish-boring and turning.

~SEARCHING FOR POSSIBLE DEFECTS~

Frequently during finish-boring the work is examined to see that the bit is running true, and great care must be exercised to prevent its running out of alignment.

After finish-boring every forging is "bore-searched," that is, the bore is carefully examined for any cracks, flaws, streaks or discoloration. A special instrument called a "bore-searcher" is used and consists of a long wooden handle which has a mirror inclined at 45° at one end, together with a light to illuminate the bore, and so shielded as to obscure the light from the observer. (See sketch.)

[Illustration]

The bore is also inspected by the foreman after each boring, but the final "bore-searching" is done by an inspector.

Now to measure accurately the inside diameters of long cylinders, such as are used in gun work, a special measuring device called a "star-gauge" is used. Its name is derived from the fact that it has three measuring points set at 120° apart and two measurements are taken, one [Illustration] and the other [Illustration], making a star [Illustration]. Every forging is "star-gauged" after being finish-bored and also the liner of the _gun_ after each assemblage operation.

~PUTTING THE PARTS OF A "BUILT-UP" GUN TOGETHER~

In preparation for the assembling of the different parts, the tube is the forging to be finished. It is bored and turned to exact dimensions and carefully "bore-searched" and "star-gauged." With the data at hand a sketch is made showing the external diameters of the liner under the tube, due allowance being made for the shrinkage when assembling.

The liner is next bored to within .35 of an inch of the finished diameter, and turned to the dimensions required by the sketch above. This extra metal in the bore is left until the gun is completely assembled and is removed in the finish-boring. The liner is then carefully "bore-searched" and "star-gauged" and liner and tube are ready for assembling.

The liner is now taken to the shrinking pit and carefully aligned in an upright position with the breech end down.

The shrinking pit is merely a well of square section with room enough to permit workmen to move freely about the gun when it is in position, and equipped with a movable table at its bottom upon which the gun rests. In the meantime the tube, with breech end down, is being heated in a hot-air furnace. This furnace is a vertical cylinder built of fire-brick and asbestos and so constructed that air which has been passed in pipes over petroleum burners can enter at the bottom, pass around and through the tube and out through the top to be reheated. This service permits a uniform heat to be transmitted to the tube and when the desired temperature has been attained the tube is lifted from the furnace by a crane, carried to the shrinking pit and carefully lowered over the liner. Great care must be exercised in this operation to prevent the tube from sticking while being lowered into place. Should it happen, the tube should be hoisted off at once, allowed to cool, any roughing of the liner be smoothed off, the tube reheated and a second trial made. When the tube is properly in place a cold spray may be turned upon any particular section where it is desired the tube

should first grip the liner. The tube is then left to cool by itself, but cold water is constantly circulating through the liner.

When the gun is sufficiently cool for handling purposes, it is hoisted out of the shrinking pit and taken to the shop for careful measurement, the liner being "star-gauged" to note the compression due to the shrinking on of the tube.

The same procedure is followed in the case of the jackets and hoops, until the entire gun is assembled. The gun is considered completely "built-up" when the last hoop has been shrunk on and is now ready to be finished.

The gun is now finish-bored, as .35 of an inch of metal was left in the liner in the first boring. "Packed bits" are used and the greatest care is exercised to keep the bit properly centered and running true. After this step the gun is finish-turned and the powder chamber is bored.

Following this operation the gun is "bore-searched" for any defects that may have shown up in the finish-boring and chambering, and then carefully "star-gauged." The gun is then ready to be "rifled."

[Illustration: RIFLING A BIG GUN

Photo by Bethlehem Steel Co.

This photograph shows a gun in the Rifling Machine in the process of being rifled.]

The "rifling" of a gun consists in cutting spiral grooves in the surface of the bore from the powder chamber to the muzzle end, and is done from the muzzle end. Rifling is a very difficult operation, and great care must be exercised that the cutting is uniform. The grooves are separated by raised portions called "lands," and after "rifling," these grooves and "lands" are carefully smoothed up to remove the rough edges or burrs caused by the cutting tools of the "rifling" machine.

The necessary holes are now drilled for fitting the breech mechanism and the breech block fitted. This operation usually takes some little time, as quite a bit of hand work is necessary to insure a perfect fit. The "yoke," really another "hoop," is now put on at the breech end and the gun is complete.

The centre of gravity of gun and breech mechanism is now determined by balancing on knife edges and the whole then weighed. The breech mechanism is also weighed and the two weights marked on the rear faces of the gun and breech mechanism.

The gun is now fitted in its "slide," that part of the mount which carries the trunnions and through which the gun recoils when it is fired, and after it is adjusted, all is in readiness for the "proof-firing" or testing of the gun.

What Is Motion?

There are practically but two things we see when we use our eyes. One of them is matter, which is a term we apply to the things we see, speaking of them as objects only, and the other is motion which we observe some of the matter to possess. Some of the things we see confuse us, if we bear in mind that everything is either matter or motion. For instance, we see light and know it is not matter and are confused until we understand that light is a movement of the ether which surrounds us and is in and outside of everything. In the same way we feel heat and may think it is matter thrown off by the fire, when it is only another kind of motion of this same ether. When we understand these things we see that motion is a very important and real part of the world.

When a motion is started it will keep on going forever unless some other force which is able to overcome the motion stops it. When a ball is thrown in the air it would go on forever were it not for the law of gravitation which pulls it to the earth and the friction of the air on the ball as it goes through the air. When you stop a thrown ball you sometimes realize that motion is a real thing because it stings your hands. We do wonderful things with motion. Many things when you add motion to them acquire qualities which they did not possess before. For instance, an ordinary icicle thrown against a wooden door will break, but if you put it into a gun and give it sufficient motion, it will go right through the door. There is a story of how a man killed another by using an icicle as a bullet. The icicle entered the man's body and killed him. Then, of course, the ice melted and no one could tell how the man received his wound, for no trace of anything like a bullet could be found. A piece of paper has no cutting qualities, but if you arrange a circular or square piece of paper with a rod or stick through the center and revolve it fast enough, you can cut many things while it is whirling. The motion gives it the cutting qualities. You can take a piece of strong rope and, by tying the ends together, making a circle of it, you can make it roll down the street like a steel hoop if you catch it just the right way and set it spinning fast enough before starting it on its way. A steam engine has no power to pull the train of cars until the wheels are set in motion. So we see that motion is a

very important thing in the world.

Motion is the cause of movements of all kinds, the power which takes things from one place to another.

Is Perpetual Motion Possible?

Perpetual motion will never be possible unless some one discovers a way to overcome the law of gravitation and also the certainty that materials will eventually wear out. Many men have tried to make a machine that would keep on moving forever without the application of any power, the consumption of fuel within itself, the fall of weights or the unwinding of a spring; such a machine would be absolutely impossible, although many people have been fooled into investing money in machines that appeared to have this power within themselves.

How Can an Explosion Break Windows That Are at a Distance?

An explosion is a sudden expansion of a substance like gunpowder or some elastic fluid or other substance that has the power to explode under certain conditions with force, and usually a loud report. Some explosions are comparatively mild and accompanied by a very mild noise, while others are very powerful and accompanied by a very loud noise. When an explosion occurs, the air and everything surrounding the thing that explodes is very much disturbed. The air surrounding the thing that explodes is thrown back in air waves which are powerful in the exact proportion in which the explosion is powerful. These air waves can be so suddenly thrown back against the objects in the vicinity that not only the windows in the buildings are broken, but often the entire building blown away. The explosion acts in all directions at once with equal force. A great hole may be torn in the earth beneath the explosion. If there is anything over the explosion, that is blown away unless its power of resistance is sufficient to withstand the power of the explosion. Then, also, the air surrounding on all sides is forced back against everything in its path.

Very often this air which is suddenly forced back by the power of the explosion is thrown against houses at a distance. These houses may be so strongly built as to be able to withstand the effect of the explosion, but still certain parts of them, such as the windows and the bricks of the chimney, may not be able to withstand this sudden pressure of air against them and they are forced in. The wind from such an explosion acts on the outside of the windows just the same as though you stood on the outside with your hands against the windows and pushed them in. Anything that is thrown against a window with more force than the window glass can resist will break the window, and even slight explosions may be so powerful as to throw the air back and away from them with such force as to break windows at a great distance--even a mile or more away.

Why Do Some Things Bend and Others Break?

When an outside force is applied to some objects, some of them will bend and others break. It is due to the fact that in some things the particles have the faculty of sticking together or hanging on to each other, and it is very difficult to break them away from each other. In such instances, as in the case of a wire, the article will bend when we apply the power to it and it will not break, because the particles which make up the wire have the faculty of hanging on to each other. A piece of glass, however, can be broken right in two by the application of no more force than was used to bend the wire, because the particles which make up the glass haven't the faculty to hang on to each other. If you continue to bend a wire back and forth, however, at the same point, it will finally break apart, because you eventually overcome the ability of the particles in the wire to hang on to each other.

It all depends upon the hanging-on ability. Sometimes in undergoing different processes an article which will ordinarily only bend will become very brittle or breakable. A steel wire may bend but if you make a steel wire very hard it becomes brittle. On the other hand, glass is very brittle ordinarily, but if you make it very hot, you can bend it into any shape you wish, and thus the glass-worker makes different shapes to various dishes; lamp chimneys, bottles, etc., by heating glass and then bending it. When it becomes cool again, it also becomes brittle or breakable as before.

Why Does a Ball Bounce?

When you throw a ball against the floor in order to make it bounce the ball gets out of shape as soon as it comes in contact with the floor. As much of it as strikes the floor becomes perfectly flat, and because the ball has a quality known as elasticity, which means the ability to return to its proper shape, it returns to its shape immediately and in doing so forces itself back into the air and that is the bounce.

Of course, the first thing we think of when we consider something that bounces is a ball, and in most cases a rubber ball. We are more familiar with the bouncing qualities of a rubber ball. Other balls, like standard baseballs, are not so elastic as a rubber ball filled with air, but a solid-rubber ball is more elastic and some golf balls are much more elastic than a solid-rubber ball. The principle is the same, when you drive a golf ball, excepting that when you bounce a ball on the floor the floor does the flattening and when you drive a golf ball, the golf club does the flattening. A baseball flies away from the bat for the same reason. When you meet a fast-pitched ball squarely on the nose with a good swing, it goes farther and faster than when you hit a slow-pitched ball with an equal swing, because in the case of the fast-pitched ball you flatten the ball out more, and it has so much more to do to recover its proper shape that it bounces away from the bat at much greater speed and goes much further unless caught than a slow-pitched ball under the same circumstances.

What Makes a Ball Stop Bouncing?

A bouncing ball, when you first throw it against the wall bounces back at you about as fast as you throw it, but if you do not catch it on the rebound, it goes to the floor again, because the law of gravitation which is the pulling power of the earth, pulls it down again. When it strikes the floor it is again flattened to a certain extent and bounces up again, but does not come back so high. It goes on striking the floor and bouncing back into the air again each time a shorter distance, until the force of gravity has actually overcome its tendency to bounce back.

When you bounce a ball on the floor and it bounces up again, the motion of the ball through the air is affected by the friction that the contact with the air produces and this friction of the air overcomes part of the bouncing ability in the ball also.

What Makes a Cold Glass Crack if We Put Hot Water Into It?

Hot water will not always cause a cold glass to crack, but is very apt to, especially a thick glass. The very thin glasses will not crack. The test tubes used by chemists are made of very thin glass, and will not crack when hot liquids are poured into them.

When a glass cracks after you have poured a hot liquid into it, it does so because, as soon as the hot liquid is put in, the particles of glass which form the inside of the glass become heated and expand. They begin to do this before the particles which form the outside of the glass become heated, and in their efforts to expand the inside particles of glass literally break away from the particles which form the outside, causing the crack. The same thing happens if you put cold water into a hot glass, excepting in this instance the inside particles of the glass contract before the particles which form the outside of the glass have had time to become cool and do likewise.

What Causes the Gurgle When I Pour Water from a Bottle?

The air trying to get in causes the gurgle. Air has one strong characteristic which stands out above everything else. It wants to go some place else all the time. When it learns of a place where there is no air it wants to go there above all things, and goes at it with a rush.

Now, when you turn a bottle full of water upside down, the water comes out if the cork is out, of course, and as soon as the water starts out the air strives to get in, and every time you hear a gurgle you know the air is getting in. Every gurgle is a battle between the water and the air. Sometimes the air comes and pushes the water back enough to let it slide into the bottle; sometimes the water pushes the air back, and thus they fight back and forth. The water always gets out and the air always gets in. In doing so they make the gurgle.

Where Does the Part of a Stocking Go That Was Where the Hole Comes?

Perhaps this is a foolish question, but many boys and girls have been puzzled for an answer to it. When you put your stockings on they have no holes in the feet, and at night, when you take them off, there are often quite large holes in them. The answer is the same as in the case of the lead in the lead-pencil. The lead in the pencil wears away. You can see it wear away because that is what makes the marks.

When a hole is coming into your stocking, the stocking on your foot is being rubbed between your foot and something else (probably some part of your shoe) and this constant rubbing will wear through the yarns with which the stocking is knitted. Of

course, the yarns in the stocking are stretched somewhat when it is on your foot and the rubbing finally cuts through the threads and releases the tension of the threads of yarn, so that not always is as much stocking lost as the size of the hole. But, if you were to look carefully at your foot and inside your shoe, when you first take the stocking off and see the hole, you would find little particles of yarn all about.

Why Do Coats Have Buttons On the Sleeves?

The practice of putting buttons on coat sleeves, which serve no useful purpose at all and do not add to the beauty of the coat, is a relic of very old days.

There was a time when people did not use handkerchiefs, and it was common practice for men to wipe their noses on their sleeves. They had coats also in those days, but they did not have buttons on the sleeves. One of the old kings finally developed the idea of dressing his soldiers in fancy uniforms and, as he sat in his palace and reviewed his troops, he noticed many of them using the sleeves of their coats as handkerchiefs. He immediately issued a decree that all sleeves should have a row of buttons sewed on them, but at a point directly opposite to where they are now on the sleeves. This was done to remind the soldiers that the sleeves of their beautiful uniforms were not to be used as handkerchiefs, and those who attempted to draw their sleeves in front of the nose were quickly reminded of the decree by the buttons which scratched them. And so the buttons really had a quite useful purpose at one time, and so also all sleeves had buttons sewed on to them at this place. Later on, however, when the unsightly practice had been cured and people had learned to use handkerchiefs, the buttons remained as a decoration, but their former purpose was lost sight of. Then some tailor or leader of fashion had the buttons set on the under side of the sleeves for a change, and it became the fashion to have them there, and the tailors have been sewing them there ever since.

Why Has a Long Coat Buttons on the Back?

The buttons on the back of a long coat, i. e., one with skirts, had a more sensible reason originally. At one time the skirts of such coats were made very long, and when the wearer moved quickly the tails of the coat flapped about the legs and interfered with progress. So an ingenious gentleman had buttons sewed on to the back and buttonholes made in the corner of his coat-tails. Then when he was in a hurry he simply buttoned up his skirts and went his way comfortably.

[Illustration: TELEPHONE DISPLAY BOARD

Showing in outline the apparatus necessary to complete the simplest kind of a telephone call--to a number in the same exchange]

The Story in the Telephone

~WHAT HAPPENS WHEN WE TELEPHONE~

Mrs. Smith, at “Subscriber’s Station No. 1,” desires to telephone to Mrs. Jones at “Subscriber’s Station No. 2.” When she lifts her receiver, the movement causes a tiny white light to appear instantly on the switchboard at the Central Office. Directly beneath this light is another and larger lamp, which glows in a way to attract the operator’s attention immediately.

The operator inserts a “plug” in a little hole on the switchboard called a “jack,” directly above the tiny light which appeared when Mrs. Smith lifted the receiver. This connects her to Mrs. Smith’s line. Then she pushes a listening key on the board, connecting her telephone set to the line. “Number, please?” she calls.

Mrs. Smith gives the number; the operator repeats it to be sure there is no mistake, places another “plug” in a “jack” corresponding to the number of Mrs. Jones’ telephone and makes the connection.

Each subscriber’s telephone has a particular signal on the switchboard to which it is connected by a pair of wires. Mrs. Smith’s wires run from her instrument to the nearest “cable terminal,” a gathering point for the wires of various telephones in her neighborhood. Here they form part of a group of wires going to the Central Office. These groups, called cables, are made up of from 50 to 600 pairs of wires, according to the telephone needs of the district the “terminal” serves.

When the wires reach the Central Office they pass through the “cable vault” to the “main distributing frame,” which is the Central Office terminal of the cable.

When the wires come to this frame they are in numbered order in the cable. Subscribers living next door to Mrs. Smith may have entirely different call numbers and yet use consecutive wires. It is the task of the main frame to redistribute these wires, so that they will be arranged according to their call numbers and to make it possible to connect Mrs. Smith's line with the line of any other subscriber with the least possible delay. This frame has two parts: the "vertical side" and the "horizontal side." Before the wires are redistributed they are taken to pairs of springs equipped with devices for protecting the lines against outside currents.

[Illustration: ASKING FOR A NUMBER]

After leaving the main frame they are taken to the "intermediate distributing frame," the central connecting point for various branches of the lines going to the switchboard, signaling and other apparatus. From the "horizontal side" of this frame, wires go to the switchboard, where they terminate in little holes known as "multiple jacks." They also connect with the line and position message registers, where the calls from each Line and the calls handled at each operator's position at the switchboard are recorded. The "multiple jacks" are additional terminals placed at necessary intervals throughout the switchboard, where they can be used by operators to make connections with any other line on the board.

From the "vertical side" of the intermediate frame Mrs. Smith's wires reach the "line and cut-off relay," an electrically controlled switch which turns on the light signal that appears on the switchboard when she lifts the receiver from the hook. This "line relay" also extinguishes the light when the operator makes the connection, or when Mrs. Smith returns the receiver to the hook.

[Illustration: A TYPICAL POLE LINE, WITH CROSS ARMS, IN THE COUNTRY]

The swift moving electric current that was set in motion when Mrs. Smith began the call, instantaneously passes through all these devices for safeguarding and protecting the subscriber's telephone service. The light announcing Mrs. Smith's desire to make a call is called the "line lamp," and is flashing on the switchboard. Directly beneath it is the "pilot lamp," which glows whenever any "line lamp" lights. With the "line lamp" is a "jack" or terminal, where connection can be made with Mrs. Smith's line. This is the "answering jack."

[Illustration: THE CABLE VAULT INTO WHICH THE CABLES PASS WHEN THEY ENTER THE EXCHANGE AND FROM WHICH THEY ARE LED UPWARD TO THE MAIN DISTRIBUTING FRAME]

When the operator sees the flashing signal of Mrs. Smith's "line lamp," she inserts one end of a pair of "connecting cords," which are on the board before her, in the "answering jack" for Mrs. Smith's line. These "connecting cords" are flexible conductors that put the wires of subscribers in electrical connection. Then she pushes forward the "operator's key" directly in front of her and is connected with Mrs. Smith's line.

The operator ascertains the number wanted and places the other "connecting cord" in the "jack" corresponding to Mrs. Jones' line. If she finds she cannot herself connect with Mrs. Jones' "jack," because it is on another part of the board out of her reach, she makes a connection with another operator who can reach Mrs. Jones' line. The second operator then makes the connection with Mrs. Jones' "multiple jack" and places her line in connection with Mrs. Smith's line at the first operator's position. At the same time the first operator pushes the operator's key back, thus ringing Mrs. Jones' bell.

"Supervisory lamps" on the board before her, connected with the "connecting cords," tell the operator when Mrs. Jones answers the summons. They flash when the connection is made and one goes out just as soon as Mrs. Jones takes the receiver from the hook to answer. If one of these lamps flashes and dies out alternately it tells the operator that either Mrs. Smith or Mrs. Jones is trying to attract her attention and she connects herself and ascertains the party's wishes. When both subscribers "hang up," both lights flash to indicate the end of the conversation. The operator then disconnects the cords from the subscribers' "jacks" and presses the "message register" button recording the call against Mrs. Smith.

[Illustration: ROUTINE OF A TELEPHONE CALL

The subscriber, after looking up in the directory the desired number, takes the telephone off the hook, which causes a tiny electric light to glow in front of the operator assigned to answer his calls. (In some exchanges equipped with a magneto system, a drop is released by the turning of a crank.)]

[Illustration: The arrow indicates the light as it appears on the switchboard. Each operator can connect a caller with any subscriber in that exchange, but she is assigned to answer the calls of only a limited number of subscribers whose signals are these lights showing at her particular position.]

[Illustration: She takes up a brass-tipped cord, inserts the tip, or "plug," into the hole, or "jack," just above the light, at the same time throwing a key with the other hand in order to switch her transmitter line into direct communication with the caller, and says: "Number?"]

[Illustration: The caller replies by giving the name of the exchange and the number he wants, as for example, "Main 1268." The operator repeats the number, "One-two-six-eight," pronouncing each digit with clear articulation, to insure its correctness, and, if it be from a subscriber in the Main Exchange, she--]

[Illustration: Takes up the cord which is the team mate, or "pair," of the one with which she answered the caller, locates the jack numbered 1268, and "tests" the line by tapping the tip of the plug for a moment on the sleeve of the "jack" to ascertain if the line is "busy." If no click sounds in her ear she--]

[Illustration: Pushes in the plug and with her other hand operates a key on the desk. The first action connects the line of the subscriber called; the second rings his bell. When either party hangs up his receiver, a light glows on the switchboard desk, showing the operator that the conversation is ended.]

[Illustration: THE CENTRAL TERMINAL OF YOUR TELEPHONE

A MULTIPLE SWITCHBOARD]

[Illustration: THE BACK OF A MULTIPLE SWITCHBOARD]

[Illustration: THE BIRTHPLACE OF THE TELEPHONE, 109 COURT STREET, BOSTON

On the top floor of this building, in 1875, Prof. Bell carried on his experiments and first succeeded in transmitting speech by electricity]

How the Telephone Came to Be.

It is hard to realize that there was once a time, not so very many years ago, when the telephone was regarded as a scientific toy and hardly anyone could be found willing to invest any money in the development of the telephone business.

[Illustration: ALEXANDER GRAHAM BELL IN 1876]

[Illustration: THOMAS A. WATSON IN 1874]

The story of Professor Alexander Graham Bell's wonderful invention is full of romantic interest and the early days of its exploitation were replete with dramatic incidents.

~THE MEN WHO MADE THE TELEPHONE~

Young Bell had come to America in 1870 in search of health, the family settling at Brantford, Canada. He numbered among his forebears many distinguished professional men. For three generations the Bells had taught the laws of speech in the universities of Edinburgh, Dublin and London. He himself was an accomplished elocutionist and an expert in vocal physiology.

During the year spent in Canada in regaining his health, Bell taught his father's method of visible speech to a tribe of Mohawk Indians and began to think about the "harmonic telegraph."

In 1871 young Alexander Bell accepted an offer from the Boston Board of Education to teach the "visible speech" method in a school for deaf mutes in that city.

For two years he devoted himself to the work with great success. He was appointed a professor in the Boston University and opened a school of "Vocal Physiology" which was at once successful.

He might have continued his career as a teacher had it not been that his active brain still clung to the "harmonic telegraph" idea and his inventive genius demanded an outlet.

[Illustration: PROF. BELL'S VIBRATING REED]

So we find him in 1874 working out his idea of the "harmonic telegraph," the perfection of which meant a fortune to the young inventor. That he never realized his goal was due to the fact that while experimenting, he made a discovery which led to a far greater invention and one that was fraught with more benefit to mankind than the "harmonic telegraph" could ever have been.

It was while working with his faithful man Friday, Thomas A. Watson, in the dingy little workrooms on Court Street, Boston, that Bell got the inspiration which made him turn from the "harmonic telegraph" to devote himself to the invention which was destined to make his name famous--the speaking telephone.

~THE FIRST SOUND OVER A WIRE~

Mr. Watson has dramatically described the incident as follows:

"On the afternoon of June 2, 1875, we were hard at work on the same old job, testing some modification of the instruments. Things were badly out of tune that afternoon in that hot garret, not only the instruments, but, I fancy, my enthusiasm and my temper, though Bell was as energetic as ever. I had charge of the transmitters, as usual, setting them squealing one after the other, while Bell was retuning the receiver springs one by one, pressing them against his ear as I have described. One of the transmitter springs I was attending to stopped vibrating and I plucked it to start it again. It didn't start and I kept on plucking it, when suddenly I heard a shout from Bell in the next room, and then out he came with a rush, demanding, 'What did you do then? Don't change anything. Let me see!' I showed him. It was very simple. The make-and-break points of the transmitter spring I was trying to start had become welded together, so that when I snapped the spring the circuit had remained unbroken while that strip of magnetized steel by its vibration over the pole of its magnet, was generating that marvelous conception of Bell's--a current of electricity that varied in intensity precisely as the air was varying in density within hearing distance of that spring. That undulatory current had passed through the connecting wire to the distant receiver which, fortunately, was a mechanism that could transform that current back into an extremely faint echo of the sound of the vibrating spring that had generated it, but what was still more fortunate, the right man had that mechanism at his ear during that fleeting moment, and instantly recognized the transcendent importance of that faint sound thus electrically transmitted. The shout I heard and his excited rush into my room were the result of that recognition. The speaking telephone was born at that moment. Bell knew perfectly well that the mechanism that could transmit all the complex vibrations of one sound could do the same for any sound, even that of speech. That experiment showed him that the complex apparatus he had thought would be needed to accomplish that long-dreamed result was not at all necessary, for here was an extremely simple mechanism operating in a perfectly obvious way, that could do it perfectly. All the experimenting that followed that discovery, up to the time the telephone was put into practical use, was largely a matter of working out the details. We spent a few hours verifying the discovery, repeating it with all the differently tuned springs we had, and before we parted that night Bell gave me directions for making the first electric speaking telephone. I was to mount a small drumhead of gold-beater's skin over one of the receivers, join the center of the drumhead to the free end of the receiving spring and arrange a mouthpiece over the drumhead to talk into. His idea was to force the steel spring to follow the vocal vibrations and generate a current of electricity that would vary in intensity as the air varies in density during the utterance of speech sounds. I followed these directions and had the instrument ready for its trial the very next day. I rushed it, for Bell's excitement and enthusiasm over the discovery had aroused mine again, which had been sadly dampened during those last few weeks by the meagre results of the harmonic experiments. I made every part of that first telephone myself, but I didn't realize while I was working on it what a tremendously important piece of work I was doing.

[Illustration: WHAT THE FIRST TELEPHONE LOOKED LIKE

ALEXANDER GRAHAM BELL'S FIRST TELEPHONE]

The First Telephone Line.

"The two rooms in the attic were too near together for the test, as our voices would be heard through the air, so I ran a wire especially for the trial from one of the rooms in the attic down two flights to the third floor where Williams' main shop was, ending it near my work bench at the back of the building. That was the first telephone line. You can well imagine that both our hearts were beating above the normal rate while we were getting ready for the trial of the new instrument that evening. I got more satisfaction from the experiment than Mr. Bell did, for shout my best I could not make him hear me, but I could hear his voice and almost catch the words. I rushed upstairs and told him what I had heard. It was enough to show him that he was on the right track, and before he left that night he gave me directions for several improvements in the telephones I was to have ready for the next trial."

Then followed many heart-breaking months of experimenting and it was not until the following March that the telephone was able to transmit a complete, intelligible sentence.

[Illustration: TELEPHONE APPARATUS PATENTED IN 1876 BY PROF. BELL, PHOTOGRAPHED FROM THE ORIGINAL INSTRUMENTS IN THE PATENT OFFICE AT WASHINGTON]

On February 14, 1876, Professor Bell filed at Washington his application for patents covering the telephone which he described as "an improvement in telegraphy" and on March 3, of the same year, the patent was allowed.

That was the year of the Centennial Exposition at Philadelphia and Professor Bell had a working model of the telephone on exhibition. Tucked away in an obscure corner it had attracted but little attention, until on June 25th an incident occurred which had a tremendous effect in giving to the new invention just the sort of publicity it needed.

Professor Bell himself describes the incident in the following interesting manner:

"Mr. Hubbard and Mr. Saunders, who were financially interested in the telephone, wanted this instrument to be exhibited at the Centennial Exhibition. In those days--and I must say even up to the present time I am afraid to say it is true--I was not very much alive to commercial matters, not being a business man myself. I had a school for vocal physiology in Boston. I was right in the midst of examinations.

"I went down to Philadelphia, growling all the time at this interruption to my professional work, and I appeared in Philadelphia on Sunday, the 25th. I was an unknown man and looked around upon the celebrities who were judges there, and trotted around after the judges at the exhibition while they examined this exhibit and that exhibit. My exhibit came last. Before they got to that it was announced that the judges were too tired to make any further examinations that day and that the exhibit could be examined another day. That meant that the telephone would not be seen, for I was not going to come back another day. I was going right back to Boston.

~HOW AN EMPEROR SAVED THE TELEPHONE~

"And that was the way the matter stood--when suddenly there was one man among the judges who happened to remember me by sight. That was no less a person than His Majesty Dom Pedro, the Emperor of Brazil. I had shown him what we had been doing in teaching speech to the deaf in Boston, had taken him around to the City School for the Deaf and shown him the means of teaching speech, and when he saw me there he remembered me and came over and shook hands and said: 'Mr. Bell, how are the deaf mutes of Boston?' I said they were very well and told him that the next exhibit on the program was my exhibit. 'Come along,' he said, and he took my arm and walked off with me--and, of course, where an Emperor led the way the other judges followed. And the telephone exhibit was saved.

[Illustration: THE FIRST TELEPHONE SWITCHBOARD USED. EIGHT SUBSCRIBERS.]

An Emperor Wonders.

"Well, I cannot tell very much about that exhibit, although it was the pivotal point on which the whole telephone turned in those days. If I had not had that exhibition there it is very doubtful what the condition of the telephone would be today. But the Emperor of Brazil was the first one to bring that situation about at that time. I went off to my transmitting instrument in another part of the building, and a little iron box receiver was placed at the ear of the Emperor. I told him to hold it to his ear, and then I heard afterward what happened. I was not present at that end of the line. I went to the other end and was reciting, 'To be or not to be, that is the question,' and so on, keeping up a continuous talk."

"I heard afterward from my friend, Mr. William Hubbard, that the Emperor held it up in a very indifferent way to his ear, and then suddenly started and said, 'My God! it speaks!' And he put it down; and then Sir William Thomson took it up and one after another in the crowd took it up and listened. I was in another part of the building shouting away to the membrane telephone that was the transmitter. Suddenly I heard a noise of people stamping along very heavily, approaching, and there was Dom Pedro, rushing along at a very un-Emperor-like gait, followed by Sir William Thomson and a number of others, to see what I was doing at the other end. They were very much interested. But I had to go back to Boston and couldn't wait any longer. I went that very night."

"Now, it so happened there, that, although the judges had heard speech emitted by the steel disc armature of this receiving instrument, they were not quite convinced that it was electrically produced. Some one had whispered a suspicion that it was simply

the case of the thread telegraph, the lovers' telegraph, as it was known in those days, and that the sound had been mechanically transmitted along the line from one instrument to the other. Of course, I did not know about it at that time; but when the judges asked permission to remove the apparatus from that location I said, 'Certainly, do anything you like with it.' But I could not remain to look after it; they had to look after it themselves."

"My friend, Mr. William Hubbard, who had kindly come up from Boston to help me on this celebrated Sunday, June 25, said he would do his best to help them out, although he was not an electrician. He knew nothing whatever about the apparatus, beyond being in my laboratory occasionally, knowing me well. But he undertook to remove this apparatus and set up the line under the direction of the judges themselves. So they had an opportunity finally of satisfying themselves that speech had really been electrically reproduced."

"Sir William Thomson's announcement was made to the world in England, before the British Association, and the world believed--and from that time dates the popular interest in the telephone."

In October, 1876, the first outdoor demonstration, in which conversation was carried on over a private telegraph wire, borrowed for the occasion, took place between Boston and Cambridge, a distance of two miles.

In April, 1877, the first telephone line was installed between Boston and Somerville.

A month later an enterprising Boston man put up a crude switchboard in his office and connected up five banks, using the system for telephoning in the day-time and as a protection against burglars at night. This was the beginning of the exchange system, all previous telephoning having been between two parties on the same circuit.

~NINE MILLION TELEPHONES IN U. S.~

Soon after exchanges sprang up in several cities, and by August of that year there were 778 Bell telephones in use. From this modest beginning the telephone has grown until on January 1, 1914, there were 13,500,000 telephones in the world, nearly 9,000,000, or over 64 per cent being in the United States.

[Illustration: MODERN DISTRIBUTING FRAME

When the wires come to this frame they are in numbered order in the cable. The main frame redistributes these wires so that they are arranged according to their call numbers, making it possible to connect any wire with any other wire anywhere that telephone service is installed.]

[Illustration: HOW THE WIRES ARE PUT UNDERGROUND

Breaking Up the Asphalt Pavement. First Step in Laying an Underground Cable.]

[Illustration: Laying Multiple Duct Tile Subway Through Which the Cables Will Run.]

[Illustration: Feeding Cable Into Duct as It is Being Pulled Through Subway from the Other End.]

[Illustration: A CABLE TROUBLE]

The use of the telephone instrument is common, but it affords no idea of the magnitude of the mechanical equipment by which it is made effective.

~UNSEEN FORCES BEHIND YOUR TELEPHONE~

To give you some conception of the great number of persons and the enormous quantity of materials required to maintain an always-efficient service, various comparisons are here presented.

[Illustration: TELEPHONES. Enough to string around Lake Erie--8,000,000, which, with equipment, cost at the factory $45,000,000.]

[Illustration: WIRE. Enough to coil around the earth 621 times--15,460,000 miles of it, worth about $100,000,000, including 260,000 tons of copper, worth $88,000,000.]

[Illustration: LEAD AND TIN. Enough to load 6,600 coal cars--being 659,960,000 pounds, worth more than $37,000,000.]

[Illustration: CONDUITS. Enough to go five times through the earth from pole to pole--225,778,000 feet, worth in the warehouse $9,000,000.]

[Illustration: POLES. Enough to build a stockade around California--12,480,000 of them, worth in the lumber yard about $40,000,000.]

[Illustration: SWITCHBOARDS. In a line would extend thirty-six miles--55,000 of them, which cost, unassembled, $90,000,000.]

[Illustration: BUILDINGS. Sufficient to house a city of 150,000--more than a thousand buildings, which, unfurnished, and without land, cost $44,000,000.]

[Illustration: PEOPLE. Equal in numbers to the entire population of Wyoming--150,000 employes, not including those of connecting companies.]

The poles are set all over this country, and strung with wires and cables; the conduits are buried under the great cities; the telephones are installed in separate homes and offices; the switchboards housed, connected and supplemented with other machinery, and the whole system kept in running order so that each subscriber may talk at any time, anywhere.

Where Does Sound Come From?

Somebody or something causes every sound we hear. Sounds are the result of disturbances in the air. Sound is produced by waves in the air. The buzz of the bumble-bee is caused by the quick movement of his wings in the air. The wings themselves do not make the sound, but their motion causes waves or vibrations in the air which produce the sound of buzzing. Every motion made by anybody or anything produces waves in the air just like the waves you see in the water--a big movement makes a big wave and a tiny movement a tiny wave. When you clap your hands you make a disturbance in the air which causes a sound--the harder you clap the louder the sound. You can hear this sound and anybody else near can hear it. If there were no air about us, however, we would hear no sound, even if we could live in such a condition of things, for it is the air waves produced striking against the drum of our ears that enable us to discern sounds. When we talk we make air waves also and thus produce sound. If you were deaf, and talked, you could not hear any sound, because even when there are air waves they must still strike against a sounding board in order to be recognized as sound--and the drum of our ear is our sounding board for hearing sounds.

When the air waves produced are regular we call the sound musical, and when they are irregular we call it noise. Some people can make musical sounds when they sing, while others cannot.

If you take a piece of thin wire and stretch it tightly, fastening it at both ends, and then pull it with your finger and let go, you will hear a musical sound, because the vibrations produced will be regular and will continue for some time. If you shorten the distance on the wire where it is fastened at both ends and pull it as before, the sound produced will be in a higher key. If you take a guitar and snap the big G string you will produce the bass note of G. If the other G string (the smaller one) is in tune (if you watch the smaller one closely while you strike the larger one) you will notice the smaller one vibrate also. Sound waves of the same tone, although in different octaves, produce the same sounds, although in different keys.

This is the principle on which the piano is made to produce music. Inside the piano are wires of different lengths and the keys of the piano are arranged to operate certain little hammers, each of which strikes a certain wire. Every time you strike a piano key you cause one of the little hammers to hit its wire--the wire then makes vibrations which cause air waves. The air waves strike against the sounding board which is located behind the wires, and being thrown back into the air, strike against the drum of our ears, and we can hear the note.

Why Can We Make Sounds With Our Throats?

The sounds we make when we talk are produced in exactly the same way with the exception of the little hammers. In our throats are two cords which we call our vocal cords. When we talk we cause these cords to vibrate and thus we make the sounds of our voices. The most wonderful part of this voice of ours is that with only two vocal cords or wires, we can produce practically all the notes that can be made with a piano, which has a wire or cord for every note, excepting that we cannot make so many at one time. The human throat is so wonderfully constructed that we can lengthen or shorten our vocal cords at will and produce, with two strings, in our throats as many notes as it takes the piano many more strings to produce.

Why Does the Sound Stop When We Touch a Gong that Has Been Sounded?

When we touch the gong we stop the sound waves which the gong gives off when it is struck. These sound waves continue after the gong has been struck in continuous vibrations until something stops them. When you touch the vibrating gong, you stop its vibrating. If you only touch your finger to the vibrating gong you can feel the vibrations which cause a little tickling sensation. Naturally when you stop these vibrations you stop the air waves which the vibrations cause, and thus also the sound of these air waves striking your ear are stopped and the sound ceases.

How Can Sound Come Through a Thick Wall?

A sound will come through a thick or thin wall only if the wall is a good conductor of sound. Some things are good conductors of sound and others are not, just as some things are good conductors of electricity and others are not. If a wall is built of materials all of which are good conductors of sound, the sound will come through it no matter how thick. Wood is an especially good conductor of sound. It is even better than air. You can stand at one end of a long log and have another person at the other end hold up his watch in the air, and you cannot hear the watch tick, but if the watch is "going" as we say, and you ask the person holding it to put the watch against his end of the log, and you then put your ear to the other end, you can hear the watch ticking almost as well as if you had it to your own ear. In like manner you can hear the scratching of a pin at the other end of the log. When you put your ear against a telegraph pole you can hear the hum of the wires while you cannot hear it through the air. All sound is produced by sound waves and many solids are better conductors of sound waves than the air.

Sound waves, however, will sometimes not be heard as plainly through a wall, because of the fact that the wall may be made of materials which are not equally good conductors of sound. When a sound wave strikes a poor conductor it loses some of its power and the sound, although it may be heard through the wall, will be fainter.

What Is Meant by Deadening a Floor or a Wall?

By deadening a floor, for instance, we mean inserting between the ceiling of the room below and the floor above, or in the instance of a deadened wall, between the two sides of the wall, some substance like felt, paper or other non-conductor of sound, which will prevent the sound waves from passing through. This deadens them to the passing of sound or makes them sound-proof.

What Makes the Sounds Like Waves in a Sea Shell?

The sounds we hear when we hold a sea shell to the ear are not really the sound of the sea waves. We have come to imagine that they are because they sound like the waves of the sea, and knowledge that the shell originally came from the sea helps us to this conclusion very easily.

What Are the Sounds We Hear in a Shell?

The sounds we hear in the sea shell are really air waves or sounds made by air waves, because all sounds are produced by air waves.

The reason you can hear these sounds in a sea shell is because the shell is so constructed that it forms a natural sounding box. The wooden part of a guitar, zither or violin is a sounding box. They have the faculty of picking up sounds and making them stronger. We call them "resonators," because they make sounds resound. The construction of a sea shell makes an almost perfect resonator. A perfect resonator will pick up sounds which the human ear cannot hear at all and magnify them so that if you hold a resonator to the ear you can hear sounds you could not otherwise hear. Ear trumpets for the deaf are built upon this principle.

Sometimes when you, with your ear alone, think something is absolutely quiet, you can pick up a sea shell and hear sounds in it. But the sea shell will magnify any sound that reaches it.

It would be possible, of course, to take a sea shell to a place where it would be absolutely quiet and then there would be no sounds.

There are such places, but very few of them. A room can be built which is absolutely sound proof.

[Illustration: SIBERIAN LAMBS IN SOUTH DAKOTA]

The Story in a Suit of Clothes

Where Does Wool Come From?

We could not write the story of a suit of clothes without dealing largely with the sheep, for it is only from the wool of the sheep that the best, warmest and most lasting garment can be made. In order that we may properly understand the development of the great wool and clothing industry in America we must supply a brief history of our sheep industry, for the sheep must always come before the clothing.

Who Brought the First Sheep to America?

The sheep is not a native of America, but it came here with the first white men. History records that Columbus on his way to this country stopped at the Canary Islands to take on stores. Among other things he loaded a number of sheep, some of which were later landed on the new continent. What became of this early importation history does not record, but it is probable that most, if not all, of them perished from the attack of wild animals or at the hands of the natives. However, when settlers began pouring into the new world many of them brought along their sheep, so that from the earliest colonial days the sheep constituted our most numerous domestic animals. This, indeed, was necessary, for if the colonist was to survive the rigor of our climate he must have an abundant supply of woolen clothing. In those days clothing materials were limited to wool, flax and the skins of animals, and, as may be supposed, wools were in very great demand. England and most European countries prohibited the exportation of wool, in order to increase the demand for the clothing which she manufactured. However, as our new colonist had ample time and but little money, he desired to make his own clothing rather than send such funds as he had to the mother country. Therefore, the new settler, as a matter of necessity, was forced to increase the domestic supply of wools.

Who Started to Make Clothing from Wool in America?

Early records reveal that shortly after the year 1600 many of the colonies passed laws for the purpose of encouraging the sheep industry. In fact, some of them went so far as to prohibit the transportation of sheep or wool from one colony to another. However, our new sheep industry prospered, and well it should, for it had the backing of every prominent patriot of the early days. Washington, Jefferson, Madison, and Franklin all were enthusiastic advocates of sheep husbandry, for they knew that unless a people had a large domestic supply of wool they could not long remain independent or hope to gain independence from foreign countries. In fact, at one time Washington owned as many as one thousand sheep, and if he lived in the present day he would be regarded as a sheep baron. Wool, next to food, is the most vital necessity of a people, for when wars come wool becomes a contraband, and all foreign supplies are shut off. Thus, in stimulating a domestic wool supply the great wisdom of our early patriots was vindicated with the coming of the Revolutionary War. When that great struggle came our foreign wool supply was shut off, but on account of the foresight of these patriots in encouraging home production, our colonists had a supply ample for most of their needs.

We not only had the wool, but the housewife had learned the art of manufacturing wool into clothing by means of the spinning wheel, so that when our soldiers went forth in that great struggle, which was to bring to us independence, they were clad in garments made of American grown wool and manufactured by the good housewife during her hours of leisure.

When affairs became tranquil, following the close of the Revolution, settlement, which had largely been confined to the Atlantic coast, pushed westward farther and farther into the wilderness. Each of these settlers took with him his supply of sheep, for the purpose of furnishing wool for clothing and meat for food. In the early days wool was not grown for the purpose of sale, but to be used entirely by the family of the producer. However, when settlement reached the Mississippi River, conditions changed. Wool manufacturing had then been established in the land, and it became customary to raise wool to sell to these manufacturers, who had located along the Atlantic seaboard.

Why Does the Sheep Precede the Plow in Civilizing a Country?

In all countries the sheep has been the pioneer of civilization. They have settled and developed practically all new lands. In fact, so firmly established has been this rule that it seems almost necessary that the sheep should precede the plow, and thus prepare land for agriculture. The reason for this is that the sheep is a tractable animal and depends on man to guide its every step. It can endure hardships that would destroy other forms of animal life. However, the maintenance of a sheep industry requires an abundance of

labor, and in this way settlement always follows the sheep. So has it been in foreign countries, and so was it in this country.

Where Does Most of Our Wool Come From?

Sheep came into our western states early in the seventies, at a time when these states were thinly settled, but following the sheep came the labor incident to its care, and thus the railroads, stores, cities and schoolhouses found their way into the land. Originally all of our sheep industry was east of the Mississippi River. Then for a time it was east of the Missouri River. To-day west of the Missouri River we have about 23,000,000 aged sheep, or more than one-half of the total in the United States. In the pioneer days the western sheep skirmished on the range for most of the food that it obtained. To-day conditions are different, and, while the sheep is on the range for a short time each year, it spends its summer in the National Forest, for which grazing a fee is paid to the Federal Government. Its winters are spent largely around the hay-stack of the farmer, and about fifty to sixty cents' worth of hay is fed to each sheep in the West each winter. With the coming of spring the western sheep are divided into bands of about 1500, and each two bands are placed in care of three caretakers, who care for and protect the sheep either on the deeded land of the owner or on the land rented from the Federal Government.

[Illustration: SHEEP COMING OUT OF FOREST]

How Much Wool Does America Produce Yearly?

So much for the history of our sheep. A few words now about wool. The total wool crop of the United States is approximately 300,000,000 pounds per year. The value of this crop is around $60,000,000 annually.

How Do We Get the Wool Off the Sheep?

With the coming of spring our sheep are driven to large central plants, where they are shorn by the use of machines driven by electricity or steam power. One man shears about one hundred and fifty sheep per day. For this he receives eight cents per head. When the wool is taken off the sheep it is gathered up and carefully tied with string made of paper. The tied fleece is then dropped into an elevator, and is carried up about ten feet, where it is dropped into a large sack about three feet in diameter and seven feet long. In this sack there is always a wool tramper, who keeps tramping the fleeces down, so that about forty fleeces are finally put into each sack, making the weight of the sack approximately three hundred pounds. As these sacks are filled they are carefully stored in a dry shed, and, when shearing is completed, are hauled to the railroad station and shipped to the great wool centers of Boston or Philadelphia. While the bulk of the wool in the United States is produced west of the Missouri River, that territory manufactures very little wool. So the western sheepman, who is thus forced to grow his wool in the western states, pays about two cents a pound freight on it back to the eastern market, where it is sold and later manufactured into cloth. A part of this same clothing is then shipped west, to be sold to the very man, in some instances, who produced the wool out of which it is made.

American wool, taken as a whole, is the best wool grown in the world. It is not as soft as some Australian wool, but all of it possesses a greater strength than foreign wools, and it has long since been determined that clothing made of American wool will give better service than that made of foreign wool. Of the wool used in the United States for the manufacturing of clothing we produce about 70 per cent and import about 30 per cent.

How Much Does the Wool In a Suit of Clothes Cost?

It is customary for the person who buys clothing made of wool to believe that the value of the wool in the cloth is what makes the clothing seem expensive. However, if we take a man's suit made of medium-weight cloth, such as is worn in November, we find that it requires about nine pounds of average wool to make the suit. For this wool the sheepman receives an average of seventeen cents per pound, so that out of the entire suit the man who produces the material out of which the suit is made receives a total of $1.53. A suit such as is here described would be of all wool and free from shoddy or any wool substitute. It would be a suit that would be sold by the storekeeper at $25.00, and if you had it made by the tailor he would charge you $35.00. Yet the wool-grower furnished all the material out of which the suit was made, and received as his share but $1.53. Thus it will be clear to the person who buys clothing and reads these lines that no longer can the blame for the high cost of clothing be laid at the door of the wool-grower.

While the wool-using population of the world is increasing very rapidly, the number of wool-producing sheep in the world is decreasing. Ordinarily this would mean that a point would be reached where the supply of wool would be totally inadequate to meet

the needs of the public. However, this unfortunate possibility is being averted by the energy and thrift of the sheepmen in breeding sheep that produce more and better wool than was the case in the past. The sheep which Columbus brought to this country, and, in fact, all the sheep of the world in that day, produced wool of very coarse, inferior quality, and but very little of it. One hundred years ago our sheep did not average three pounds of wool per head, but by careful breeding and better feeding we have brought the average fleece up to slightly more than seven pounds. Of course, some sheep produce decidedly more wool than this, but the fact that in one hundred years we have more than doubled the amount of wool that a sheep produces and increased its quality very materially speaks well for the ingenuity and determination of our sheep producers. Probably as time goes on the average fleece may be still further increased, so that in the next twenty-five years it is not too much to hope that our sheep will produce on an average of one pound more wool than they now do.

Of course, as wool comes from the sheep, it naturally contains much dirt. The sheep have run on the range or in the open pasture during much of the year, and dust and dirt has settled into the wool. Then, besides producing wool, the sheep excrete into the wool a fatty substance known as wool fat. When the fleece is taken from the sheep and sent to the market the first thing that the manufacturer does with the fleece is to wash out all this foreign matter. The foreign matter is of a considerable quantity, for 60 per cent of wool as it comes from the sheep is dirt and grease, so that only 40 per cent of the sheep's fleece represents wool fibres.

This wool fibre is a very delicate affair, being made up of thousands of little cells, one laid on top of the other. On the surface of the fibre are a lot of scales arranged something like the scales on a fish. In the process of manufacturing the scales on one fibre lock with scales on another fibre, and in that way the fibres are held together in the piece of cloth.

When wool is received at the factory it is in fleeces, and each fleece contains different kinds of fibres--long and short--coarse and fine, and it is necessary that these should be sorted into different kinds or grades, as may be desired--perhaps six or eight different kinds, according to the particular uses to which the different qualities are to be put.

[Illustration:

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WOOL SORTING]

The fleece is spread out on a table, the center of which is covered with wire netting, and through this netting part of the dust and other matter from the wool falls while the sorting is going on. Sorters tear with the hands the different parts of the fleece from each other and separate them into piles, according to their different qualities.

All unwashed wool contains a fatty or greasy matter called yolk, which is a secretion from the skin of the sheep. The effect of this yolk is to prevent the fibres of the wool from matting, except at the ends, where, of course, it collects dust, and, forming a sort of a coating, really serves as a protection to the rest of the fleece while on the sheep's back.

After the wool is sorted it is next cleansed or scoured, in order to remove all this yolk, dirt and foreign matter, and this is accomplished by passing the wool, by means of automatic rakes, through a washing machine, consisting of a set of three or four vats or bowls, which contain a cleansing solution of warm, soapy water, until all the grease and dirt have been removed.

Each bowl has its set of rollers, which squeezes out the water from the wool before it passes into the next bowl. Having passed through the last bowl and set of rollers the wool is carried on an apron made of slats on chains, to the drying chamber, called the dryer, where is taken out most of the moisture.

The wool is now blown through pipes or carried on trucks to the carding room.

~DIFFERENCE IN WOOLENS AND WORSTEDS~

From this point the wool follows one of two different processes of manufacture--that of making into worsteds or that of making into woolens.

Speaking in a general way, worsted fabrics are made of yarns in which the fibres all lie parallel, and woolens are made of yarns in which the fibres cross or are mixed. Ordinarily, worsteds are made from long staple wools, and woolens from short staple wools.

[Illustration:

Copyright American Woolen Company

WOOL SCOURING]

By means of the comb the fibre is still further straightened out, the short stock and noil, or nibs, are removed, and when the sliver comes from the combs most of the fibres are parallel to each other. A number of the slivers taken from the comb are then put through two further operations of gilling, and wound into a large ball, which is called a finished top.

The next process in the manufacture of worsteds is carding. In this process the wool is passed between cylinders and rollers, from which project the ends of many small wires. These cylinders revolve in opposite directions. The result is the opening, separating and straightening of the fibres; and the wool is delivered in soft strands, which are taken off by the doffer comb and wound upon a wooden roll into the shape of a large ball, known as a card-ball or card-sliver, or put into a revolving can. The sliver from a number of these balls or cans is now taken and put through what is known as the gilling machine, which to a degree straightens the fibres.

From the gilling machine the wool comes off in soft strands. Four strands are then taken to the balling machine, where is made a large ball, ready for the combing. It takes eighteen of these balls to make a set or fill up the comb.

The dyeing is done in three ways--in the top, in the thread or skein after being spun, or in the piece after it is woven. If the wool is to be stock dyed--that is, dyed in the top--it is sent to the dyehouse to be dyed the shade required, and afterwards returned to be gilled and recombed ready for the drawing.

[Illustration:

Copyright American Woolen Company

WORSTED CARDING]

Up to this point there has been no twist given to the wool, nor any appearance of a thread. The top, the soft untwisted end, is now run through the drawing machine, the process sometimes consisting of nine distinct operations, and is drawn and redrawn until reduced to the size required for its special purpose; and the stock is then delivered to the spinning room on spools, and is called roving.

[Illustration:

Copyright American Woolen Company

GILLING AFTER CARDING]

[Illustration:

Copyright American Woolen Company

COMBING]

In the spinning the process of drawing continues until the twisted thread is reduced to the size required, which, either singly or twisted together in two, three or four strands, is to be used for weaving.

The yarn is then very carefully inspected, and all imperfections which would show in the finished goods are removed, and, if it is to be dyed in the skein, the yarn is taken to a reel, where the skeins are made ready for the dyehouse.

~HOW CLOTH IS MADE FROM WOOL~

The threads must now be prepared for the loom, in order that the actual weaving may be done. The thread is used in two ways in weaving--as warp, which is the thread which runs lengthwise of the cloth, and as filling, or woof, which runs across the cloth from side to side.

[Illustration:

Copyright American Woolen Company

GILLING AND MAKING TOP AFTER COMBING]

The warp threads--the threads which run lengthwise of the cloth--are sized and wound upon large reels, and from these transferred to a large wooden roll called the warp beam, which holds all the warp threads, usually several thousands.

The filling threads are put on shuttle bobbins and placed in the shuttles to be refilled by the operatives as required, and as the weaving progresses.

The warp beam is then taken to the drawing-in room, where these several thousand threads are drawn through wire heddles in a frame called the harness, then drawn through a wire reed. The completed warp beam is now ready for the loom.

The harnesses are placed in the loom, and by means of what is called the “head-motion,” part of the threads are raised and part are lowered. This allows the filling shuttles to pass above some threads and below others, filling out the pattern required.

The cloth, having been made in such length as is desired, is taken from the loom, and, by what is known as burling and mending, any knots or threads woven in wrongly are removed, and any imperfections which have been discovered through a careful examination are corrected.

The web or cloth is scoured or washed and the oil and any foreign matter removed.

Undressed fabrics would now be fulled. This consists of running cloth through a fulling machine, where, moistened with a specially prepared soap, it is subjected to a great pressure and pounding, which aids in giving the required finish.

There are different kinds of finishes which require different treatments, and it would be impracticable for us to dwell in detail upon this matter here.

If dyed in the piece, the web or cloth is taken to the dyehouse and dyed. It is thoroughly rinsed, all moisture is extracted from it, and it is dried.

After drying the cloth is run through a machine by which it is brushed and sheared, the brushing lifting the long fibres, and the shearing cutting them off at even length. The cloth is put through the press, which irons it out, giving it the lustre or the finish that is desired. It is examined again for further imperfections, and if such have occurred they are corrected.

Measuring, weighing, rolling and tagging follow, and the cloth is packed and ready for the market.

Woolens are made from short staple wools, known as clothing wools, and in the finished woolens the fibres of the yarns cross or are mingled together. In the case of woolens, after the scouring, it is frequently necessary to remove burrs or other vegetable matter from the wool. To accomplish this the wool is dipped in a bath of chloride of aluminum or sulphuric acid solution, then the moisture is extracted and the wool is put through a drier, where the temperature must be at least 212 degrees. This heat carbonizes the foreign substance, but has little effect on the animal fibres of the wool.

[Illustration: FINISHING BOX

ENGLISH DRAWING

Copyright American Woolen Company

GILLING

ENGLISH DRAWING

Copyright American Woolen Company]

Next, an ingenious machine called the burr picker removes the burr.

Sometimes there is to be a blend of the wool with other stocks, and in that case the several different wools are mixed together.

[Illustration: GILLING, FIRST OPERATION

ENGLISH DRAWING

Copyright American Woolen Company

REDUCER

ENGLISH DRAWING

Copyright American Woolen Company]

~HOW WOOLEN CLOTH IS DYED~

Dyeing of woolens is done in three ways--in the wool, in the thread after it is spun, or in the piece after it is woven. If the wool is to be “dyed in the wool” it is now conveyed to the dyehouse, dyed the shade required, then returned to the mixing room.

During the process of scouring, when the yolk was removed, a large part of the natural oil of the wool was also eliminated, and, in order to restore this lubricant, the wool is sprinkled with an oil emulsion, and the mixing picker thoroughly blends the wools.

From here the wool goes to the cardroom, and by means of the carding machine the fibres are carded and drawn and delivered to the finisher in a broad, flat sheet. By means of the condenser it is divided into narrow bands, and the wool--free as yet from twist--comes out in soft strands. These strands or threads are called roping.

[Illustration: MENDING ROOM

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BURLING RAISING KNOTS

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MENDING PERCHING

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[Illustration: DRAWING IN WARP THREADS

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Copyright American Woolen Co.

WEAVING AND SCOURING]

Now comes the mule spinning. The roping passes through rolls by which it is drawn and twisted to the size required, and wound on paper cop tubes or bobbins. Such of the yarn as is to be used for warp is then spooled from the bobbins to dresser spools. It is sized and wound upon large reels: from these transferred to the warp beam, as in the case of worsteds.

The processes of drawing-in, preparation for weaving, burling and mending are practically the same as in the case of worsteds.

~HOW THE CLOTH IS MADE PERFECT~

The finishing processes of woolens, like the finishing processes of worsteds, vary with different fabrics, some fabrics being scoured and cleansed in the washers before fulling, others going to the fulling mill without cleansing. After fulling, the cloth is again washed and rinsed, and if necessary to remove any vegetable fibres it is carbonized.

Napping or gigging raises the fibres to the nap desired. Gigging is done by means of a wire napping machine or teasel gig, which raises the ends of the fibres on the face of the cloth. The teasel is a vegetable product about the shape of a pine cone, and it is interesting to note that no mechanical contrivance has ever been invented to equal it for the purpose.

[Illustration: SPINNING THE WOOL

Copyright American Woolen Company

ENGLISH CAP SPINNING]

The napping which has been raised by the teasel is sheared or cut to a proper length by machine. The cloth is pressed, and, if it is desired to finish it with lustre, it is wound upon copper cylinders and steam is forced through it at a high pressure.

[Illustration:

Copyright American Woolen Company

RING TWISTING]

[Illustration:

Copyright American Woolen Company

BEAMING--YARN INSPECTING]

[Illustration:

Copyright American Woolen Company

WOOLEN MULE SPINNING]

[Illustration:

Copyright American Woolen Company

FINISHER WOOLEN CARDING]

Next the cloth is dyed, if it is to be piece-dyed--that is, dyed in the piece. If the cloth is a mixture, the wool was dyed immediately after the scouring. In worsteds the dyeing is done either just after it has been subjected to the first combing processes, or the yarn is dyed in the skein or hank.

[Illustration:

Copyright American Woolen Co.

PIECE DYEING

Copyright American Woolen Co.

FULLING CLOTH

Copyright American Woolen Company

FINISH PERCHING]

[Illustration:

Copyright American Woolen Company

FINISHED CLOTH, READY FOR THE TAILOR]

In the dry finishing the cloth is finished with various kinds of finishes desired, and it is steamed, brushed, sheared and pressed. Another examination for any imperfections or defects follows; the cloth is measured, packed and tagged and is ready for the market.

The difference between worsteds and woolens is principally that in the threads or yarns from which worsteds are made the fibres of the wool lie parallel, one to another, being made from combed wool, from which the short fibres have been removed; and woolens are made from yarns in which the fibres cross and are matted and intermixed. When finished the effect of worsteds and woolens is materially different. Upon examination it will be found that the worsted thread resembles a wire in evenness, while the woolen thread is uneven and irregular.

A worsted fabric when finished has a clear, bright, well defined pattern, seems close and firmly woven, and is of a pronounced dressy effect; while woolen cloths are softer, they are more elastic, the colors are more blended, the threads are not so easily distinguishable and the general effect is duller.

Why Can't We See in the Dark?

We cannot see in the dark because there is no light to see by. To understand this we must first understand that when we see a thing, as we generally say, we do not actually see the thing itself, but only the light coming from it. But we have become so used to saying that we see the thing itself that for all practical purposes we can accept that as true, although it is not scientifically exact. Scientifically speaking, we see that part of the sunlight or other light which is shining upon it, which the object is able to reflect.

If there were no air about us we could not hear any sounds, no matter how much disturbance people or things created, because it requires air to cause the sound waves which produce sound, and air also to carry the sound waves to our ears. In the same way, if there is no light to produce light rays from any given object to our eyes, we can see nothing. It requires light waves to produce the reflections of objects to our eyes. Without light our eyes and their delicate organs are useless. You cannot see yourself in a mirror when the quicksilver which was once on the back of the glass has been removed, because there is then nothing to reflect the light. We can only see things when there is light enough about to reflect things to our eyes. When it is dark there is no light, and that is the reason we cannot see anything in the dark.

Why Can Cats and Some Other Animals See in the Dark?

They cannot see in the real dark any more than human beings. These animals can find their way in the dark and can see more than a human being, because of one distinct difference in their eyes, which may for them be considered an advantage. The pupils of their eyes can be made much larger, and they can, therefore, let more light into their eyes than people. The result is that when it is so dark that you cannot see a thing and you decide it is really dark, the cat can still see, because there is always a little more light left and she can open the pupils of her eyes and make them larger, thus letting in more light, and the little bit of light there is still left gets into her eyes and she is able to see. But in a really dark room a cat could see no more than you can. You see, our eyes open and shut more or less just like those of the cat, according to the intensity of the light. When you go out of the dark and shaded room into the bright sunlight and look at the sun, you naturally squint your eyes without deliberately intending to do so. This is nature's way of preventing too much light getting into your eyes at one time. Gradually the pupils of your eyes contract and get smaller, until you can see, without squinting, anything in the sunlight. If, then, you were to go right back into a dark or shaded room, you would have to wait a moment or two before you could see things distinctly in the room--until the pupils of your eyes had dilated (become larger), so as to let in enough light to enable you to see normally. The eye automatically enlarges and contracts the pupil of the eye, to enable us to see distinctly in either light or less light places.

Why Is It Difficult to Walk Straight with My Eyes Closed?

The reason we cannot do this always is because when we walk naturally the steps taken by our right and left feet are not of equal length. This difference in the length of the steps is due to the fact that our legs are never exactly the same length. We think of them generally as of the same length, but they are not, and this will be proven if you measure them accurately. Now, then, the longer of the legs will always take a longer step than the shorter one, and so, if our eyes are shut, we walk in circles, unless we have something to guide us. When we walk with our eyes open, we are able to overcome the tendency to walk in circles, because our eyes help the brain to direct the legs on a straight course. Another reason which affects the matter is that our eyes are very necessary in keeping our bodies balanced on our feet, and it is very difficult to learn to keep the body balanced with the eyes closed. Now, when your eyes are closed and you attempt to walk in a straight line your body balances from one side to the other, and this fact, coupled with the first reason given, makes your course irregular. But, say you, the man on the tight-rope has his eyes bandaged and he walks a very straight line. Yes; but remember that he has a straight tight-rope to guide him, and all he needs is to maintain his balance. One can learn to walk in a straight line with the eyes closed, but it takes a good deal of practice, as you will learn if you try.

Why Can't We Sleep with Our Eyes Open?

We cannot sleep with our eyes open, because to be asleep involves losing control of most of the functions of the body. When we sleep the brain sleeps also. Perhaps it would be stated more clearly to say that we cannot sleep while the part of the brain which controls our activities is awake. There is a part of the brain which has the power to open our eyes, i. e., lift the eyelids, and when that portion of the brain ceases to exercise its power to keep the eyes open, they go shut. Even when we are awake that part of our brain cannot keep our eyes from winking, because there is another part of the brain which sees to it that our eyes wink every so often. This is done for the purpose of washing the eye-ball, and is the answer to another of your questions which is given in another

place in this book. When the engineer at the electric light plant shuts off the power all the lights go out, and when you go to sleep you automatically shut off the power that opens your eyes, and the eyes are shut. The brain is asleep also, and if it is not completely asleep, you are restless.

Why Do Our Eyes Sparkle When We Are Merry?

If you should watch very closely the eyes of a merry person when you see them sparkle you would probably notice that the eyelids move up and down more often under such conditions than ordinarily, and if you know what moving the eyelids up and down in front of the pupil of the eye does, you will have your answer.

Every time the eyelid comes down it releases a little tear, which spreads over the eyeball and washes it clean and bright. It does this every time the eyelid comes down. Now, there is something about being merry which has the effect of making the eyelids dance up and down, and thus, every time the lid comes down, the ball of the eye is washed clean and bright, and gives it the appearance of sparkling, as we say.

Why Do We Laugh When Glad?

We laugh when glad because the things which make us laugh combine together to rouse those parts of the body which are involved in a good laugh to act in a certain harmony, and when this combination is arranged in a certain way it produces a laugh. Certain things in the world, whether they are funny, ludicrous, or other things that produce the laughing effect, cause the brain to work certain muscles and nerves in a combination that produces a laugh. The impression which reaches the brain causes these muscles and nerves to act involuntarily and the laugh comes. It works just like the keys of the piano. Some combinations of notes produce sad sounds and other combinations produce glad sounds, but the combination when once touched will always produce the same sound. It is the impressions made on the brain which start the proper combination, and it does this instantly. Just as a pin prick in the arm will at once send a "hurt" message to the brain and cause the brain to jerk the arm away, so a laugh-producing combination of sounds, or things we see, or feel, sends an impression to the brain which at once sends out the "laugh" order. Some things make some people laugh while they do not affect others at all. That is because our brains are not always the same in regard to recording impressions. Some things impress some brains one way and others entirely in a different way or not at all. You do not laugh so heartily the second time you hear a funny story, because the impression the brain receives when the story is told the second time is not so vivid.

Why Do I Laugh When Tickled?

Practically the same things happen when we are tickled, and explains why you laugh when tickled. When some one tickles the bottom of your feet or your ribs or another part of your body it produces, in most cases, the same effect on the brain as the laugh-producing sound or sight, and arouses the same combination of muscles and nerves to activity. It is just like pushing the button of an electric bell. When you push the button the contact produces the spark which sets the machinery of the bell in motion and the bell rings and will continue to ring as long as you keep your finger on the button, or until the spark-producing power of the battery is gone. Then, as in the case of the bell, you cease to laugh, because the spark that produced the laugh combination is gone. That is why some things tickle some people very much and do not affect others. Some are not so sensitive to the laugh-producing combination as others. After the thing that tickles you has been going on for some time you are not tickled into laughter any more, because the impression on the brain ceases to be as strong.

Why Don't I Laugh When I Tickle Myself?

Your mind tells you there is no need to laugh when you tickle yourself. Your mind will not respond to the tickling sensation when it is aware that the cause of the tickle is yourself. The reflex action of the mind which causes laughter and squirming when some one else tickles you only acts when it is not conscious of the cause.

The whole purpose of the sensitive organization of our skins is to give us information and cause action which will enable us to protect ourselves when any outside influence touches us. An injurious touch causes shock and pain, and the harmless tickle arouses the laughing and squirming sensation.

What Happens When We Laugh?

Laughter is what we call a reflex action. When something occurs to make us laugh, whether it is something we see, or feel, or hear, it is because certain sensory nerves receive an impression in one of three ways, carry it to the nerve centre and the nerve centre then sends the same impression along certain efferent nerves, which connect with certain muscles or glands, and excite them to activity. The action is practically the same as when you hold a light before a mirror. The rays from the light strike the surface of the mirror and are reflected back from the surface, lighting perhaps corners of the room, which the direct rays from the light could not reach, all depending upon the angle of reflection. Light will always reflect from a mirror that is exposed to it.

Now, then, when you see, hear or feel anything that makes you laugh, the sensory nerves have only to receive the impression to bring on the explosion of laughter. Something touched the laugh nerves or the laugh trigger that caused it to go off. You can prove that it is a matter of impression entirely by noting that some people can listen to a perfectly funny story, even when told by a clever performer, and never crack a smile, while others burst into uncontrollable laughter, and he who does not even smile may be listening even more intently than the other--he may even be looking for a laugh. It all depends upon the impression that is made upon the nerves. The muscles have the power to express the state of gladness which is indicated by laughter when certain impressions pass along the nerves which operate them, just as they can be made to do other things when the proper cause for action is shown them.

Why Do We Cry When Hurt?

We cry when we are hurt for the same reason that we laugh when we are glad. The muscles and nerves, under the direction of the brain, produce the cry just as the muscles and nerves produce laughter, although they are probably, but not necessarily, a different set of muscles and nerves.

When we are hurt in any part of our body or feelings the impression does not affect us until it reaches the brain. Then instantly, of course, the body and brain go to work to destroy the pain. The first thing, of course, is to give a warning to other parts of the body that there is a hurt, and our crying is a warning to other people that we are hurt. That is probably the only good that crying does. It does not remove the hurt--it only tells others of our troubles. We cry with the lower part of the brain--the only portion of the brain which is active in a little baby. This is why even a tiny baby can cry. Crying is the only thing a baby can do to give warning of its distress or discomfort. Later in life the upper part of the brain develops. This is the master of the lower part. Therefore, we do not always cry when hurt as we grow older, because the master brain sometimes tells the lower brain that to cry will not help matters in the least, even though we are inclined to cry. Sometimes the hurt or shock to older people is so great or sudden that we cry out before the controlling part of the brain has had time to get in its work of preventing the outcry, but we are able to stop crying when the master brain again secures control.

Where Do Tears Come From?

Tears are not made only when we cry. They seem to come only when you cry, because it is then that they spill over. A little part of you is making tears all the time, and your eyes are constantly washing themselves in them. You have often noticed how you wink every few seconds? You have often tried to keep from winking--to see how long you could keep from winking. Boys and girls often do that, and when you keep from winking what seems a long time, you notice how your eyes ache and feel very dry just before you have to let them wink, in spite of how hard you try not to, and just when you think you are not going to. I will tell you just what winking does for the eyes. All of the time your eyes are open the front, or the part you see things with, is exposed to the dust and dirt that fills the air at all times, although we cannot always see the dust. The wind, too, is constantly making them dry. But have you ever noticed that although you never wash the inside of the front of the eye, or pupil, it is always clean? Well, it is because your eye washes itself every time you wink. I will tell you how this is done. Up above each eye, inside, of course, there is a little gland called the tear-gland. This gland is busy all the time you are awake making tears. As soon as the front of your eye becomes dry, or if a particle of dust or anything else strikes it, the nerves you have there tell the brain, and almost at once the eyelid comes down with a tear inside of it, and so washes the front of your eye clean again. It does its work perfectly and as often as necessary. There is always a tear ready to be used in this way.

Where Do the Tears Go?

Let me show you. Look right down here at the inner corner of my eyelid, where you will see a little hole. That is where the tears get out of the eye, when they have washed your eyeball clean. Where do they go then? Did you ever notice how soon after you cry you have to blow your nose? The reason for that is that when the tears go through the little hole they run down into the nose. This making of tears and winking goes on all the time while you are awake, and after they wash your eye off they go on out through this little hole. But when you cry you make more tears come than you need, so many, in fact, that they cannot all get away through this little hole, and as there is no place else for them to go, and as there is no place to keep them inside the eye, they simply spill themselves right over the edge of your lower eyelid and run down your cheek.

Story in a Barrel of Cement

What Is Cement?

The dictionary tells us that cement is "any adhesive substance which makes two bodies cohere." Thus any material performing this function may be called cement, such, for example, as the cement used in mending broken china. Glue also is a form of cement. This story has to do with Portland cement, which is a structural or building material used in countless ways.

Why Is Cement Called Portland Cement?

After being wet with water it hardens into stone, and it was given the name "Portland" because, when first manufactured in England, and mixed with sand and stone, it resembled a celebrated building stone called Portland, which was obtained from the Isle of Portland. Compared with other American industries, the manufacture of Portland cement is of recent origin. Formerly all Portland cement was brought from foreign countries. After successful manufacture became established in this country, however, the industry advanced with great rapidity. A few years ago the entire United States did not use as much cement as is now used in any one of our large cities. At the time these facts were written (1914) the manufacturers were making more than 90 millions of barrels a year.

What Is Cement Made Of?

Portland cement is composed chiefly of lime, alumina and silica. It is manufactured from rocks, marl, clay and shale containing these ingredients. If any one of them is lacking in the raw material as it is taken from the earth, it is supplied during process of manufacture. The greatest cement district in America is in Pennsylvania, and is known as the "Lehigh District." A rock containing proper constituents for making Portland cement was found there in vast quantities, and for a number of years the Lehigh District was the center of the industry. In time it was found that certain clays, marls and shale could also be manufactured into Portland cement, and thus mills have been erected in all sections of the United States. One of the largest companies in the United States found that cement could be manufactured from a combination of blast-furnace slag and limestone, and this is now made by the company in large quantities, the product being a true Portland cement.

What Is Concrete?

Portland cement is the strongest and most lasting of all modern mortars or binding materials. When mixed with sand and stone the resulting mixture is called concrete. Being a plastic material when first mixed, it cannot be used as we use brick or stone, but must be poured into molds or forms, which hold it in place until it hardens into rock. It may be cast in any form or shape, and thus it is useful for a vast number of purposes. It will harden under water, and time and exposure to the elements merely increase its strength. The most common form in which it is used, one familiar to everybody, is in the construction of sidewalks. It is used in all great engineering projects, such as the building of dams, bridges, retaining walls, sewers, subways and tunnels. Being fireproof, large quantities of it are used in buildings and likewise on our farms, where it is extremely valuable as an enduring and sanitary material.

What Is Cement Used For?

It has been said that concrete is a plastic material, meaning that it is soft and pliable in the sense that clay or putty are plastic. For this reason it is cast in forms or molds. Sometimes it is used in the form of plain concrete, and on other occasions it is reinforced, meaning that iron rods, steel bars or woven wire mesh are imbedded in the concrete. When we speak of a "reinforced" concrete building, imagine a huge wire bird cage encrusted within and without with concrete. Place a block, beam or column of concrete upon the ground and it will bear a tremendous load, meaning that it has great strength in compression. On the other hand, if we were to place a long beam upon supports at either end, leaving the greater length of it suspended and without support, it would

carry but a small load compared with concrete in compression. Therefore, in making concrete beams or girders in a building, strong steel bars are embedded in the concrete to take up what are termed the tensile strains.

[Illustration: WHAT A CEMENT MILL LOOKS LIKE

This is a picture of a cement mill. Millions of dollars are invested in these great mills, which are now located in practically all sections of the country. Material is brought from the quarry to the mills, where it passes through various stages, such as grinding, burning and bagging. Expert chemists are employed to see that the cement is made exactly right. It is a very scientific matter to make a thoroughly good cement. There must be no guess work. Some mills are very large, the plant comprising a number of buildings, and some companies operate several mills in different localities. A single company supplied all of the cement used in the Panama Canal, which great project required more than six million barrels.]

[Illustration: This picture shows a quarry in the famous Lehigh cement district. The giant steam shovel or excavator burrows into the hill like some great animal, and when the bucket is full it is dumped into the cars shown on the track, which convey the rock or the raw material to the mill.]

[Illustration: WHERE THE MATERIAL IS OBTAINED

This is an illustration of a method of excavating and loading marl and clay to be manufactured into Portland cement. The large bucket suspended over the cars does not gouge into the hillside as shown in the preceding picture, but descends like a huge steel hand, the metal parts opening and closing like fingers. The long derrick elevates the bucket and swings it over the train of cars.]

[Illustration: This is a view of a powerful rock crusher, which is operated by the electric motor shown at the right. The cement rock is brought from the quarry and dumped into the machine, from which it issues in broken fragments, as shown in the illustration, this being the first or preliminary crushing process.]

[Illustration: THE HUGE ROCK GRINDERS

This is a view of the electric motors operating the grinding machines which reduce the raw material to a very fine powder. There are various types of mills or grinders, to which the material comes after going through the rock crusher. They grind it in preparation for the kilns.]

[Illustration: The kiln is a very important feature of the cement plant. The finely ground raw material must be calcined or burned before it becomes Portland cement. These kilns range from 60 to 240 feet in length. They are slightly inclined and revolve upon rollers. The finely ground material enters the kiln at the upper end and travels throughout its length as the kiln slowly revolves. Powdered coal dust is fed into the kiln at the lower end, where it is ignited and generates intense heat. When the finely ground raw material comes into contact with the heat, which reaches 2800 degrees F., it is transformed into what is known as clinker, which issues from the lower end of the kiln and is passed on to other machinery, which grinds it into impalpable powder or Portland cement.]

[Illustration: HOW CONCRETE IS MIXED

This is an ingenious machine which bags and weighs the cement. The bags are suspended as shown, and when filled and weighed by the machine are placed in barrels and shipped to their destination. Every device of this kind that will save time and labor cheapens the cost of manufacture.]

[Illustration: In mixing cement, sand and stone together in order that concrete may be obtained, it is customary to use, if the operation is a large one, what are known as mechanical mixers. These are large iron cylinders into which the three materials are put and water added. The cylinder or iron drum revolves until the contents are thoroughly mixed, when they issue from the mixer through a chute or spout. A mixer of this type is shown on a succeeding page describing the making of a concrete road. This picture shows mixing concrete by hand. The sand and cement are first thoroughly mixed in the dry state and subsequently the stone and water are added. Concrete should be thoroughly mixed in order that every grain of sand may be entirely coated with cement, and then these two combined make a rich mortar, which should surround entirely every piece of stone.]

[Illustration: HOW CONCRETE BUILDINGS ARE MADE

This picture shows how concrete houses or walls are built through the use of what are known as forms. In building a wall we have an inside and outside form, as shown in the picture, between which the concrete is placed. After it hardens the forms are removed.

In some operations, such as the construction of a large factory building or great bridge, there is such a vast array of timber construction as to make the scene quite impressive, especially when bridge arches of great span and height are under construction.]

[Illustration: This is a view of an arch built of concrete during the Jamestown Exposition. It is a striking illustration of how concrete may be used for both ornamental and practical purposes. In no field has concrete proved to be of more value and economy than in the construction of bridges, whether large or small. Some of the largest bridges in the world are built of concrete, and in many cases iron bridges are incased in concrete to keep them from rusting.]

[Illustration: CONCRETE HOUSES CANNOT BURN

This is a curious example of concrete construction. It is a coal pocket, from which locomotives are supplied with fuel. Railroad companies have adopted it because of its great strength and durability.]

[Illustration: Just as mammoth structures are created with poured concrete, so we may produce the most delicate and ornamental patterns. These are usually cast in plaster molds and often in molds of wood or iron. Where undercut work is required, such as in the sun-dial shown, a wood or metal mold could not be removed without injury to the concrete, and so sculptors have invented the pliable glue mold, which can be easily removed and which will spring back to its original shape if necessary to use it a second time.]

[Illustration: Concrete in dwelling construction means the elimination of fire danger and also cost of painting and repairs. This picture shows a solid concrete house, parts of which have been encrusted with beautiful tiles. Concrete has been successfully used in all types of dwellings, from the humble abode of the workingman to the palace of the multimillionaire. An entire house may be made of concrete, even to the roof and stairways, and where a dwelling is constructed of this material throughout, it is proof against fire and decay.]

[Illustration: HOW THE FARMER USES CONCRETE

This is an interesting example of concrete construction. It is a large water tower which will never warp, rust or decay. In this field concrete has been of great service, whether reservoirs are constructed in the form of towers or tanks. As already stated, water does not affect the life or strength of concrete, except to improve it.]

[Illustration: This is a concrete silo. A silo made of concrete is merely a huge stone jar in which green food for cattle is preserved. The crop is gathered and placed in the silo, thus insuring abundance of green and wholesome food throughout dry seasons and during the winter. The contents of the silo is known as silage or ensilage, and is merely corn fodder cut when green. Concrete silos are both storm- and fire-proof.]

[Illustration: It is usual to consider concrete in connection with great engineering enterprises, but nevertheless many millions of barrels are used each year by the farmers of the United States. This picture shows a clean, sanitary and durable concrete stable. In buildings of this character concrete is rapidly supplanting wood, which soon goes to decay, to say nothing of accumulation of filth.]

[Illustration: HOW CONCRETE ROADS ARE BUILT

MECHANICAL CEMENT MIXER]

[Illustration: A CONCRETE ROAD

Our two last pictures relate to an exceedingly important and rapidly increasing use of cement. It is the construction of concrete roads. The first picture shows a concrete road in course of construction. The mechanical mixer referred to above is shown in this picture. It is a self-propelling machine and mixes the concrete very rapidly. As it comes from the mixer in a wet and mushy mass it is placed between rigidly staked side forms, where it hardens into imperishable rock. The road is brought to its shape by working to and fro a long plank called a template, after which the surface of the road is troweled with wooden floats, giving it a texture which prevents horses and cars from slipping. The last picture shows a narrow concrete road in the state of Maryland. Wherever these roads have been built they mean much to the women and children of the community. They never grind up into mud or dust, and are as pleasant to walk upon as the sidewalks of the city. Children, especially, delight in them. In Wayne county, Mich., where they have the most celebrated concrete roads in the world, the children go to and from school on roller skates, and various games are played on the concrete road.]

Why Don't We Make Roads Perfectly Level?

Roads are made with a curving upper surface, i. e., higher in the middle, in order that the rain will drain away from the road into the gutters or ditches which you find at the sides. You see water has the faculty of running only in one direction, and that is downward. If it cannot go down on one side or the other, it will collect in puddles and make the road impassable. For this reason we build our roads so they are higher in the middle than at the sides--not much higher; only about six inches or so--giving them just the gentle slope toward each side that is necessary to allow the water to run off gradually, but sufficiently sloping to keep the water from collecting in puddles in the road. Thus after the dust has been settled by the first rain that falls, most of the surplus rain that falls on the roads finally runs into the ditches at the side of the road.

Why Are Some Roads Called Turnpikes?

Undoubtedly the name turnpike as applied to some roads arose from the fact that pikes or gates were set across the roads by the keeper or toll-collector. In addition to collecting tolls, it was a part of the toll-keeper's business to keep the road in repair. His wages and other expenses for doing this were received from the tolls collected from the people who used the road to ride on in carriages, wagons, etc. In the early days the toll-collector was armed with a pike, a long-handled weapon with a sharp iron head, which he used to prevent people who travelled his road from going by without giving up their toll. Later on a swinging gate was built across the road, which made it unnecessary to use the pike, though the name was retained, for no one could pass while the gate barred the way. When the passerby had paid his tolls, the toll-collector opened the gate and let him pass. If he did not pay the gate remained closed and the driver had to turn back or decide to pay. Hence comes the name turnpike. In some parts of the country they call these toll roads.

What Is Dust?

A large part of the dust we see in the roadway when the horses kick it up, or when an automobile passes, is made up of the pulverized dirt of the roadway. It becomes mixed with other things, such as the street deposits of animals, particles of carbon, etc. Particles of this dust get into our throats, and as there are many germs in it, they are very liable to cause sickness, especially the colds from which we suffer.

What Becomes of the Dust?

The dust of the roadway is generally blown away by the wind, to come down to earth again wherever the wind happens to carry it--on the lawns, the doorsteps or back to the road, perhaps. In any event, the rain which is certain to come sooner or later, washes this dust back into the soil, or into the sewers. Part of it mixes with the soil. The organic matter in dust helps to fertilize the soil, and is therefore useful. Other parts of the dust are oxidized and consumed by the air, through the heat of the sun. So you see the dust is continually changing from one thing to another.

Are Stones Alive?

Real stones are not alive. They do not become stones until they have been burned out--until they have become what is known as dead matter. This is meant entirely in the sense that we commonly think of the meaning of the word "alive," which is to be able to breathe and grow. Stones can neither breathe nor grow. They belong to the inanimate kingdom of things on the earth. Particles of this dead matter, found in stones, etc., are in many cases taken up by things that are actually alive, and help to form the bodies of living things.

The most common thing to be found in rocks and stones is what is called "silicon," and we find this silicon in the straws of the wheat, oats and corn, and in many other things, but not in a way that can be detected except by chemical analysis. A great many of the things found in stones are found in living things, but rocks and stones are not alive in any sense.

What and Why Is Smoke?

Smoke is produced only when something which is being burned is burning imperfectly. If we were to put anything burnable into the fire and establish just the right amount of draft, and knew how to build our fires properly, there would be no smoke and very little

ashes.

In the case of the black coal smoke which we think of mostly when we think of smoke at all, the black portion is principally little unburned particles of coal which pass up the chimney with the gases which are thrown off when the coal is being burned. These gases would be invisible--they really are invisible--if it were not for the little particles of coal which are drawn up the chimney with them. If you look at the chimney from which a wood fire expels the gases you find the smoke very light in color--showing that not so much unburned matter is being thrown off. A charcoal fire makes no smoke, because the charcoal has had the unburnable things taken out of it beforehand, and the charcoal stove is almost perfect in construction from the standpoint of combustion.

Of course, the thickness of the smoke from a coal fire is often increased by the fact that there are unburnable things mixed in with the coal, some of which also pass off through the chimney.

Why Can't We Burn Stones?

We cannot burn anything that has already been burned, and a stone has already been burned. To understand how this is we must first find out what takes place when a thing is burned. When a thing is burning it means merely that that particular thing is taking into its system all of the oxygen of the air that it can combine with. When it has done this it cannot be burned any more. Of course, in doing this the thing originally burned changes its character. The elements in a candle when lighted mix with the oxygen in the air and disappear in the form of gases. The elements in coal mix when fired with oxygen and change into ashes, gases and smoke. A stone, however, is the result of a burning that has already taken place. The original element of most of the rocks and stones we see was silicon, and when that combines with oxygen, the result is some form of rock, which you may be able to break up or throw, but which you cannot burn again.

What Is Fog?

The fog which we generally think of when we speak this word is the fog at or on the sea or other body of water--the one that makes the ships stand by and blow their fog horns. A fog of this kind is nothing more nor less than a cloud, come right down to earth and spread out a little more. People who have gone up into the air in balloons and other airships through the clouds, say that the clouds are only fogs, and that above them it is as clear as it is on a sunshiny day on the water when there is no fog.

There is another kind of fog which settles down over the land, especially in the cities. It is a damp mist which combines with the smoke and other impurities in the air and forms a black and dirty cloud about everything. This occurs when the upper air prevents the smoke which rises from a city with all its people and fires in the furnaces from passing up and away. The upper air acts like a blanket and keeps the misty, smoky air down, until the wind comes along and blows it away.

What Becomes of the Smoke?

There are a number of things in smoke, and when we know what they are, we will find a natural answer to this question. First, there are, of course, the little unburned particles of fuel which get carried up the chimney by its drawing power. These naturally fall to the ground of their own weight, once they get beyond the drawing power of the chimney and out of the current of air so formed. Some of the gases are already quite burned out when they pass up the chimney. There is a lot of carbonic acid gas which, of course, mixes with the air and eventually becomes food for the plants. Then there are some gases which are not entirely burned, and the air burns them still more until they, too, become carbonic acid gas, or water which is also thrown off by a burning fire.

Why Does an Apple Turn Brown When Cut?

The reason is that when you cut an apple, the exposure to the air of the inside of the apple causes a chemical change to take place, due to the effect the oxygen in the air has on what is scientifically known as the enzymes in the apple, or what are commonly called the "ferments." When the peel is unbroken it protects the inside of the apple against this action by the oxygen. The brown color happens to be due to the chemical action. The action is similar to the action of the air on wet or damp iron or steel, in which case we call it rust.

Why Does a Piece of Wood Float in Water?

A piece of wood will float in water because it is lighter than the same amount of water. We do not mean that a piece of wood weighing one pound, for instance, would weigh any more than a pound of water, of course, but if you took the measurements of each you will find that it took less bulk to make a pound of water than of wood. If you had a piece of wood so shaped that it just filled a glass completely, and then took another glass and filled it with water, you would find that the glass containing the water weighed the most. Another name to give to this difference would be to say that the water was more dense than the wood. By the law of gravitation the denser thing will always go to the bottom, and as wood is less dense than water, it will stay at the top if put in water. The piece of wood has more air in it than the water. If you could expel the air from the piece of wood and then put it in water, it would sink.

Why Does Iron Sink In Water?

The explanation in regard to the piece of wood floating in water is the beginning of the answer to this question. A piece of iron is heavier than an equal bulk of water, and will therefore go to the bottom, as will all things which are more dense than water. A piece of iron has no air in it. The particles of a piece of iron are so close together that there is no room for air in it and it will therefore sink in water. A piece of wood from which all of the air had been expelled would also sink.

Why Doesn't an Iron Ship Sink?

This is a very natural question for you to ask right after you were told why iron sinks in water. The explanation is that by making an iron ship in the way we do, we fix it so that it holds a lot of air in between the bottom and sides, making the combination of the two--the iron ship and the air in it--lighter than the water on which it sails. Men thought at one time that a ship would sink if made of iron, and therefore built all of their ships of wood. Finally one inventor made a ship of iron and it was one of the wonders of the world. When we found that iron ships would float if they were built to retain sufficient air to keep them from sinking, we made the hulls of most ships of iron for a time. Now, however, the best ships are made of steel, which is even better.

If you bore a hole in the bottom of a ship, the water will run in if the ship is in the water, and the ship will sink, because the water coming in drives out the air; and when the ship is full of water, the water in it, with the ship itself, are heavier than the water on which it sails, and the ship will go down. Filling a ship with water makes the iron part of the ship just like a bar of iron, so far as its sinking qualities are concerned.

Of course, an iron ship must be made long enough and broad enough so that when it is completed there will be sufficient air contained within the hull to make the combination lighter than water. Always, therefore, when a ship is to be built, competent engineers must go over the plans of the vessel and calculate the air capacity, so as to make sure she will float.

Nowadays it would be difficult to sink a modern vessel by boring one small hole in the bottom, because the bottom and sides are lined with enclosed steel air-chambers, and a ship will keep afloat even if one or a number of holes are made. The reason is, of course, that when you bore a hole into one of these air-chambers the water rushing in will fill that air-chamber with water, but as there is no connection from the inside with the rest of the ship, the water can get no further.

Why Does a Poker Get Hot at Both Ends if Left in the Fire?

Both ends of the poker become heated because the poker is made of iron, and iron is a particularly good conductor of heat. To understand this we must look into the question of what a good conductor of heat is. In this case the particles of iron, which combined form the poker, are so close together that when those at the end of the poker which is in the fire get hot, the particles at that end hand the heat on to the particles next to them, and so on until the whole poker is hot. The difference between a thing which is a good conductor of heat and a thing which is not a good conductor, lies in the ability of the different particles which compose it to hand the heat on to the others. Did you ever notice that the handle of a solid silver spoon will become hot if the spoon is left in hot coffee? Solid silver is a good conductor of heat. A plated spoon is not a good conductor, however, and will not become hot if left in the cup of hot coffee as a solid silver spoon will.

Would a Wooden Spoon Get Hot?

A wooden spoon would not get hot, because wood is not a good conductor of heat. The atoms which compose the wood have not the power to transmit the heat to each other. This is strange, too, when we think that a poker is a good conductor of heat, but will

not burn, while wood is not a good conductor, but will burn readily. Perhaps you have already discovered this in connection with a wood fire. One end of a stick of wood may be burning fiercely, and yet you can pick it up by the other end and find it is not even warm. This proves to you that wood is not a good conductor of heat, and explains why the handle of a wooden spoon in a bowl of hot soup will not get hot while the handle of a silver spoon will.

Why Does Iron Turn Red When Red Hot?

The answer is that the piece of iron has been heated to the point where it gives off light of its own. The red you see is only one stage in the development of iron to the point where it makes its own light. If you heat it still more it will make a white light. You know that it produces the light itself, because if you take a piece of iron into a perfectly dark room and heat it to a white heat it will show better than where there is other light. If you continue the process the iron will melt and change in form. Therefore, the "red hot" name for a piece of iron in that state is a perfect name. It is a warning that the iron is coming to a point where if the heating process is continued, it will change its form and in this state, when treated according to known methods, the iron is turned into steel, which has many characteristics that iron does not possess. Now, I can, of course, hear you ask why doesn't an iron kettle get red hot? and I can answer that easily. If you treat the kettle the same way as you do the piece of iron, it will get red hot. The difference is that you are thinking of an iron kettle with water in it. As long as there is any water in the kettle, that keeps it from getting hot. The water inside keeps the kettle from becoming red hot. If you took a hollow rod of iron and filled it with water, it would not become red hot as long as any water remained in the hollow portion.

How Did the Sand Get on the Seashore?

The sand on the seashore is nothing more or less than ground-up sandstone. In dealing with the inanimate things in the world we find that a very important element of all of them has been given the name silicon. When the crust of the earth, which is the part we call the land and rocks, and includes the part under the sea, was a molten mass, this silicon was burned, combining with the oxygen which surrounded everything, and produced what is known as silica. Silica is the name given to the thing which is left after you burn silicon. A very large part of this silica was deposited in parts of the earth, and when the crust of the earth cooled off it was sand. By pressure and contact with other substances it became stuck together, just as you can take wet sand at the seashore to-day and make bricks and houses and tunnels, excepting that in the case we speak of it was something besides water that pressed and stuck the little particles of sand together. They stuck together more permanently. Then when the oceans were formed, as shown in another part of this book, much of the sandstone was found to be at the bottom and on the shores of the oceans. The action of the water continually washing against the sandstone gradually broke the sandstone up into the tiny particles of sand again, and this is what makes the sand on the seashore.

What Makes a Soap Bubble?

A bubble is merely a hollow ball of water with air inside. The air in coming up through the water in trying to rise out of the water is caught in the water in such a way as to form the bubble, and since the ability of the air inside of the bubble to rise is greater than that of the water which forms the bubble, and which has a tendency to pull it down, the bubble rises into the air. The water ball is very thin and keeps running down to the bottom of the ball, where you see it form into drops, and soon this makes the walls of the water bubble so thin that the air bursts through the ball of water, and that is

What Makes the Bubble Explode?

Sometimes we blow soap bubbles. We mix soap in the water and that makes the walls of the water ball which we produce a little tougher, and it requires a great deal more effort for the air to escape from it, as the soap keeps the water in the walls of the bubble from running down to the bottom for quite some time, and, therefore, soap bubbles will often travel in the air for some distance. The colors we see on soap bubbles are produced by the rays of sunlight, which strike the bubble and reflect them back to us in colors very similar to those of the rainbow.

Why Are Bubbles Round?

Bubbles are round because the air which forms the inside of the bubble exerts an equal pressure in all directions. It presses equally against all sides of the bubble at the same time.

The Story in a Yard of Silk

God's Creation and Man's Invention.

~WHERE DOES SILK COME FROM?~

Silk in its finished state is an ideal product. It is at once durable, magnificent to the eye, tender to the touch, and its rustle is soft music to the ear. Hence it is easy to understand why the silkworm, from the earliest times, has been an object of much consideration and concern from a commercial and industrial point of view. In this country alone, we annually expend as much for silk goods as we do for public education and thirty times as much as we do for foreign missions. Such an indomitable producer of wealth is the silkworm, and a producer of wealth it has been from an age as remote as when Joseph was down in old Egypt, interpreting the dreams of King Pharaoh's butler and baker and later that of the King himself.

To-day we speak of twenty centuries, and our minds can hardly comprehend such a lapse of time. What shall we think of the silkworm, that for twice twenty centuries has furnished practically all the raw material for the world's silk supply? Because man's ingenuity is at present actively engaged in the attempt to displace it by cheaper substitutes, the thought has come to us that, without going too minutely into mechanical processes, a good opportunity is presented to give some interesting information in regard to the silkworm as the creation of the Divine Hand, in contrast to the silkworm as the creation of man.

According to Chinese authority, the use of silk dates from 2650 B.C., and it is generally conceded that, in point of age, it stands midway among the great textiles, wool and cotton having preceded it, while flax, hemp and other fibrous plants followed shortly in its train.

The first patron of the silkworm was Hoang-Ti, Third Emperor of China, and his Empress, Si-Ling-Chi, was the first practical silkworm breeder and silk reeler. It is related of her that she was once walking in the palace gardens when she discovered a strange and repulsive looking worm. It was small, of a pale green color, and was feeding greedily on a mulberry leaf. She interested the Emperor in this strange creature, and, at the Emperor's suggestion, took the fine silken web which the worm finally spun, and was the first to successfully reel the new filament and weave it into cloth. So beneficial to the nation was her work considered that her gratified subjects bestowed upon her the divine title of "Goddess of the Silkworms," and to this day the Chinese celebrate in her honor the "Con-Con Feast," which takes place during the season in which the silkworm eggs are hatched.

In accounting for the presence of silkworms in the garden of this early empress, we can rightly conclude that certain parts of China have always abounded in forests of mulberry trees, and that the worms themselves had existed in great numbers in a wild state and attached their cocoons to the trees for ages before any use was discovered for their web. In fact, such wild silkworms not only abound in China to-day, but have also been found in Southern and Eastern Asia, inhabiting the jungles of India, Pegu, Siam and Cochin China, but the cocoons of these worms are, naturally, of a very inferior quality, and are only used for the crudest kind of work.

[Illustration:

Illustration by courtesy The Brainerd & Armstrong Silk Co.

THE INTRODUCTION OF SILK INTO EUROPE

Pilgrims brought silkworm eggs in their staffs, together with the branches of mulberry trees, from China to the Court of Justinian at Byzantine, A.D. 555. The penalty for taking silkworm eggs out of China was death.

The accompanying illustration is a reproduction of a mural painting on rep in the Royal Textile Museum at Crefeld, Germany, one of the great silk textile centers of the world. The artist shows the pilgrims presenting the silkworm eggs and the mulberry branches to Justinian, beside whom, just in the act of rising, is his famous queen Theodora.]

Silk culture from the time of Hoang-Ti became one of the cherished secrets of China. The headquarters of the industry was in the Province of Chen Tong, where was produced the silk for the royal family. In time the silk and stuffs of China became articles of export to various portions of Asia. Long journeys were made by caravans, occupying two-thirds of a year in going from the cities of

China to those of Syria, but the price obtained there exceeded the expense of the journey, and thus left a large margin of profit to the merchants. In this manner, for one thousand years, the Chinese sent their silk to the Persians who, without knowing how or from what it was made, carried it to the Western nations.

So carefully did the Orientals guard their secret, that there is reason to believe that Aristotle was the first person in the occidental world to learn the true origin of the wrought silk from Persia. In commenting on the silk which was brought from that country on the return of Alexander's victorious army, he described the silkworm as a "horned insect," passing through several transformations, which produced "bomby-kia," as he called the silk. But the classics must convince one that Aristotle's discovery did not at once become matter of current knowledge. In fact, for five hundred years after Aristotle's time the common theory of the origin of silk among the Greeks and Romans was that it was either "a fleece which grew upon a tree" (thus confounding it with cotton), or a fibre obtained from the inner bark of a tree; and some, deceived by the glossy and silky fibres of the seed vessels of the plant that corresponds to our milk or silk weed, believed it to be the product of some plant or flower. So Virgil, in speaking of silk, says, "the Seres comb the delicate fleecings from the leaves."

In the Sixth Century, A.D., all the raw silk was still being imported from China by way of Persia, when the Emperor Justinian, having engaged in war with Persia, found his supply of raw silk cut off and the manufacturers in great distress. His foolish legislation did not help the situation, and a crisis was averted only by two Nestorian monks, who came from China with seed of the mulberry tree and a knowledge of the Chinese method of rearing worms. No one, on pain of death, was allowed to export the silkworm eggs from China, but Justinian bribed the monks to return to that country, and in 555 they came back, bringing with them a quantity of silkworm eggs concealed in their pilgrim's staffs. And here let us say that there has only once since been an important importation of eggs from Asia. That was about 1860, when Dr. Pasteur was making a study of a germ disease which was threatening the industry. Consequently, it can truly be said that practically all the silkworms of the Western world are descended from those brought in the eggs by the monks to Constantinople. Justinian gave the control of the silk industry to his own treasurer. Weavers, brought from Tyre and Berytus, were employed to manufacture the silk, and the whole production was a monopoly of the emperor, he fixing its prices. Under his management, the cost of silk became eight times as great as before, and the Royal Purple was twenty-four times its former price. But this monopoly was not of long duration and, at the death of Justinian in 565, the monopoly ceased, and the spread of the industry commenced in new and diverse directions.

While every detail of the growth of the industry has an unusual interest, as showing how such an insignificant thing as a worm may become a potent factor in Nature's economy, the scope of this article will hardly allow us to more than sketch some of the other more salient points of the history of the silkworm.

About the year 910, the silkworms made their appearance in Cordova, Spain, being brought there by the Moors. From Spain silk culture soon extended to Greece and Italy.

~WHEN SILK CULTURE WAS INTRODUCED IN AMERICA~

Silk was introduced on this continent through the Spanish Conquest of Mexico, and the first silkworm eggs sold for $60.00 an ounce.

A century later royal orders were issued requiring mulberry trees to be planted in the Colony of Virginia, and a fine of twenty pounds of tobacco was imposed for neglect, and fifty pounds of tobacco was given as a bounty for every pound of reeled silk produced.

Silk culture spread rapidly in the other Colonies, and to-day the story of the ineffectual attempts to profitably rear the silkworm in this country is as voluminous as it is interesting. Suffice it to say, as a sop to our inherent Yankee pride, that silk culture was introduced into Connecticut as early as 1737, the first coat and stockings made from New England silk being worn by Governor Law in 1747, and the first silk dress by his daughter, in 1750. This State, for the eighty-four years following, led all the others in the amount of raw silk produced. In Connecticut also, was built the first silk mill to be erected on this continent for the special purpose of manufacturing silk goods. This building was constructed in 1810 by Rodney and Horatio Hanks, at Mansfield, and is still standing as an heirloom which has come to us from the infant days of the industry.

The silkworm has become domesticated, since, during the long centuries in which it has been cultivated, it has acquired many useful peculiarities. Man has striven to increase its silk producing power, and in this he has succeeded, for, by comparing the cocoon of the silkworm of to-day with its wild relations, the cocoon is found to be much larger, even in proportion to the size of the worm that makes it or the moth that issues from it. The moth's loss of the power of flight and the white color of the species are

probably the results of domestication.

[Illustration: JAPAN THE NATURAL HOME OF THE SILK WORM

GATHERING MULBERRY BRANCHES.[1]

This picture shows a grove of mulberry trees from which branches are being gathered as food for the worms. This is often done by the children.]

[Illustration: FEMALE MOTHS DEPOSITING EGGS.[1]

The moths are placed upon pieces of cardboard, upon which they deposit their eggs.

The cards with the eggs are kept in a cool place until the season for hatching arrives.]

[Illustration: PREPARING COCOONING BEDS.[1]

This picture shows two boys preparing a bed of twigs or branches upon which the worms may spin their cocoons.]

[1] Illustrations by courtesy The Brainerd & Armstrong Co.

[Illustration: HOW THE SILKWORMS ARE CARED FOR

HATCHING THE EGGS.

As the eggs hatch on the cards, the young worms are removed to other cards or trays, where they are fed and cared for.]

[Illustration: REMOVING SILKWORMS FROM CARDS WHERE THEY WERE HATCHED.

Every few days the young worms are changed to new and clean cards.]

[Illustration: METHOD OF REELING RAW SILK.

The cocoons are soaked in hot water in the basins shown in the front to loosen the gum. The silk threads then pass through the hands of the operators and are reeled on swifts in the cabinet shown in the rear.

A more modern appliance for reeling the silk is shown on one of the following pages.]

The foregoing pages and pictures by courtesy of Brainerd & Armstrong Silk Company, from their book entitled, “Silk, the Real versus the Imitation.”

[Illustration: FULL GROWN LARVA--SHOWING POSITION IN MOLTING.[2]]

[Illustration: MALE MOTH.[2]]

[Illustration: FEMALE MOTH.[2]]

[Illustration: SIDE VIEW OF CHRYSALIS.[2]]

[Illustration: BOTTOM VIEW OF CHRYSALIS.[2]]

[2] The cuts on this page and balance of cuts in the story of silk copyright by the Corticelli Silk Mills.

The silk moth exists in four states--egg, larva, chrysalis, and adult. The egg of the moth is nearly round, slightly flattened, and closely resembles a turnip seed. When first laid it is yellow, soon turning a gray or slate color if impregnated. It has a small spot on one end called the micropyle, and when the worm hatches, which in our climate is about the first of June, it gnaws a hole through this spot. Black in color, scarcely an eighth of an inch in length, covered with long hair, with a shiny nose, and sixteen small legs, the baby worm is born, leaving the shell of the egg white and transparent.

~THE SILKWORM—HOW HE DOES HIS WORK~

Small and tender leaves of the white mulberry or osage orange are fed the young worm which simply pierces them and sucks the sap. Soon the worm becomes large enough to eat the tender portions between the veins of the leaf. In eating they hold the leaves by the six forward feet, and then cut off semi-circular slices from the leaf’s edge by the sharp upper portion of the mouth. The jaws

move sidewise, and several thousand worms eating make a noise like falling rain.

The worms are kept on trays made of matting, that are placed on racks for convenience in handling. The leaves are placed beside the worms, or upon a slatted or perforated tray placed above them, and those that crawl off are retained, while the weak ones are removed with the old leaves. The worms breathe through spiracles, small holes which look like black spots, one row of nine down each side of the body. They have no eyes, but are quite sensitive to a jar, and if you hit the rack they stop eating and throw their heads to one side. They are velvety, smooth, and cold to the touch, and the flesh is firm, almost hard. The pulsation of the blood may be traced on the back of the worm, running towards the head.

The worm has four molting seasons, at each of which it sheds its old skin for a new one, since in the very rapid growth of the worm the old skin cannot keep pace with the growth of the body. The periods between these different molts are called "ages," there being five, the first extending from the time of hatching to the end of the first molt, and the last from the end of the fourth molt to the transformation of the insect into a chrysalis. The time between the four "molts" will be found to vary, depending upon the species of worm.

[Illustration: HOW THE SILKWORMS ARE REARED.[2]]

When the worm molts it ceases eating, grows slightly lighter in color, fastens itself firmly by the ten prolegs, and especially by the last two, to some object, and holding up its head and the fore part of its body remains in a torpid state for nearly two days.

By each successive molt the worm grows lighter, finally becoming a slate or cream white color, and the hair, which was long at first, gradually disappears. The gummy liquid which combines the two strands hardens immediately on exposure to the air.

The worm works incessantly, forcing the silk out by the contraction of its body. The thin, gauze-like network which soon surrounds it gradually thickens, until, twenty-four hours after beginning to spin, the worm is nearly hidden from view. However, the cocoon is not completed for about three days.

~SIXTY-FIVE MOTIONS OF HIS HEAD A MINUTE~

The cocoon is tough, strong, and compact, composed of a firm, continuous thread, which is, however, not wound in concentric circles, but irregularly in short figure eight loops, first in one place and then in another. In doing this the worm makes sixty-five elliptical motions of his head a minute or a total of 300,000 in an average cocoon. The motion of the worm's head when starting the cocoon is very rapid, and nine to twelve inches of silk flow from the spinneret in a minute, but later the average would be about half this amount per minute.

[Illustration: SILKWORM EATING.[2]]

[Illustration: SILKWORM—ONE OF THE WORLD'S GREATEST WORKERS

SILKWORM PREPARING TO FORM ITS COCOON.]

Having attained full growth, the worm is ready to spin its cocoon. It loses its appetite, shrinks nearly an inch in length, grows nearly transparent, often acquiring a pinkish hue, becomes restless, seeks a quiet place or corner, and moves its head from side to side in an effort to find objects on which to attach its guy lines within which to build its cocoon. The silk is elaborated in a semi-fluid condition in two long, convoluted vessels or glands between the prolegs and head, one upon each side of the alimentary canal. As these vessels approach the head they grow more slender, and finally unite within the spinneret, a small double orifice below the mouth, from which the silk issues in a glutinous state and apparently in a single thread.

[Illustration: COCOON BEGUN--SILKWORM CAN STILL BE SEEN.]

The color of the worm's prolegs before spinning indicates the color the cocoon will be. This varies in different species, and may be a silvery white, cream, yellow, lemon, or green.

[Illustration: COMPLETED COCOON.]

~WHEN THE SILKWORM'S WORK IS DONE~

When the worm has finished spinning, it is one and a quarter inches long. Two days later, by a final molt, its dried-up skin breaks at the nose and is crowded back off the body, revealing the chrysalis, an oval cone one inch in length. It is a light yellow in color, and

immediately after molting is soft to the touch. The ten prolegs of the worm have disappeared, the four wings of the future moth are folded over the breast, together with the six legs and two feelers, or antennæ. It soon turns brown, and the skin hardens into a tough shell. Nature provides the cocoon to protect the worm from the elements while it is being transformed into a chrysalis, and thence into the moth.

[Illustration: MOTHS EMERGING FROM COCOONS.]

With no jaws, and confined within the narrow space of the cocoon, the moth has some difficulty in escaping. After two or three weeks the shell of the chrysalis bursts, and the moth ejects against the end of the cocoon a strongly alkaline liquid which moistens and dissolves the hard, gummy lining. Pushing aside some of the silken threads and breaking others, with crimped and damp wings the moth emerges; and the exit once effected, the wings soon expand and dry.

[Illustration: COCOONS FROM WHICH THE MOTHS HAVE EMERGED.]

The escape of the moth, however, breaks so many threads that the cocoons are ruined for reeling, and consequently, when ten days old, all those not intended for seed are placed in a steam heater to stifle the chrysalis, and the silk may then be reeled at any future time.

The moths are cream white in color. They have no mouths, but do have eyes, which is just the reverse of the case of the worm. From the time it begins to spin until the moth dies, the insect takes no nourishment. The six forward legs of the worm become the legs of the moth. Soon after mating the eggs are laid.

The male has broader feelers than the female, is smaller in size, and quite active. The female lays half her eggs, rests a few hours, and then lays the remainder. Her two or three days' life is spent within a space occupying less than six inches in diameter.

One moth lays from three to four hundred eggs, depositing them over an even surface. In some species a gummy liquid sticks the eggs to the object upon which they are laid. In the large cocoon varieties there are full thirty thousand eggs in a single ounce avoirdupois. It takes from twenty-five hundred to three thousand cocoons to make a pound of reeled silk. Do you wonder that, centuries ago, silk was valued at its weight in gold?

Growers of silk in the United States, by working early and late every day during the season, which lasts from six to eight weeks, could scarcely average fifteen cents for a day's labor of ten hours. Silk, once regarded as a luxury, is now considered a necessity.

[Illustration: HOW THE COCOON IS UNWOUND

REELING THE SILK FROM COCOONS BY FOOT POWER, CALLED "RE-REEL" SILK.

The cocoons are first assorted, those of the same color being placed by themselves, and those of fine and coarse texture likewise. The outside loose silk is then removed, as this cannot be reeled, after which the cocoons are plunged into warm water to soften the "gum" which sticks the threads together. The operator brushes the cocoons with a small broom, to the straws of which their fibers become attached, and then carefully unwinds the loose silk until each cocoon shows but one thread. These three operations are called "soaking," "brushing," and "cleansing."

Into one or two compartments in a basin of warm water below the reel are placed four or more cocoons, according to the size of the thread desired. The threads from the cocoons in each compartment are gathered together and, after passing through two separate perforated agates a few inches above the surface of the water, are brought together and twisted around each other several times, then separated and passed upward over the traverse guide-eyes to the reel. The traverse moves to and fro horizontally, distributing the thread in a broad band over the surface of the reel. The rapid crossing of the thread from side to side of the skein in reeling facilitates handling and unwinding without tangling, the natural gum of the silk sticking the threads to each other on the arms of the reel, thus securing the traverse. Silk reeled by hand or foot power is known as "Re-reel" silk, while silk reeled by power machinery is called "Filature."]

[Illustration: A FILATURE--REELING THE SILK FROM COCOONS BY POWER MACHINERY.[2]]

[Illustration: DRYING SKEINS OF SILK.]

[Illustration: THE SILK IS WOUND ON SPOOLS

WINDING FRAMES--WINDING THE SILK ON BOBBINS.]

~WHERE MAN'S WORK ON THE SILK BEGINS~

The raw silk is first assorted, according to the size of the fiber, as fine, medium, and coarse. The skeins are put into canvas bags and then soaked over night in warm soapsuds. This is necessary to soften the natural gum in the silk, which had stuck the threads together on the arms of the reel. Following the soaking, the skeins are straightened out and hung across poles in a steam-heated room, as shown in the accompanying photograph. When the skeins are dry, they are ready for the first process of manufacturing. The room we now step into is filled with "winding frames," each containing two long rows of "swifts," from which the silk is wound on to bobbins. The bobbins are large spools about three inches long. The bobbins filled with silk, as wound from the skeins, are next placed on pins of the "doubling frames"; the thread from several bobbins, according to the size of the silk desired, is passed upward through drop wires on to another bobbin. Should one of the threads break, the "drop wire" falls, which action stops the bobbin. By this ingenious device absolute uniformity in the size of silk is secured. The "doubling frame" is shown in one of the photographs herewith.

[Illustration: DOUBLING FRAMES--THE SILK THREAD IS MADE UNIFORM.]

The bobbins taken from the "doubling frame" are next placed on a "spinner." Driven by an endless belt at the rate of over six thousand turns a minute, the bobbins revolve, the silk from them being drawn upward on to another bobbin. This spins the several strands brought together by the "doubling process" into one thread, the number of turns depending on the kind of silk--Filo silk being spun quite slack, and Machine Twist just the reverse.

[Illustration: SPINNING SILK.[2]]

[Illustration: TWISTING SILK.[2]]

A transferring machine combines two or three of these strands; two for sewing silk and three for machine twist; and the bobbin next goes on to the "twisting machine"--a machine that is similar to a "spinner," but the silk is twisted in the opposite direction from the spinning. To stand before these machines and watch how rapidly and how accurately they do the work assigned them is a revelation. No one realizes how nicely the parts are adjusted. If but one tiny strand breaks that part of the machinery is stopped by an automatic device which works instantaneously. After twisting, the silk is stretched by an ingenious machine called a "water-stretcher." This smooths and consolidates the constituent fibers, giving an evenness to the silk not to be obtained by any other known process. The bobbins are placed in water and the silk is wound on to the lower of the two copper rolls. From the lower roll it passes upward to the upper roll, which turns faster than the lower one, thereby stretching the silk. From the upper roll it passes again on to a bobbin.

[Illustration: SILK THREADS READY FOR THE WEAVER

WATER STRETCHER--MAKING THE SILK THREAD SMOOTH.]

The dyeing process is a very important one, and upon its success depends the permanency of the various colors.

Vast tubs, tanks, and kettles surround you on every side, and the hissing steam seems to spring from all quarters. The "gum" of the silk is first boiled out by immersion in strong soapsuds for about four hours. The attendants, standing in heavy "clogs" (big shoes with wooden soles two inches thick), turn the silk on the sticks at intervals until the gum is removed. After the silk is dyed it is put into a "steam finisher," a device looking like a long, narrow box with a cover opening on the side, set upright on top of an iron cylinder. The hanks of silk are placed upon two pins in the steam chest, the cover fastened, and the live steam rushes in around the silk. This brightens the silk, giving it the lustrous, glossy appearance.

The editors are indebted to the Corticelli Silk Mills, Florence, Mass., for this story of how silk is made, as well as for permission to use their splendid life-like copyrighted photographs of the silkworm. Many teachers will be glad to know that they can obtain from the Corticelli Silk Mills, at slight expense, specimen cocoons and other helps for object lesson teaching.

What Animal Can Leap the Greatest Distance?

The galago, or flying lemur. This singular animal is a native of the Indian Archipelago. It is from 2 ft. to 3 ft. in length, and is furnished with a sort of membrane on each side of its body connecting its limbs with each other; this is extended and acts as a parachute while taking its long leaps, which measure about 300 ft. in an inclined plane. The kangaroo can leap with ease a distance

of between 60 ft. and 70 ft. and can spring clean over a horse and take fences from 12 ft. to 14 ft. in height. The animals that can leap the greatest distance in proportion to their size are the flea and the grasshopper, the former being able to leap over an obstacle five hundred times its own height, while the grasshopper can leap for a distance measuring 200 times its own length. The springbok will clear from 30 ft. to 40 ft. at a single bound. The flying squirrel, in leaping from tree to tree often clears 50 ft. in a leap. This animal also has a broad fold of skin or membrane connecting its fore and hind legs. A steeplechase horse, called The Chandler, is reported to have covered 39 ft. in a single leap at Warwick some years ago. Some species of antelopes can make a leap 36 ft. in length and 10 ft. in height. A lion and a tiger each clear from 18 ft. to over 20 ft. at a bound while springing on their prey. A salmon often leaps 15 ft. out of the water in ascending the falls of rivers.

Why Do We Call Voting Balloting?

The term covers all forms of secret voting, as in early times such votes were determined by balls of different colors deposited in the same box, or balls of one color placed in various boxes. The Greeks used shells (ostrakon), whence we derive the term ostracism. In 139 B.C. the Romans voted by tickets. The ballot was first used in America in 1629, when the Salem Church thus chose a pastor. It was employed in the Netherlands in the same year, but was not established in England until 1872, although in Scotland it was used in cases of ostracism in the 17th century. In 1634 the governor of Massachusetts was elected by ballot, and the constitutions of Pennsylvania, New Jersey and North Carolina adopted in 1776, made this method of voting obligatory. The ballot progressed slowly in the Southern States, Kentucky retaining the viva voce method until a comparatively recent date. In certain states, the constitutions stipulate that the legislature shall vote viva voce, i. e., cast their votes orally. Since 1875 all congressmen have been elected by ballot. In 1888 the Australian ballot system, which requires the names of all the candidates for the various offices to be placed on one large sheet of paper, commonly known as a "blanket" ticket, was adopted in Louisville, Ky., and some sections of Massachusetts. It is now in very general use in this country. The voter, in the privacy of an individual booth, indicates his preference by making a mark opposite a party emblem or a candidate's name. This system originated in 1851 with Francis S. Dutton, of South Australia, and Henry George, in a pamphlet, "English Elections," published in 1882, was the first to advocate it in the United States. The first bill enacting it into a law here was introduced in the Michigan legislature in 1887, but it did not pass until 1889.

Why Do We Call a Cab a Hansom?

The term is applied usually to a public vehicle, known in England as a "two-wheeler," or "Hansom" (from the name of the inventor), and drawn by one horse. In a hansom cab, the passenger or hirer of the vehicle sits immediately in rear of the dashboard, the driver sitting on an elevated perch behind, the reins being passed over the top. The term cab is sometimes also applied to a four-seated, closed or open carriage, drawn by one or two horses, the driver sitting in front. The term is also applied to the covered part of a locomotive, in which the engineer and fireman have their stations. The word cab is derived from the cabriolet, a light one-horse carriage, with two seats and a calash top. In London, England, the cab or hansom was called the "gondola" of the British metropolis by Disraeli.

Where Did the Name Calico Come From?

A fabric of cotton cloth, the name being derived from the city of Calicut, in Madras, where it was first manufactured, and in 1631 brought to England by the East India Company. Calico-printing, an ancient Indian and Chinese art, has become a great industry in this country and in Britain, as well as in Holland.

Who Made the First Postage Stamp?

The stick on postage stamps so generally used today was invented by an Englishman James Chalmers in 1834. The English Government passed a bill calling for uniform postage of One Penny in 1840 and furnished envelopes bearing stamps printed on them. The people did not like them, however, and the adhesive stamp invented by Chalmers was substituted. The first stamps used in America were introduced in 1847. People have, it seems, always preferred to lick their postage stamps.

How Many Languages Are There?

It is said that there are more than 3,400 languages, including dialects, in the world. Most of them belong, of course, to savage or uncivilized people. There are said to be more than 900 languages used in Asia, almost 600 in Europe, 275 in Africa and more than 1,600 languages and dialects which are American.

What Is the Deepest Mine In the World?

The mine that goes farther down than any other in the world is the rock salt mine near Berlin, Germany which is 4,175 feet. It is not, however, straight down but somewhat slanting. The Calumet Copper Mine near Lake Superior is at a depth in some places of 3,900 feet.

The deepest boring in the world is an artesian well at Potsdam, Missouri, which is 5,500 feet deep or more than one mile straight down.

What Is Color?

~WHAT PRODUCES THE COLORS WE SEE?~

What is termed the color-sense is the power or ability to distinguish kinds or varieties of light and their distinctive tints. We owe the faculty of doing this to the structure of the eye and its elaborate connecting nerve machinery. The eye in man is specially sensitive to light, and the sensations we feel through it enables us to distinguish the different colors. Over 1,000 monochromatic tints are said to be distinguishable by the retina of the eye, though these numerous tints are, in the main, merely blendings or combinations of the three primary color-sensations, the sense of red, of green and of violet. Each of these colors, it has been demonstrated, is produced by light of a varying wave length, while white light is only light in which the primary colors are combined in proper proportion. Colored light, on the other hand, as Newton proved, may be produced from white light in one of three ways: First, by refraction in a prism or lens, as observed in the rainbow; second, by diffraction, as in the blue color of the sky, or in the tints seen in mother-of-pearl; and third, by absorption, as in the red color of a brick wall, or in the green of grass--the white light which falls upon the wall being wholly absorbed, save by the red, and all that falls upon the grass being absorbed except the green. In art, color means that combination or modification of tints which is specially suited to produce a particular or desired effect in painting; in music, the term denotes a particular interpretation which illustrates the physical analogy between sound and color.

Where Did the Term Dixie Originate?

The term was applied originally to New York City when slavery existed there. According to a myth or legend, a person named Dixie owned a tract of land on Manhattan Island and had a large number of slaves. As Dixie's slaves increased beyond the requirements of the plantation, many were sent to distant parts. Naturally the deported negroes looked upon their early home as a place of real and abiding happiness, as did those from the "Ole Virginny" of later days. Hence "Dixie" became the synonym for a locality where the negroes were happy and contented. In the South, Dixie is taken to mean the Southern States. There the word is supposed to have been derived from Mason and Dixon's line, formerly dividing the free states from the slave states. It is said to have first come into use there when Texas joined the Union, and the negroes sang of it as Dixie. It has been the theme of several popular songs, notably that of Albert Pike, "Southrons, Hear Your Country Call"; that of T. M. Cooley, "Away Down South where Grows the Cotton," and that of Dan Emmett, the refrain usually containing the word "Dixie" or the words "Dixie's Land." During the Civil War, the tune of "Dixie" was to the Southern people what "Yankee Doodle" had always been to the people of the whole Union and what it continued, in war times, to be to the Northern people, the comic national air. The tune is "catchy" to the popular ear and it was played by the bands in the Union army during the war as freely as by those on the other side. During the rejoicing in Washington over the surrender of Lee at Appomattox, a band played "Dixie" in front of the White House. President Lincoln began a short speech, immediately afterward, with the remark, "That tune fairly belongs to us now; we've captured it."

How Big Is the Earth?

The third planet in order of distance from the sun, Mercury and Venus being nearer to it. It is in shape a sphere slightly flattened at the poles and bulged at the equator, hence it is called an oblate spheroid. The equatorial diameter or axis measures 7,926 miles and 1.041 yds., and the polar diameter is 7,899 miles and 1.023 yds. The earth revolves upon its axis, completing its diurnal or daily revolution in a sidereal day, which is 3 minutes and 55.9 seconds shorter than a mean solar day. It revolves around the sun in one

sidereal year, which is 365 days, 6 hours, 9 minutes, and 9 seconds. Its orbit or path around the sun is an ellipse, having the sun in one of the foci. The earth's mean distance from the sun is 93,000,000 miles. Its axis is inclined to the plane of its orbit at an angle of 23° 27′ 12.68″. The circumference at the equator measures 24,899 miles. The total surface is 196,900,278 sq. miles, and the solid contents is 260,000,000,000 cubic miles. As we descend into the earth the temperature rises at the rate of 1° Fahr. for every 50 ft. At the depth of 10 or 12 miles the earth is red-hot, and at a depth of 100 miles the temperature is such that at the surface of the earth it would liquefy all solid matter in the earth.

What Causes Hail?

Hail is the name given to the small masses of ice which fall in showers, and which are called hailstones. When a hailstone is examined it is found usually to consist of a central nucleus of compact snow, surrounded by successive layers of ice and snow. Hail falls chiefly in Spring and Summer, and often accompanies a thunderstorm. Hailstones are formed by the gradual rise and fall, through different degrees of temperature (by the action of windstorms), and they then take on a covering of ice or frozen snow, according as they are carried through a region of rain or snow.

With regard to rain, it may be said, in popular language, that under the influence of solar heat, water is constantly rising into the air by evaporation from the surface of the sea, lakes, rivers, and the moist surface of the ground. Of the vapors thus formed the greater part is returned to the earth as rain. The moisture, originally invisible, first makes its appearance as cloud, mist or fog; and under certain atmospheric conditions the condensation proceeds still further until the moisture falls to the earth as rain. Simply and briefly, then, rain is caused by the cooling of the air charged with moisture.

Why Does a Human Being Have To Learn to Swim?

It is strange, isn't it, that almost every animal, excepting man and possibly the monkey, knows how to swim naturally; others such as birds, horses, dogs, cows, elephants, can swim as soon as they can move about alone.

The trouble with man in this connection is that his natural motion is climbing. He has been a climber ever since he was developed from the monkey, and when you throw him into the water before he has learned to swim, he naturally starts to climb and as a climbing motion won't do, for swimming, the man will drown.

This climbing motion is as much of an instinct in man and monkeys as the instinct in dogs which causes him to turn round once or twice before he lies down just as his forefathers used to do ages ago when, as wild dogs, they first had to trample the grass before they could lie down comfortably.

Why Do I Get Cold in a Warm Room?

I suppose you mean the instances when you get cold while in a warm room even when you are perfectly well. This will happen often when all of the moisture in the room outside of what is in your body, is evaporated by the heat in the room. The remedy is, of course, to keep a pan of water some place in the room as the air has become too dry.

While heat is necessary to evaporate water, the process of evaporation produces cold. The quicker the evaporation the sharper the cold feeling produced. Now your body is continually evaporating the water from your body which comes out in the form of perspiration through the pores of the skin. This is one of nature's ways of taking the impurities and waste out of the body. You know, of course, don't you, that more than one-half the waste material which the body expels from the system comes out through the pores of the skin rather than through the canals.

When the air in the room becomes too dry, the evaporation on the outside of the body proceeds faster and makes you cold. By keeping water in some vessel in the room you keep the air of the room from becoming too dry.

Why Do They Call Them Wisdom Teeth?

The wisdom teeth are the two last molar teeth to grow. They come one on each side of the jaw and arrive somewhere between the ages of twenty and twenty-five years. The name is given them because it is supposed that when a person has developed physically and mentally to the point where he has secured these last two teeth he has also arrived at the age of discretion. It does not

necessarily mean that one who has cut his wisdom teeth is wise, but that having lived long enough to grow these, which complete the full set of teeth, the person has passed sufficient actual years that, if he has done what he should to fit himself for life, he should have come by that time at the age of discretion or wisdom. As a matter of fact these teeth grow at about the same age in people whether they are wise or not.

What Makes Freckles Come?

Freckles are generally caused by the exposure of unprotected parts of the body to the sun, but this will not cause freckles on all people. Only people with certain kinds of sensitive skins freckle. What happens when freckles are produced in this way is this: The sunlight shining on the face, neck or arms of anyone who has a tendency to freckle, has a peculiar action on certain cells of the skin which produces a yellowish brown coloring pigment, which remains for a time.

Then again the skins of some people are so peculiarly sensitive the cells develop this kind of coloring matter in almost any kind of light and such people are, so to speak, apt to be freckled for life.

[Illustration: First successful power-driven aeroplane. The Langley monoplane with steam engine, which flew over the Potomac River in 1896.]

The Flying Boat

When Did Man First Try to Fly?

~HOW MAN LEARNED TO FLY~

Man's desire to conquer the air is older than recorded history. When a kite was flown for the first time the principle of aviation, or dynamic flight, was uncovered. For centuries man has sought the mechanical equivalents for the things that keep a kite flying steadily in the air,--the power that lies in the cord that keeps a kite headed into the wind; an equivalent for the wind's own power; an equivalent for the tail which controls the kite's lateral and longitudinal balance.

Each separate part of the modern flying machine, or aeroplane, was worked out long ago, with the exception of the gas engine light enough and reliable enough to be used for this work. The present generation knows dynamic flight as a commonplace thing, not because we are so much more clever than previous generations in designing flying machines, but because of the development of the modern gasoline or internal combustion engine.

Who Invented Flying?

No one invented flying, nor did any one man invent all the separate parts of the flying machine. They are the result of evolution,--of the combined work and thought of hundreds of men, many of whose names are unrecorded. To attempt to find the true beginning of the modern flying machine would be as difficult as attempting to discover who planted the seed of the tree from which one has gathered a rose. But the tree from which all the flying machines, or aeroplanes, of today have sprung undoubtedly is Dr. Samuel Pierpont Langley, third secretary of the Smithsonian Institution.

Some of the Men Who Helped.

Taking the most conspicuous names of scientists who worked out various details of the aeroplane during the past century we find that a century ago Sir George Cayley built a machine on lines very similar to those accepted today, and he went so far as to foretell the necessity of developing the internal combustion engine before dynamic flight could be a success. Mr. F. H. Wenham, in 1866, also built a flying machine along conventional lines and tried to fly it with a steam engine, which of course, proved too heavy.

[Illustration: One of Dr. Langley's first models; a biplane with flexible wing-tips and twin propellers. 1889.]

~EARLY TYPES OF FLYING MACHINES~

M. A. Penaud, a Frenchman, in experimenting with models, seems to have been the first to discover the necessity of vertical and horizontal rudders in maintaining balance. Mr. Horatio Phillips, an Englishman, discovered, and patented, the use of curved instead of flat surfaces for the planes. Otto and Gustav Lilienthal are said to have been the first to attempt to balance aeroplanes by flexing or bending the wings. Various others, including Messrs. Richard Harte, Boulton, Mouillard, worked out ideas for balancing

machines by the use of auxiliary planes which could be set at different angles with regard to the line of flight, thus forcing the machines to different positions by the force of the air rushing against them.

Dr. Langley, trained in scientific investigation, conducted an elaborate series of experiments covering many years and costing thousands of dollars to test and prove the value of the claims of the earlier investigators. Some things which he thought he was the first to discover,--such as the effect of the vertical and horizontal rudders,--he later found had already been proven by others. Independently he covered the entire field of experiment and after building hundreds of small models he succeeded, in 1896, in making a machine weighing several pounds equipped with a very light steam engine which flew safely as long as the fuel lasted. For his early experiments Dr. Langley was afforded financial assistance by Mr. William Thaw of Pittsburg. After the success of his small machines Dr. Langley was asked to undertake the construction of a large, man-carrying machine, and Congress voted him $50,000 to carry on the work. A large share of this was spent on the development of a very light gasoline engine. The machine finally was completed, but was twice broken through defective launching apparatus. Congress and Dr. Langley were so ridiculed by the public press that the machine was temporarily abandoned. Not, however, until after Dr. Langley had successfully flown a steam driven machine much larger than many of the racing aeroplanes of today.

But eight years after Dr. Langley's death, which is said to have been due to the heart-breaking disappointment he suffered in trying to demonstrate the large machine, Glenn H. Curtiss, at the request of the Smithsonian Institution, rebuilt the old Langley machine and succeeded in making a flight with it at Hammondsport, N. Y., on May 28, 1914.

[Illustration: THE FIRST MAN-CARRYING AEROPLANE

First successful man-carrying aeroplane. Designed by Dr. Langley in 1898; flown by Glenn H. Curtiss at Hammondsport, N. Y., 1914.]

[Illustration: Front view of big Langley machine in 1914.]

While longer flights probably will be made with this machine none will attain greater importance, because this first flight with it was sufficient to establish for all time the fact that Dr. Langley built the first man-carrying machine equipped with a gasoline engine and able to fly and raise itself with its own power. This was considerably more than was accomplished by other machines for some time after Dr. Langley's death. The Langley machine not only lifted the weight it was designed to fly with, but also carried pontoon and other fittings, added by Mr. Curtiss to make flight from the water possible, which added 340 pounds to the original weight of the machine.

[Illustration: THE MACHINE WITH WHICH BLERIOT FLEW IN EUROPE

Copy of early Langley model with which Bleriot made first circular flight in Europe.]

The connection between Dr. Langley's work and present machines is now very easy to trace, though not obvious until 1911, when the Smithsonian Institution published memoirs written by Dr. Langley in 1897, and some memoirs of Mr. Octave Chanute, a French engineer who resided in Chicago, and who forms one of the main connecting links. The chain is practically completed by notes left by the late Lieut. Thomas Selfridge, U. S. A., America's first martyr to aviation.

Dr. Langley's knowledge is represented in modern aviation by three distinct lines. The central and most direct line is through Dr. Alexander Graham Bell, inventor of the telephone, to the Aerial Experiment Association, and thence to Mr. Glenn H. Curtiss, and finds its expression in what is known as the Curtiss type of machines.

Another line is that carried by a Mr. A. M. Herring to Mr. Chanute and by him transmitted to Mr. Wilbur Wright, finding expression in the Wright type of biplane.

The third line is that leading to the modern monoplane school; M. Bleriot having first copied in toto the tandem monoplane form, generally known as the Langley type, and later, with the development of better gasoline engines, developing into the monoplane as known today.

With the exception of M. Bleriot it is doubtful if the others fully realized the source of their inspiration,--not to call it information.

Dr. Bell was interested in Dr. Langley's work for more than ten years before Dr. Langley gave up. He observed many of the trials, and his reports of the first successful flights are incorporated in the official publications of the Smithsonian Institution. Dr. Bell began some independent experiments, but following Dr. Langley's death he formed the Aerial Experiment Association, to carry on the

work left by Dr. Langley. The members of this organization were, Mr. Curtiss, at that time the most successful builder of light motors; Lieut. Thomas H. Selfridge, U. S. A.; Mr. J. A. D. McCurdy and Mr. F. W. Baldwin, two young Canadian engineers. Mrs. Bell financed the project, furnishing the sum of $35,000 for the experiments.

~WHAT TWO BROTHERS ACCOMPLISHED FOR FLYING~

The Wright Brothers, for Wilbur Wright was joined by his brother Orville in the experiments, were the first to reap success from the seeds of Dr. Langley's sowing. Mr. Chanute had been experimenting with a biplane form of motorless glider with little success, because of lack of means for balancing the machines in the air, until he was joined by a former employe of Dr. Langley. He appears to have imparted to Mr. Chanute the secret of the stabilizing effect of the Penaud tail, or combination of vertical and horizontal rudders. Thereafter hundreds of successful gliding flights were made with the Chanute biplane, though Chanute seems not to have grasped the full significance of the rudders,--though it was well understood by Dr. Langley. To the Chanute machine, as described to him, Mr. Wright added first the idea of flexing or warping the wings, after the fashion set by the Lilienthals. He found, however, as Dr. Langley had found years before, that in attempting to correct lateral balance in this way caused the aeroplane to swerve to such an extent that the fixed vertical rudder, as originally employed, did not correct the upsetting tendency that was developed. Mr. Wright then arranged his rudder in such a way that when the wing was warped the rudder turned in a way to offset the swerve. This combination was patented all over the world and has resulted in much complicated litigation.

To this machine the Wright Brothers added a gasoline motor in December, 1903, and with it made numerous flights during 1904-5. Their claims were not generally credited however until a later date for their experiments had been conducted with considerable secrecy, and during 1906, 1907 and until late in 1908 they did no more flying.

In the meantime M. Bleriot had made a copy of one of the early Langley tandem monoplane models and made some fairly successful flights with it in Europe. Later, as gasoline motors developed in power for weight, he reduced the rear surface until the modern monoplane evolved.

While Bleriot was working in Europe, Dr. Bell's Aerial Experiment Association in America was evolving still another type of machine, and the members of the association made the first successful public flights in America. Mr. Curtiss won the Scientific American Trophy for the first time on July 4th, 1908, by a straightaway flight of more than a kilometer. The balancing system employed by the A. E. A. differed from that employed by the Wrights and by Bleriot in that small auxiliary planes took the place of warping planes for righting the machine. This they claimed to be a superior method, first, because it eliminated the use of the rudder as being absolutely essential to the balance of the machine; second, because it enabled them to make the main planes rigid throughout, and consequently stronger than the flexible planes.

There are several other names that must be mentioned in connection with the early history of successful flight; these are the Frenchmen, Messrs. Henri Farman, Maurice Farman, the brothers Voisin, and Santos Dumont. These produced some of the first notably successful aeroplanes in Europe but seem to have discovered nothing which has had any marked effect upon the later development of flying machines. M. Farman adopted the auxiliary planes used by the A. E. A. and modified them to suit his ideas.

~WONDERFUL RECORDS OF AEROPLANES~

Volumes could be, in fact, have been written about the exploits of the first demonstrators of the practical heavier-than-air flying machines,--of the crossing of the English Channel by Bleriot, of the flights by Wilbur Wright at Rheims, France; of Mr. Curtiss' winning of the first Gordon Bennet International speed trophy and his flight down the Hudson from Albany to New York; of Orville Wright's flight at Fort Meyer, and the death of Lieut. Selfridge who was flying with him. The barest record of these interesting accomplishments would fill volumes. Of the aeroplane proper it is enough to say here that since 1908 its development has been too rapid for accurate recording. In strength, in speed, in reliability, in size and carrying capacity, it has developed at a remarkable rate. At this writing the speed record is about 130 miles per hour; the duration record is more than 24 hours, non-stop; the distance record is some 1,300 miles in one day; the altitude record some 26,000 feet. New records succeed the old ones with such rapidity that probably before this can be printed all these present records will have been greatly eclipsed.

[Illustration:

AEROPLANE "RED WING" HAMMONDSPORT, N.Y.

FIRST AMERICAN PUBLIC FLIGHT, MAR 12 1908]

[Illustration: The biplane in which G. H. Curtiss flew from Albany to New York in 1910.]

Meantime the aeroplane has developed greatly in other directions. In flying over land with the early types of machines many fatal accidents occurred, particularly to the fliers who gave exhibitions everywhere during 1909, 1910 and 1911. A majority of these accidents were indirectly due to the fact that a very smooth surface is required for landing a fragile machine running at high speed. The obvious expedient was to develop machines capable of rising from and alighting upon the water.

[Illustration: SOME FAMOUS FOREIGN MONOPLANES

A modern German monoplane.]

[Illustration: The machine in which Bleriot crossed the English Channel in 1909. A modified Langley type.]

[Illustration: Rolland Garros and monoplane in which he flew across the Mediterranean Sea in 1914.]

~THE WONDERFUL FLYING BOAT~

During the winter of 1910 and 1911 Mr. Curtiss, who had continued independent experiments upon the disbandment of the Aerial Experiment Association, succeeded in producing the first machine to safely leave and return to the water. For the development and demonstration of this type of flying machine he was awarded the Aero Club of America Trophy, and when during 1912 he produced still another type of water flying machine, the Curtiss Flying Boat, he was again awarded the Aero Club Trophy and also voted a Langley Medal by the directors of the Smithsonian Institution.

[Illustration: Different views of flying boat.]

Not until the development of the flying boat did the general public begin to take a participative interest in aviation, but as soon as the comparative safety of this type of machine became apparent the new sport began to be taken up rapidly both in this country and in Europe. The experiences of naval fliers and amateurs alike went to show that water flying offered not only the fastest and most comfortable mode of rapid travel, but also the safest, for during 1913 several hundred thousand miles were flown by navy aviators and amateur enthusiasts in Curtiss water flying machines without a single serious accident.

What aviation will mean to future generations,--even to this generation in the course of a few years,--it would be foolhardy to try to guess. Mr. Rodman Wanamaker already has agreed to furnish the financial support for Mr. Curtiss' attempt to build a machine to fly across the Atlantic Ocean, from America to Europe. If the venture is successful it is expected the crossing will be made in a fraction of the time taken by the fastest Transatlantic liners. The discovery of new metals and new manufacturing methods will certainly result in the development of light motors that may be relied upon to run for days without stopping, and automatically stable aeroplanes seem to be not far away. This will result in overland flight as safe and sure as we now enjoy over water.

[Illustration: INSIDE OF A MODERN FLYING BOAT

Interior arrangement of modern flying boat, showing fuel tank and instrument board.]

[Illustration: Six-passenger flying boat hull. This machine will fly 1,000 miles without stopping for fuel.]

[Illustration: FUN IN A FLYING BOAT

Flying at speed of a mile a minute.]

[Illustration: Monoplane flying boat, built for R. V. Morris.]

[Illustration: In a flying boat on pleasure bent.]

~GREATEST PRESENT VALUE OF AEROPLANE~

At present the greatest value of the aeroplane seems to be for military reconnaissance and all the great powers are striving their utmost to secure supremacy in the air. France, Germany, Russia and England have to date spent millions in developing aeroplane fleets. Only the government of the United States has failed as yet to appreciate the military significance of the flying machine. If the relative aeronautical strength of the world's nations were represented alphabetically the U. S. would naturally scarce have to change its initial, U being slightly in advance of Z which would stand for Zululand. But even with its modest equipment the navy fliers of the United States proved the great worth of the aeroplane and the flying boat, when during the recent trouble in Mexico the

air scouts gathered in a few minutes information that could only have been secured by days of cavalry scouting before the advent of the flying machine. Indeed, the name of Lieut. P. N. L. Bellinger, the most able of the naval fliers at Vera Cruz, has figured more prominently in the despatches from the front than that of any other officer connected with the expedition.

Flying seems certain in the very near future to take its place as the fastest, safest and most comfortable mode of conveyance. The flying boat will render quickly accessible the vast country lying along the great rivers of South America, Africa, and Australia; it will bridge the great lakes and the oceans; bring near together the islands of the Pacific and Indian oceans. It will make imperative, because of the speed with which distances will be traversed, of a language common to all peoples; and treble man's life without extending his years by making it possible to see and do three times as much in the same length of time.

~TEN YEARS OF FLYING~

Ten years ago on that day, December 17, 1913, Wilbur and Orville Wright made four flights on the coast of North Carolina near Roanoke Island, a spot historic in America's history as the site of the first English settlement in the Western Hemisphere.

[Illustration: Flying over military post in Curtiss biplane.]

The first flight started from level ground against a 27-mile wind. After a run of 40 feet on a monorail track, the machine lifted and covered a distance of 120 feet over the ground in 12 seconds. It had a speed through the air of a little over 45 feet per second, and the flight, if made in calm air, would have covered a distance of over 540 feet.

Altogether four flights were made on the 17th. The first and third by Orville Wright, the second and fourth by Wilbur Wright. The last flight was the longest, covering a distance of 852 feet over the ground in 59 seconds. After the fourth flight, a gust of wind struck the machine standing on the ground and rolled it over, injuring it to an extent that made further flights with it impossible for that year.

[Illustration:

1900

1901

1902

1905 1904

1903]

The gliding experiments of Lilienthal in 1896 led the Wright Brothers to become interested in flight. The next four years were spent in reading and theorizing. In the Fall of 1900 practical experiments were begun with a man-carrying glider. These experiments were carried on from the sand hills near Kitty Hawk, North Carolina. The first glider was without a tail, the lateral equilibrium and the right and left steering were obtained by warping of the main surfaces. A flexible forward elevator was used. This machine was flown as a kite with and without operator, and several glides were made with it.

A second machine was designed of larger size, and many glides were made with it in 1901. This machine was similar to the one of 1900 but had slightly deeper curved surfaces. Experiments with this machine demonstrated the inaccuracy of all the recognized tables of air pressures, upon which its design had been based.

In 1902 a third glider was constructed, based upon tables of air pressures made by the Wright Brothers themselves. The lateral control was maintained by warping surfaces, and a vertical rear rudder operated in conjunction with the surfaces. Nearly a thousand gliding flights were made with this machine.

In 1903, the Wright Brothers designed a machine to be driven with a motor. They also designed and built their own motor. This had four horizontal cylinders, 4 in. by 4 in., and developed 12 h.p. Two propellers, turning in opposite directions, were driven by chains from the engine. After many delays the machine was finally ready and was flown on the 17th of December, 1903, as related above.

In the Spring of 1904, power flights were continued near Dayton with a machine similar to the one flown in 1903, but slightly heavier.

The first complete circle was accomplished on the 20th of September, 1904, in a flight covering a distance of about one mile. Altogether 105 flights were attempted during the year, the longest of which were two of five minutes each, covering a distance of

about three miles. All of the flights were started from a monorail.

After September a derrick and a falling weight were used to assist in launching the machine.

[Illustration:

1908-9

1910

1910

MODEL R, 1910]

~INTERESTING GOVERNMENTS IN FLYING MACHINES~

It was not till 1908 that the Wright Brothers found purchasers for their invention. In that year they made a contract to furnish one machine to the Signal Corps of the United States Army and to sell the rights to their invention in France to a French company. In both cases they agreed to carry a passenger in addition to the operator, fuel sufficient for a flight of 100 miles, and to make a speed of 40 miles an hour.

After making some preliminary practice flights at their old experiment grounds near Kitty Hawk in May, 1908, Wilbur Wright went to France to give demonstrations before the French Syndicate and Orville Wright to Washington to deliver the machine to the United States Signal Corps. The machines used by Wilbur Wright had been standing in bond in the warehouse at Havre since August of the year before. Owing to damage done to the machine in shipment, it was not ready for the official demonstrations until late in the year.

Meanwhile Orville Wright in September, 1908, started demonstrations of the machine contracted for by the United States Government. On the 9th he made two flights, one of 57 minutes, and the other one hour and 2 minutes, world's records. On the 10th and 11th, these records were increased and on the 12th a flight of 1 hour and 15 minutes was made. On the 17th, the tests were terminated by an accident in which Lieutenant Selfridge met his death and Mr. Wright was severely injured, so that he was not able to complete the tests until the following year.

Four days after the accident, on the 21st of September, Wilbur Wright made a flight of 1 hour and 31 minutes at Le Mans, France, which record he improved several times during the following months, and on the 31st of December, won the Michelin Trophy by a flight, in which he remained in the air 2 hours and 24 minutes.

Where Is the Wind When It Is Not Blowing?

The answer is, of course, that there isn't any wind then. To understand this perfectly we must study a little and find out what wind is. In plain words it is nothing more than moving air.

If you make a hole in the bottom of a pail of water the water will run out slowly. If you knock the whole bottom out of the pail filled with water, the water will rush out before you know it.

That is about what happens to make the wind. The air is constantly full of air currents, like the currents you can see in a river. Down the middle of the river you may notice a softly-flowing current going straight. Along the shores there will be little side currents going in all directions, and you may find some little whirlpools. That is exactly what we should see in the air if we could see air currents.

Where Does the Wind Begin?

The movement of these currents of air leaves many pockets of space where there is no air, and when one of these is uncovered the air rushes in and creates a wind in doing so. These air currents are continually pressing against each other to get some place else. They change their direction according to the pressure that is being applied to them. Sometimes the pressure will be very light in one part of the air, many miles away perhaps, and then the air in another part, which is under great pressure, will rush with great force into the part where the pressure is light, and thus form a big wind. When the pressure stops the wind stops.

We have probably felt the wind which comes out of the valve of the automobile tire when the cap is taken off to pump up the tire. It is a real wind that comes out. The reason is that the air in the tube of the tire is under great pressure, and when the opportunity is given to get where the pressure is light it starts for that place with a rush and comes out of the valve a real wind.

What Causes the Wind's Whistle?

The whistle of the wind is caused very much like the whistle you make with your mouth or the noise made by the steam escaping through the spout of the kettle. You do not hear the wind whistle when you are out in it. You can hear it when you are in the house and the wind is blowing hard. When the wind blows against the house it tries to get in through all the crevices, under the cracks of the doors, down the chimneys, wherever it finds an opening. And whenever it starts through an opening that is too small for it, it makes a noise like the steam coming out of the spout of the kettle, provided the opening is of a certain shape.

Not all the noises made by the wind, however, are made in this way. The wind in blowing against things makes them vibrate like the strings of a piano or violin, and when things vibrate, as we have already seen, they produce sound waves, which, when they strike our ears, produce sounds of various kinds. The wind even on ordinary days makes the telegraph and telephone wires hum, as you can prove to yourself by placing your ear against a telegraph or telephone pole, and whenever the wind makes anything vibrate, a great many queer sounds are produced, which often frighten us more than they should.

Why Does the Air Never Get Used Up?

Simply because it is constantly being replenished. The three gases, oxygen, nitrogen and carbonic acid gas, which are found in the air about us, are constantly being used up. All living animal creatures are at all times taking oxygen out of the air to live on. Certain microbes are using up quantities of the nitrogen all the time, and the plants live on the carbonic acid gas. But while these different kinds of life between them use up the air, they give back something also. The plants give off oxygen. The bodies of the animals and plants when they die decompose, and as they are full of nitrogen, that is given back to the air in that way, and then all living creatures are always throwing off carbonic acid gas through their lungs, and thus everything that is taken out of the air is put back again. The plants live on carbonic acid gas, and give us back oxygen. The living creatures live on oxygen and give off carbonic acid gas, and when they die their bodies put back in the air the nitrogen which the microbes take out, and so, consumption and production are about equal all the time.

Why Can't We See Air?

We cannot see air because it has no color and is perfectly transparent. If at times it appears that there is color in the air it is not the air you see, but some little particles of various substances in it. Sometimes you think when you look off toward a range of mountains or hills, for instance, that the air is blue. You know the grass and trees on the mountains are green, so it cannot be they that have turned blue, and so you think the air is blue. But it is only the sunlight reflected to your eyes from the little particles of dirt and other substances which fill the air at all times which makes the blue that you see, and not the air.

Pure air is a mixture of gases without any color and is perfectly transparent. Air is nearly entirely composed of a gas called nitrogen--the remainder being oxygen with a little water and carbonic acid gas, which latter is thrown off in breathing. This is, however, but a very small percentage.

Air has been and still can be reduced to a liquid state, and with the use of it in this form many seemingly wonderful things can be done, which are interesting to look at, but have not as yet become commercially practical.

Why Does Thunder Always Come After the Lightning?

This occurs simply because lightning or light travels so much more quickly than sound. Light travels at the rate of 186,000 miles per second, and sound travels only at the rate of 1090 feet per second when the temperature is at 32 degrees. Now, the thunder and lightning come at the same time and place in the air, but the light travels so much faster that you see the lightning often quite some seconds before you hear the thunder. In fact, you can tell quite accurately how far away from you the flash of lightning and clap of thunder are by taking a watch and noting the number of seconds which elapse between the flash of the lightning and the time when you hear the roll of the thunder. If as much as five seconds elapse you can figure that it was about a mile away from you, since sound travels only about 1100 feet per second and there are 5280 feet in a mile. When the thunder and lightning come close

together you may know that it is near by, and when they come at the same time you may be sure it is very close. When, therefore, you see the lightning and then have to wait several seconds for the noise of the thunder, you may rest easy about the lightning hurting you, because you know then it is too far away to harm you, and when it is so close that the lightning and thunder come simultaneously, there is no use being afraid, because if you were to be struck you would have been struck at the same instant or before you would have had time to notice that the lightning and thunder come together.

How Big Is the Sun?

It is very difficult to gain a clear idea of how very large the sun really is. We know from the scientists who have measured it with their accurate measuring instruments that it is 865,000 miles through it, and that at its largest part it is 2,722,000 miles around. Now, you can see why I said it is very difficult to get a clear conception of the sun's size. A mile is quite a long distance to walk on a hot day. Now, the earth is 8000 miles through. If there were a tunnel right through the earth, like the subway, and you started to walk it, it would take you 83½■ days if you walked day and night without stopping to rest or eat, if you kept going at the rate of four miles every hour. This would be a long, hot walk, for, of course, the inside of the earth is hot, as we have already learned. It would take an automobile, going at the rate of 40 miles an hour night and day, about nine days to make the trip through such a subway from one side of the earth to the other. That makes it look like a pretty big old earth, doesn't it? But let us see what would happen if we started to do the same thing on the sun. The sun is 865,000 miles through. If you were to walk through a similar tunnel on the sun at four miles per hour it would take you 20 years, not counting the stops, and an automobile going 40 miles an hour day and night would take two years and a half to make the trip one way.

The sun is ninety million miles from the earth and an automobile travelling at the rate of forty miles per hour day and night on a straight road, without stopping, would be 257 years in getting there.

When we stop to think of how big the bulk of the sun is it is altogether beyond us. We have a general idea that our earth is a pretty large affair as worlds go, and yet we cannot conceive how much the bulk of the earth amounts to. Still, the sun is so large that it could contain a million worlds like our own.

How Hot Is the Sun?

We think the sun is pretty hot in summer when the thermometer goes up to 90 degrees in the shade or out. We begin to get sunburned long before it reaches that high. But right on the sun's surface it is between 10,000 and 15,000 degrees hot. That is, of course, a degree of heat which we cannot conceive. How much hotter still it is on the inside of the sun we don't as yet know. It must be awfully hot there.

Why Is It Warm in Summer?

It is warm in summer because at that season of the year the heat rays of the sun strike our part of the earth through less air. The blanket of air which surrounds the earth is very much in comparison as to thickness like the peeling of an orange and surrounds the earth in just the same way. If you stick a pin straight into an unpeeled orange you only have to stick it in a little way before you reach the juicy part of the orange, but if you stick the pin in at an angle the pin will travel a much longer ways through pure peeling before it strikes the juicy part. Now, then, in summer the rays of the sun come down to us straight through the peeling of air, and less of the heat is lost by contact with the air, and that makes it warmer in summer. The explanation also accounts for your next question.

Why Is It Cold in Winter?

In winter the heat rays of the sun strike at our part of the earth at the angle at which you stick the pin into the orange when you wish to make it travel through the most peeling. In winter the rays strike the earth at such an angle that a great deal of the heat is lost in travelling through the air, because they have to come through so much more of the air. Of course, the sun's rays strike some part of the earth straight down through the peeling of air at all times, and at the equator this occurs all the year round, so it is always summer there, while at the North and South Poles the rays always strike the earth at the greatest possible angle, and it is always very cold winter there. In between, when it is neither hot nor cold, we have spring and fall, due to the fact that the rays come down at an angle, but not so great an angle.

Why Have We Five Fingers on Each Hand and Five Toes on Each Foot?

All animals, it seems, from a study of nature were started with ten fingers and ten toes, the fingers originally having been the toes of the fore legs. In a good many cases the environment in which animals have lived has caused a change in the formation of the ends of the limbs as well as in the limbs themselves. The horse, for instance, has developed into a one toe or one finger animal, while a cow is a two finger animal. The hen has only three toes on each foot and a part of another. But if we go back into the history and examine how the horses' foot used to look we will find that he originally had five toes. The same is true of the cow and also the hen. Something happened to cause the change, for the rule of five fingers and five toes on the end of each limb has been universal. If you examine a chicken in a shell just before it is ready to come out, you can distinctly count five toes on each foot and at the ends of the wings you will see five little points, which under other conditions would develop into fingers, perhaps. Some of these toes of the new-born chicken do not develop. It can be accepted as a rule that creatures were intended in the original plan to have five fingers on each hand and five toes on each foot, making our count of tens, which is the world's basis for counting, and has always been.

Why Do We Have Finger Nails?

Finger nails and toe nails are only another phase of the development of man from the animal that originally walked on four feet. Animals that walk on all fours use the finger and toe coverings which in man is the nail, to scratch in the ground, to attack enemies, and to climb with, and our nails of the present day are what the development of man into a civilized being has changed them to. At that, there are still uses for finger nails and toe nails, or man in his changing to a higher plane would have found a way to develop away from them. They are useful to-day in making our fingers and toes firm at the end, and enable us to pick up things more easily. The time may come when man will have neither finger nails nor toe nails.

Why Are Our Fingers of Different Lengths?

There is no known reason why our fingers should be of different lengths to-day; in fact, it is thought by some people that the hand would be stronger if the fingers were all of the same length. Certainly, however, the hands would not then be so beautiful, and it might not be so useful. The human hand to-day is perhaps the most versatile thing in the world. You can do more things with the hand than with any other thing in the world. The probability is that the shape of the hand to-day and the length of the fingers are the result of the different things the human being has called upon the hand to do during man's development up to the present time.

We must go back to the time, however, when man walked on fours, for that is probably the real explanation. Originally man's fingers were of different lengths because all four-footed animals had the same peculiarities. The shape and length of the toes and their arrangement were the ideal arrangement for giving the proper balance and support to the body, and in moving about and in climbing produced the best toe hold.

Why Does It Hurt When I Cut My Finger?

It hurts when you cut your finger, or, rather, where you cut it, because the place you have cut is exposed to the oxygen in the air, and as soon as it is so exposed a chemical action begins to take place, just as when you cut an apple and lay it aside you come back and find the cut surface all turned brown. If the apple could feel it would hurt also, because the chemical action is much the same. The apple has a skin which protects its inside from the oxygen in the air, and you have also a skin which protects you from the oxygen as long as it is unbroken.

What happens, of course, is this: When you cut your finger you sever the tiny little veins and nerves which are in your finger. They are spread all over your body like a net-work under the skin, close to the surface in most places. The nerves when cut send a quick message to the brain, with which they are connected, telling that they are damaged, and the brain calls on the heart and other functions to get busy and repair the damage along the line. There may be some hurt while this process of repairing is going on, but the principal part of your hurt, outside of what we call your feelings, is due to the fact that the inside of you is thus exposed to the chemical action of the air. Then I can hear you say next:

Why Don't My Hair Hurt When It Is Being Cut?

It does not hurt to cut anything that has no nerves. There are no nerves in the hair which the barber cuts. If he pulls out a hair it hurts, because the root of the hair has nerves, which telegraph notice of the damage to the brain. When a dentist takes out or kills the nerve in your tooth you cannot have any more toothache in that tooth, because there is no nerve there to send the message to the brain. You can cut your finger nails without feeling pain, because they have no nerves at the ends, but underneath, where they join the skin of the finger, there are a great many nerves, and it hurts very much to bruise the nails at that location.

Of What Use Is My Hair?

~WHY WE HAVE HAIR~

Your hair is a relic of the days when the entire body was covered with hair, just like some animals to-day, to protect the body from the heat, cold and wet. Man has, however, for so long a time worn clothes over most of his body that the need of the hair to protect him from these elements has all but disappeared, and so also has the hair, excepting in such places as the top of the head and face and other exposed parts. If you were to go out into the woods without clothes and live a long time your body would probably again become covered with hairs. The time is coming, however, it is believed, when human beings will have no hair at all on their bodies. You have hair on your head, but if you were to wear a hat or cap all the time you would soon be bald. Hair is of no use to us to-day excepting to adorn our bodies and add to our appearance. This it seems to do to-day, probably because we are accustomed to seeing it, and will make no difference in our looks relatively if the time comes when we have no hair at all.

Why Does My Hair Stand On End When I Am Frightened?

It does this under certain conditions, because there is a little muscle down at the root of each hair that will make each hair stand up straight when this muscle pulls a certain way. It is difficult to say just how these muscles are caused to act in this way when we are frightened. We know that when thoroughly frightened our hair will sometimes stand straight up, and we know that it is this muscle at the root of each hair that makes it possible, but why it is that a big scare will make this muscle act this way we do not as yet know.

What Makes Some People Bald?

The chief cause of baldness is the lack of care of the hair. It is as necessary for the roots of the hair to have a free circulation of the blood and that the hair itself should have plenty of air as it is necessary for the brain to have a good circulation. A great many men become bald through wearing their hats most of the time. The hat pulled down tight over the head presses against the scalp and interferes with the circulation of the blood in the scalp. Then, also, many hats do not have any means of ventilation, and that keeps the pure air away from the hair. The hair then becomes sick and dies, just as flowers wilt if you keep them away from the air. You will notice that women do not become bald so easily. One reason is that even when the women wear large hats, as they often do, there is plenty of room for the air to circulate through the hair, even when the hat is on, and women's hats are not pulled down tightly on the scalp. Therefore, they do not press on the arteries and veins in the scalp and interfere with the circulation of the blood. Another reason why women do not become bald is that the hair of women has long been their "crowning glory"; a man likes to see a fine head of hair on a woman, and as women have long tried to please men in every possible way, they take better care of their hair than men do, because they like to have the men consider it beautiful.

What Makes Some Things in the Same Room Colder than Others?

The objects in a room which has been kept at a given even temperature of heat will be all the same temperature, because heat spreads from one thing to another equally.

Still, if you put your hands on various objects in such a room some of them will feel colder than others. You touch the tiling of the fireplace and that will feel cool to you. On the other hand, the upholstered furniture will feel quite warm. The piano keys feel cool, while the wood of the piano and case is warm. The difference is due to the fact that heat or cold will run through some objects more quickly than through others. It will run through the tiling on the hearth and the piano keys more quickly than through the upholstering on the furniture or the wood of the piano case. When you touch a thing with your finger you supply some of the heat of your body to the object through your finger. If the object is the tiling on the hearth or the keys of the piano the heat runs through it quickly and you get a cold impression in your finger. On the other hand, if you touch the upholstery on the furniture, through which the heat runs slowly, you get a warm feeling for the very same reason. Thus, anything which carries the heat away from our contact

quickly we call a cold feeling object, and if the object touched does not carry the heat away so quickly we call it a warm feeling object.

Why Does the Hair Grow After the Body Stops Growing?

The hair on our bodies is one of the things that is continually wearing or falling away, and since, like the skin, it is necessary to protect certain portions of the body, the hair keeps on growing long after the grown up period has arrived. The skin is a very necessary protection of the whole body, but is constantly being worn away, and is all the time being replaced. Your hair falls out when it is not healthy. Unless proper care is given to it, it will fall out and not grow in again, and then we become bald.

Will People All Be Bald Sometime?

There is a theory that before many years have passed human beings will lose all of the hairs which now grow on different parts of their bodies, due to the fact that we wear so much clothing and keep so much of our bodies away from the sunlight. If that time comes we shall have a hairless race of men and women.

THE STORY IN A LUMP OF SUGAR

[Illustration: PREPARING THE GROUND.--PLOWING AND HARROWING WITH A CATERPILLAR ENGINE.

Sugar beets require deep plowing, ten to fourteen inches, or twice the usual depth. When using horses, farmers are inclined not to plow deeply enough to secure maximum results, and some of the factories have put in power plows which turn six furrows and harrow the land at the same time. They plow and harrow the land of beet farmers for $2.50 per acre, which is about one-half of what it costs the farmers to plow equally deep with horses. The traction engines also are used for hauling train wagon loads of beets to the factory. In some localities farmers are banding together and purchasing engines for plowing and hauling beets. The outfit illustrated above costs about $4,500.]

[Illustration: DRILLING THE SEED.

Beets are drilled in rows, usually eighteen inches apart, 18 to 25 pounds of seed being drilled to each acre. Practically all the beet seed used in America is grown in Europe, principally in Germany, but it has been demonstrated that superior seed can be produced in the United States. Sugar-beet seed growing requires five years of the utmost skill, care and patience, from the planting of the original seed to the maturing of the commercial crop which is sold to the trade. The factories contract for their seed for three to five years in advance, sell it to farmers at cost price, and deduct the amount from the payment for beets.]

[Illustration: HOW THE BEETS ARE GROWN

BLOCKING AND THINNING.

When the beets are up and show the third leaf they should be “thinned.” Unless thinned at the proper time the pulling up of the superfluous beetlets injures the roots of the remaining ones. Scientific experiments in Germany, where all other conditions were identical, showed that one acre thinned at the proper time yielded 15 tons; the next acre, thinned a week later, yielded 13½■ tons; the third acre, thinned still a week later, yielded 10½■ tons; and the fourth acre, thinned three weeks after the first, yielded 7½■ tons.

The men in the foreground are “blocking” the beets, leaving a bunch of them every eight inches. Those in the rear are “thinning,” or pulling up the superfluous beetlets, leaving one in a place, eight inches apart.]

[Illustration: READY FOR THE HARVEST.

This field of beets yielded 20 tons to the acre. Ex-Secretary of Agriculture James Wilson is convinced that when American farmers become expert in beet culture they will average to produce more than 20 tons per acre because of the superiority of our soils. The ideal factory beet weighs about two pounds, and a perfect “stand” of such beets, one every eight inches, in rows eighteen inches apart, would yield 43½■ tons per acre. The present average yield in the United States is about 10 tons per acre, while the hitherto “worn-out soils” of Germany yield 14 tons per acre, or 40% more than is secured from our “virgin soils.”]

[Illustration: HUGE BINS TO HOLD THE BEETS AT FACTORY

TOPPING THE BEETS.

After the beets are plowed out they are topped or cut off by hand and the tops are fed to stock, for which purpose they are worth $3.00 per acre. They are topped just below the crown and the factories require that they be so topped as to remove any portion which grew above the ground, as such portion of the beet contains but a small percentage of sugar. The beet will grow in length, and, if as a result of shallow plowing or coming in contact with a rock it cannot grow downward, it will grow upward and out of the ground, thus necessitating a deeper topping and consequent loss to the farmer.]

[Illustration: DUMPING CARS AT FACTORY WITH HYDRAULIC JACK.

Beets arriving at the factory by rail from receiving stations either are stored in bins until needed or are floated directly to the beet washers. If to be used at once, they are dumped, as shown above, and slide directly into a cement flume filled with warm water, which has been pumped to its upper end, and is flowing in the direction of the beet end of the factory. In whatever manner they may be received, they first are weighed, and as they are dumped, a basket is held under them to catch a fair sample of both beets and the loose dirt, which the car or wagon contains. These samples, properly tagged, are conveyed to the beet laboratory, where they are washed, and trimmed if not properly topped, and the difference in the weight of the sample beets as received and their weight when washed is called the "tare." Whatever percentage this amounts to is applied to and deducted from the weight of the car or wagon load. A sample of these beets then is tested by the polariscope for its sugar content and its purity; farmers often being paid a stipulated price per ton for a beet of a given sugar content and 25 to 33½■ cents per ton additional for each extra degree of sugar which they contain. The tare rooms and the beet-testing laboratories are open to any one, and in some localities the farmers' associations employ experts to tare and analyze each sample of beets.]

[Illustration: MILLIONS OF BUSHELS OF BEETS

FACTORY BEET BINS FILLED TO CAPACITY.

As they arrive by rail from receiving stations, or by team, or traction engines from the farm, beets are stored in bins or sheds, the capacity of which ranges from 6000 to 35,000 tons per factory, depending upon location and general climatic conditions.

The bins are V shaped, about 3 feet wide at the bottom, 20 to 30 feet at the top, and they are 20 to 30 feet high. As beets are needed, beginning at one end of the bin the loose three-foot planks at the bottom are removed one at a time, and with hooks attached to long poles the beets are rolled into the flume or cement channel below, in which they are floated into the factory. This is not only to save labor, but to loosen up the dirt which attaches to the beets, thus partially washing them. The water which is used in the flumes is warm water from the factory.]

[Illustration: TYPICAL AMERICAN BEET SUGAR FACTORY.

These factories cost from half a million to three million dollars. They consume from 500 to 3,000 tons of beets per day, and during the "campaign," which usually lasts about three months, will produce from 12 to 75 million pounds of granulated sugar. There are 73 of these factories, located in 16 States, from Ohio to California. During the operating season they give employment to from 400 to 1000 men each.]

[Illustration: WASHING THE SUGAR BEETS

CHEMICAL LABORATORY.

In a beet-sugar factory each set of apparatus for performing a given process is termed a "station." In the chemical laboratory the juices and products from each station are tested hourly to check up the correctness of the work and to determine the losses of sugar in each process in the factory.]

[Illustration: CIRCULAR DIFFUSION BATTERY.

After being floated in from the sheds the beets are elevated from the flume to a washer, where they are given an additional washing before being sliced. From the washer they are elevated and dropped into an automatic scale of a capacity of 700 to 1500 pounds. From the scale they pass to the slicers, where with triangular knives they are cut into long, slender slices, which look something like "shoestring" potatoes. These slices drop through the upright chute seen at the right side of the picture, and are packed tightly into cylindrical vessels holding from two to six tons each; the battery consisting of eight to twelve vessels arranged either in a straight line or in circular form. Warm water is run into these slices, and coaxes out the sugar as it passes from one vessel to the

succeeding ones. After passing through the entire series of vessels the water has become rich in sugar, of which it contains from 12 to 15 per cent, depending upon the richness of the beets. It then is drawn off and is called diffusion juice or raw juice. This is carefully measured into tanks and recorded. As this juice is drawn off the vessel over which the water started is emptied of the slices from the bottom, the exhaust slices containing in the neighborhood of ½■ to ½■ per cent of sugar. These slices are carried out from the factory in the form of pulp and fed to stock, as explained later.]

[Illustration: HOW THE SUGAR IS TAKEN FROM THE BEET

CARBONATATION AND SULPHUR STATION.

Warm raw juice is drawn into the carbonatation tanks and treated with about 10 per cent milk of lime--about like ordinary whitewash. This lime throws out impurities, sterilizes the juice and removes coloring matter. Carbonic acid gas from the lime kiln is forced through the lime juice in the tank, throwing out the excess of lime, converting it into a carbonate of lime or chalk. Tests are taken here by the station operator to show when the process is finished.]

[Illustration: FILTER PRESSES.

From the carbonatation tanks the juice is pumped or forced through filter presses consisting of iron frames so covered with cloth that the juice passes through the cloth as a clear liquid, leaving the lime and impurities precipitated by it, in the frame, in the form of a cake. This cake, after washing, is dropped from the presses and conveyed out of the factory. It contains from one to two per cent of its weight in sugar, which constitutes one of the large losses of the process. It also contains organic matter, phosphate and potash, besides the carbonate of lime, which makes it an excellent fertilizer, all of which is used in Europe on the farm, but so far to too small an extent in America.]

[Illustration: EVAPORATING THE WATER FROM THE SUGAR

EVAPORATORS.

After a second, and sometimes a third carbonatation and filtration, the juice is carried to the evaporators, commonly called the "effects," usually four (4) large air-tight vessels furnished with heating tubes running from 3000 to 7000 square feet in each vessel. A partial vacuum is maintained in these evaporators which makes the juice boil out at a low temperature, thus preventing discoloration, and to a large degree the destruction of sugar which will come about by high temperature. There always is, however, some unavoidable loss of sugar in this apparatus. The juice passes along copper pipes from first to last vessel, becoming thicker as it does so. It comes into the first vessel at 10% to 12% sugar and is pumped out of the last one so thick that it contains about 50% of sugar.]

[Illustration: VACUUM PANS.

After a careful filtration, the juice that comes from the evaporators, and is called thick juice, is pumped to large tanks high up in the building, and from these is drawn into vacuum pans. These are large cylindrical vessels from 10 to 15 feet in diameter and from 15 to 25 feet high, with conical top and bottom, built air-tight. Around the inner circumference they are furnished with 4- to 6-inch copper coils, which have a heating surface of 800 to 2000 square feet. Exhaust steam is used in the evaporators, live steam in the pans, the juice in both being boiled in a vacuum to prevent discoloration and reduce losses.

After considerable thickening by this evaporation, minute crystals begin to form. When sufficient of these have formed, fresh juice is drawn in and the crystals grow, the operator governing the size of the crystals to suit the trade. If small crystals be desired, a large quantity of juice is admitted at the outset, while if large crystals are desired, a small quantity of juice first is admitted, and, as it boils to crystals, fresh juice gradually is added to the pan, and the crystals are built up to the desired size. The operator of this pan, known as the "sugar boiler," is one of the must important men in the factory. The water furnished the condensers of these vacuum pans and the evaporator goes to the beet sheds and is used for floating in the beets. It amounts to from 3,000,000 to 8,000,000 gallons every 24 hours, depending upon the size of the factory, and must be very pure.]

[Illustration: HOW SUGAR IS GRANULATED

FRONT VIEW OF CENTRIFUGAL MACHINES.

The mass of crystals with syrup around them and containing about 8 per cent to 10 per cent of water is let out of the vacuum pan into a large open vessel called a mixer, beneath which are the centrifugal machines. These are suspended brass drums perforated

with holes and lined with a fine screen. They are made to revolve about 1000 times to a minute, and the crystal mass of sugar rises up the side like water in a whirling bucket. The centrifugals force the syrup out through the screen holes, leaving the white crystals of sugar in a thick layer on the inner surface. These are washed with a spray of pure warm water and then are ready for the dryer.]

[Illustration: SUGAR GRANULATOR OR DRYER.

The damp white crystals from the centrifugal machine are conveyed to horizontal revolving drums about 25 feet long by 5 to 6 feet in diameter. These drums are furnished with paddles on the inside circumference, the paddles picking the sugar up and dropping it in showers as the drum revolves. Warm dry air is drawn through and takes the moisture out of the sugar, which now is ready to be put in bags or barrels for the market.]

[Illustration: BY-PRODUCTS OF THE SUGAR BEET

CRYSTALLIZERS.

The syrup that was thrown off from the crystals in the centrifugal machines is taken back to the vacuum pan, evaporated in the same manner as previously described, and from the vacuum pan goes into the crystallizers to carry the process of crystallization as far as it will go. These contain from 1000 to 1600 cubic feet of the crystallized mass which remains in them from 36 to 72 hours, during which time it is kept in constant motion by a set of slowly revolving paddles, or arms, to facilitate further crystallization. From the crystallizers it goes to the centrifugal machines, where the syrup is separated from the crystals as before. The crystals are remelted and go in with the thick juice for white sugar. The syrup, still containing a large amount of sugar, goes out to be sold as cattle feed or to an Osmose or Steffens process, where a portion of the remaining sugar may be recovered. This lost syrup constitutes the largest loss in the entire process. It contains all the impurities of the beet juice not removed by the lime. These impurities prevent more than one and one-half times their weight of sugar from crystalizing, and make what is called molasses.]

[Illustration: A SEA OF BEET PULP.

For a century the high feeding value of sugar-beet pulp has been recognized in Europe, but until a few years ago millions of tons of this valuable by-product rotted about American beet-sugar factories, as shown above, because American farmers could not be made to believe it possessed sufficient value to pay for hauling it back to the farm.]

[Illustration: MACHINE THAT FILLS, WEIGHS AND SEWS THE BAGS OF SUGAR

SACKING ROOM.--SHOWING AUTOMATIC SCALES AND SEWING MACHINE.

After the moisture has been thoroughly removed in the granulators or dryers, the sugar drops directly to the sacking room through a chute, at the lower end of which the top of the double bag is attached. The sugar flows directly into the sack, the flow being cut off automatically with each 100 pounds, when an endless belt conveyor passes the upright sack past the sewing machine at the proper speed and the product is sealed ready for storage or shipment.

While it requires from 400 to 1000 men to man a factory, not a human hand has touched either beets or product since the beets were topped in the field, and at no stage of the operation could flies or vermin or filth come in contact with the product, which from the beginning has been subjected to continuous high temperatures.]

Pictures herewith by courtesy of United States Beet Sugar Industry.

How Can We Smell Things?

You do not need to be told what organ of the body we use in exercising the sense of smell. You can prove that easily to yourself by getting the nose within range of a distasteful smell.

We do not use all of the nose to smell with, and the nose is useful to us in other ways besides this. We use the nose a great deal in the act of respiration or breathing, and it is also useful in helping us to make sounds, form words, and, though you may not have known it, helps our sense of taste.

We smell things by means of the olfactory nerves which are located within the nose. The entire interior surface of the nose is covered with a membrane. The ends of olfactory nerves, or the nerves which give us the sensation of smell, are in this membrane, and the air, which is filled with the odor of things we smell, passes over this membrane, and thus the ends of the nerves feel the

odor and cause sensation of smell in the brain. The nerves of smell do not, however, go all through this membrane.

There are other nerves in the nose, however, besides those which give us the sensation of smell. These are also very sensitive and serve to make the nose exercise other functions when the inside of the nose is hurt or tickled. When a foreign substance, one of the many smaller particles which are constantly floating in the air, gets into the membrane in the nose, it irritates these nerves and often causes us to sneeze, which is only nature's effort to drive out this foreign substance and clean out the nose. Smell is one of the lesser of the five senses which we possess. It is one of what has been called the chemical senses. The sense of smell does not act at any great distance. This sense could be made of more value to us if we developed it. Some people have a more highly developed sense of smell than others. The lower animals have a much keener sense of smell than people. A great many of them can follow a trail for miles merely by the smell of the foot-prints, and it is said that a deer will note the presence of man or any other animal that may subject him to danger even when miles away, the odor being carried to him through the air.

How Do We Taste Things?

The sense of taste is closely associated with the sense of smell. In fact we do a good deal of what we think is tasting by using our sense of smell. A cold in the nose will sometimes destroy almost altogether the taste of food, so that there is a very close connection between the sense of taste and the sense of smell.

The sense of taste comes to us through the tongue, which is the principal organ of taste. The remainder of our sense of taste lies in the surface of the palate and in the throat. As in the case of the other senses, the sensation of taste is given us through nerves, the ends of which are all through those parts of the tongue, the palate and the throat, which contribute to this sense. More nerves of taste are located in the back part of the tongue than on the front, and it is said that when you have to swallow a bad dose of medicine it won't taste so much if you put it on the front part of your tongue and then swallow, because there are so few tasting nerves there. The extreme tip of the tongue, however, is very thickly covered with the ends of the taste nerves. In like manner one could have the front end of the tongue cut off and still retain most of the sense of taste.

Now, in order to produce the sensation of taste, the substance to be tasted must come in contact with something which mixes with it and causes the sensation of taste. This is what happens when we taste anything. The juices or liquids which are caused to flow when anything is put into the mouth act on the substances which enter and give the taste nerves a chance to taste them. Really the nerves of taste are so placed in the mouth as to be regular guards or inspectors of what shall go into the stomach. You can see how well they are arranged. In the tip of the tongue quite a few of them; in the back part of the tongue a great many nerves, for from there the food goes into the throat, which delivers it to the stomach; then those in the palate and in the throat. They are arranged so that the taste nerves have ample opportunity to test what comes in and to give warning to the brain of what is being sent to the stomach. Sometimes the things that come into the mouth are so distasteful to the nerves of taste that they refuse to hand it over to the stomach, but instead cause the distasteful substance to be thrown out again immediately.

It is said that a good rule to follow in eating would be to swallow only such things as are pleasing to the sense of taste. On this principle many children would decide to eat nothing but candy, but do you know, if you tried that, the continuous tasting of sweets by our sense of taste nerves would cause them to repel further insertion of candy after a while. You know that too much of a good thing is bad for you, and that is what makes you feel badly when you have eaten too much of one thing.

What Happens When We See?

~HOW WE SEE THINGS~

Of course, it is the eyes with which we see things. When we think of the things with which we see, we think only of eyes, which give us our sense of vision, but there are certain forms of animal life which have no eyes but which have what are called eye spots or eye points, which are sensitive to light and which are merely spots. These eye spots may be located in any part of the body, and are often found in great numbers on the same body. These rude eyes are, however, not real eyes. They are, as has already been said, sensitive to light, but are found only in some of the very low forms of animal life which live in the water. A real eye is an organ in which the parts are so arranged that optical images may be formed.

As animal life becomes developed to a higher scale, the parts which contain the making of real eyes become more distinct although, of course, the eyes themselves are not so highly developed as in man. One of the first kinds of life which has eyes with a

definite structural character are the worms, snails, etc., though their sense of vision is more or less dim.

When we come to the family of mollusks, however, low down in the scale of life though they are, we find them to possess eyes which enable them to see almost as well as animals which have a backbone, although this kind of eyes is constructed in a very different manner than the eyes of vertebrate animals referred to. As we ascend the scale of animal life in the study of eyes, we come next to the crustaceous, which is an important division of animal life that embraces the crabs and lobsters, shrimps, crawfish, and insects such as sand-hoppers, beach-fleas, wood-lice, fish-lice, barnacles. The eyes of such animals are quite developed, but the number that each will have varies. Some have only a single eye and others two, four, six or eight, but only certain kinds of this class of life have more than two eyes. The spiders generally have the most.

In vertebrates, which is the class of animal life to which we belong, the number of eyes is almost always two and no more. The eyes are formed in special sockets in the skull, which are called eye sockets or orbits. This arrangement of placing them in a socket is of great advantage because the eye is thus protected from chance of injury except from one direction--the front. These animals have also eyelids, eyebrows and eyelashes, which serve as a further protection to the eyes.

The principal parts of the eye are arranged in a globe-like ball called the eyeball. This eyeball is movable in the socket under control of various muscles. The eyeball is almost surrounded by a membrane which is opaque in most parts, but very transparent at the front. This transparent portion of the surrounding membrane is called the cornea, and is quite hard. This is the outside coat of the eye. The second coat of membrane consists of parts of various names and contains the iris. The third coat is the retina, which is the end of the optic nerve entering the eye full from behind and expanded into a membrane which spreads out over the second coat.

The retina or optic nerve receives optical impressions focused upon it by the crystalline lens. These impressions are carried along the optic nerve to the brain, and the brain then receives the sensation of seeing the image. The eyeball is hollow, and its three surrounding coats form what is practically the same as the interior of a camera. The crystalline lens of the eye acts the same as the lens in the camera. This crystalline lens is suspended within the eyeball right in front of the transparent opening in the front of the eyeball, and when the rays of light strike this lens it focuses them on the retina, which is the same as the film in your camera.

Why Can We Hear?

We can hear because nature has provided us with a very wonderful organ called the ear and which catches the sound waves that come through the air into the ear and make a part of the ear vibrate.

In man and mammals the ear is generally found on the outside of the body, but the principal part of the ear is located within the skull. What we call ears are only the funnel-shaped extensions on the outside of the head which are not so very important so far as hearing is concerned, because they only help the real ear to hear more easily. The outside of the ear gathers in the sound waves and, because it is much larger than the little hole which takes the sounds in to the real ear, we can detect more sounds by having this funnel-shaped arrangement on the outside.

The inside of the ear contains an eardrum or tympanum which is separated from the outside part of the ear by a membrane. Behind this eardrum is the real hearing part of the ear in a labyrinth containing the nerves of hearing.

Now, when a sound wave strikes the membrane which hangs over the opening before the eardrum, the membrane vibrates and transmits the sound wave through the eardrum into the inner ear which contains the ends of the nerves by which we hear. These nerves, on receiving the sensation, transmit it to the brain which thus records the impression of sounds.

As we descend the scale of animal life from the mammals downward, the ear becomes a more and more simple organ. In the vertebrates which are not mammals, there is no external ear at all, and we find great simplifications of the ear the lower down in the scale we go.

What Is a Totem Pole For?

Before people had individual names, the savage people who lived in clans or tribes referred to themselves in the name of some natural object, usually an animal which they assumed as the name or emblem of the clan or tribe. These names never applied to one individual more than another, but only to the clan or tribe, so that everyone in a tribe which had taken the “wolf” for its emblem was known as “Wolf.” Later on they began to distinguish individuals by giving them additional names characteristic of the individual,

such as “Lonely Wolf,” “Growling Wolf,” or other names. The name of this animal was then the emblem of one tribe. They, therefore, placed this emblem upon their bodies, their clothes, utensils, etc. Through this, these emblems also became at times idols of worship and so they erected poles upon which their emblems were engraved. The word totem is a North American Indian word meaning “family token.” The tribes called themselves after animals from which they believed themselves descended.

Where Does a Flower Get Its Perfume?

The perfume or smell of the flower comes from within the plant itself. The perfume arises from an oil which the plant makes, and just as there are many kinds of flowers, so almost every flower has a different smell. Of course, flowers belonging to the same family or species are likely to develop different smells. The oils produced are what are known as the volatile oils, which means “flying oils,” because, if extracted from the flower and placed in a bottle and the cork left out, they will vanish into the air. Without this quality we could not, of course, smell them at all.

Why Do Flowers Have Perfumes?

Man uses these oils to provide himself with perfumes, but the plant or flower has another purpose than this. The perfume is not made for man’s use, but for the use of the plant itself. In the plant and flower world the smell of the plant which is in the flower is a part of the scheme whereby plants reproduce themselves.

Every plant in order to reproduce itself must produce a seed. The flowers are in most cases the advance agent of the coming seed. Each flower produces within itself a little powder called the pollen, but as plants are like people--also male and female--they are dependent upon each other for the production of a perfect seed. Some of the pollen from the male plant must be mixed with the pollen of the female plant before a perfect seed results.

How Do Flowers Produce Seeds?

Naturally, the nearest male plant to a female plant may be quite some distance off. How, then, is the pollen from the male plant to mix with the pollen of the female plant? In some cases it is the wind which blows the pollen powder from one to the other, and this thus leaves the development of a perfect seed from a perfect flower open to chance. In the case of perfumed flowers, however, which are mostly low-growing plants, the wind cannot be depended upon. So nature gives to such plants the power to make the perfumed oil and the busy bee does the rest. The perfume being a flying oil rises up into the air and attracts the bee. He is gathering honey and visits in turn all the flowers to which he is attracted. He lights on a male flower and gathers in his honey, and incidentally acquires on his legs, without intending to do so, some of the pollen of the male flower. Then he flies about to the next flower, and to others, and sooner or later he will come across a female flower of the same kind as that from which he secured the pollen on his legs. When he thus enters the female flower, the pollen on his legs mixes with the pollen of the same kind of the female flower, and quite unintentionally the bee helps thus to make the perfect seed. It is not a part of a bee’s business to do this carrying. It only happens that he does this in connection with his regular business of gathering honey. It is a wonderful thing which may be noted here that the pollen from a male of any flower will not mix with the pollen of the female of any other kind of flower, but that the same kinds only have attractions for each other. Flowers are given these attractive perfumes in order that they may attract the bees and other insects in this way. The plants or flowers which grow closest to the ground have generally the strongest and most far-reaching smells. This is so that they will not be overlooked.

Why Are Leaves Not All the Same Shape?

Leaves are of different shapes because they belong to different families of plants or trees. They are a good deal like people in this respect. Hardly two people in the world look exactly alike, but there is a distinct family resemblance in members of the same family. It is difficult to say just what happens inside the tree to determine the shape of the leaf and that causes them to possess different shapes from others. The shape of the leaf is a mark of identification of the family to which the tree or plant belongs, just as you can tell from a dog’s ears and from other characteristics what his breeding has been. In the case of plants and trees however it is quite probable that the shape and texture of the leaves has been developed as the result of the conditions under which the plant grows. A plant or tree throws off oxygen and takes in carbonic acid gas through the surface of the leaves. To thrive and be healthy it must secure just the proper amount of this food and as the quantity of food taken in depends upon the amount of surface exposed through the leaves, each particular tree or plant has developed in its own direction in this respect until this feature of their structures

has been adjusted properly to their needs. It is a good deal like the radiation of heat in your home.

Why Are Some Radiators Longer Than Others?

When the plumber gets ready to put in the radiators in the home he figures the cubic measurements of the room and then puts in a radiator, the outside surface of whose pipes, is in the right proportion to throw off sufficient heat to fill the room or heat all the air in the room. It requires a certain number of square inches of radiator surface to heat each cubic foot of air space and a good plumber can figure this to a nicety. If he puts in a radiator however that has not sufficient number of square inches on the outside of the pipes, the room will not be heated properly. In the same way, the trees, require that their leaves have a certain amount of square inches of surface space in proportion to the size of the tree, to enable them to do what is required of them and this is arranged by nature so that the trees grow naturally, and no doubt the shape of the leaves has something to do with this.

What Makes Roses Red?

All roses are not red. Some are white and others pink or of still another color. The color of the rose, and in fact the color of all flowers is due to the way they absorb and reflect the sunlight. In the case of the red rose, the something in the plant that determines the color, absorbs all the other colors in the sunlight and reflects the pure red rays and that makes the color of the red rose. You cannot see the color of any flower when it is perfectly dark. That is because they have no color of their own, but only the colors which they reflect when in the sunlight or some other light. The question of colors is more fully explained in another part of the book.

Why Do Plants and Trees Grow Up Instead of Down?

As a matter of fact plants and trees do grow downward as well as up. There is a part of each called the root whose business it is to grow down and take certain things necessary to the life of the tree out of the ground. But the part we see above the ground and which is the part we generally think of only when we think of plants or trees.

The tree or plant, in order to grow properly, and eventually produce flowers and perfect seeds, must have sunshine and carbonic acid gas, and it is the business of the leaves and other parts above the ground to get these out of the air for the good of the plant or tree. So they start to grow toward the sun. It is easy to prove how a plant will turn toward the light. Take notice of the plants in the flower pots at home. Set one of them on the window sill inside the window where the sun can shine on it and notice how quickly the leaves and branches will be bent over against the window pane. Turn it completely around then so that the plant leans away from the sunlight and watch it for a day or two. Before long you will find that it has not only straightened itself completely out but started to lean toward the window glass again so as to get as near the sun as possible. Most plants, if kept where the sunlight cannot touch them, will die. The sunlight is a necessary part of their lives.

What Becomes of the Plants and Flowers in Winter?

A great many, in fact the large percentage of plants, live only during one season. This kind of plant actually dies completely after, in the natural course of growth and flowering, it has produced its seed which is the method by which such plants are reproduced. Other plants only appear to die in the winter. Parts of them, such as the leaves and flowers actually die, but the roots and stalks of such plants do not die in winter. The part that represents the life in them goes to sleep and lies dormant until the light and warmth of summer bring forth the leaves and flowers again.

The flowers, however, always die and the same flowers never appear again but others just like them appear in their places.

Even in hot countries where there is no winter, the plants must go through a period of rest or sleep, although this change is not so marked in plants which grow in these hot countries.

How Can Some Plants Climb a Smooth Wall?

To get at the answer to this question, we should pick out one kind of plant like the creeping ivy vine. If we examine same as it climbs a brick wall, we find that it sends out little shoots which attach themselves around the little rough places in the bricks of the wall which, if examined under a microscope are quite large apparently--at least they are large enough for the tiny creepers of the ivy to hold on to. Of course, if there were only one little “shoot” to reach out and take hold of the rough spots in the wall, the vine

could not cling to the wall, but the vine puts out a great many of these shoots--which it would perhaps be best to call "clingers" and as each helps a little to hold on, the great number all holding on together enable a quite heavy vine to hang on to an apparently smooth wall.

Some vines have actually the ability to send out little suckers which are made on the same principle as the boys' sucker (a circular piece of leather with string attached to the middle with which a boy can pick up stones) and such plants can cling to and climb up an almost perfectly smooth wall.

What Are the Thorns on Roses and Other Plants Good For?

The thorns of roses and other plants which have thorns originally grew for the purpose of enabling the plants to fasten themselves on to other things thus helping them to climb. Many plants with thorns are permitted to grow now in places where they can use their thorns for climbing but many others with thorns are cut down by the gardener to make the plants shapely and to make them produce more flowers and less branches, but they keep on growing their thorns just the same.

Do Plants Breathe?

Yes, indeed, plants do breathe. To breathe is just as important to the life of a plant as it is to a boy or girl. Plants do not have lungs like boys and girls and grown up people, but they find it necessary to breathe. You know, of course, that fishes breathe, but they haven't any lungs either, even though they belong to the animal kingdom. Fishes do not, however, breathe the air in the same form as we do because they must use the air which they find in the water. That is why we say fishes drown when on the land. They cannot breathe air in the form in which we are able to use it any more than people can breathe the air in the water.

Breathing, however, is necessary to all living things and the gas which we take in when breathing is oxygen. There is oxygen in the water as well as in the air. Things which live in the air take their oxygen out of the air and things which live in the water get their oxygen out of the water. For this purpose it is necessary for plants and animals that live under the water to have a breathing apparatus especially adapted for getting oxygen out of the water.

What Happens When Breathing Occurs?

The act of breathing consists really of two actions. Taking something into the body and expelling something. Every living thing inhales and expels in breathing. We take in oxygen and expel it again but when it comes out it has added something to it and the combination or result is carbonic acid gas--so we take in oxygen and expel carbonic acid gas.

How Do Plants Breathe?

The lungs of a plant, or what the plant breathes with corresponding to our lungs, are located in the leaves of the plant. Under a magnifying glass we can see the lungs of the leaf quite clearly. In addition to this we know that plants breathe, because if we put them in a vacuum where there is no air they die very quickly. The plant needs air or it will suffocate just as any animal will suffocate under similar conditions. Plants, however, do not make use of the oxygen as they find it in the air. They live on the carbon which they find in the air mixed with oxygen. What happens then is this. The plants take in through their lungs in the leaves carbonic acid gas from which they take the carbon and use it as food, and throw off the oxygen which they cannot use. Human beings and other animals take the oxygen into their lungs and use it and expel carbonic acid gas. The result is that each kind of life is dependent upon the other. If it were not for the plant life, men and other animals would find it difficult perhaps to find sufficient oxygen in the air to keep them alive, and if it were not for the carbonic acid gas which the animals throw off, plants and other vegetable life would have great difficulty in finding sufficient carbonic acid gas to go around.

Why Do Plants Need Sunlight?

Most plants, if placed where no light from the sun can reach them, will die very quickly. To prove that a plant needs the sunlight we have only to place it in a dark corner of the cellar and notice how soon it dies. In fact if it were not for sunlight there would be no life on earth at all. The plant or tree drinks in sunlight through the surface of the leaves. In fact the ability to take in sunlight constitutes the real life of the tree or plant. Leaves grow thin and flat in order that as much surface as possible may be exposed to the sunlight.

If a leaf were curled up like a hoop only a part of the outside surface would be exposed to the sunlight and the amount of life that a leaf could supply to the rest of the tree would be much less. The leaf is so constructed that when the sunlight strikes down upon its green surface, it changes the carbonic acid gas which it drinks in, into its elements, i.e., it takes out the carbon which goes into the body of the plant and combining with other food and water supplied by the roots causes the plant or tree to grow and then returns the oxygen part of the carbonic acid gas to the air.

Why Does Milk Turn Sour?

The milk turns sour because a little microbe, known as the milk microbe gets into it, and being very fond of the sugar which is in the milk, turns this sugar into an acid.

If we could keep milk entirely away from the air after the cow is milked, it would not turn sour, but as soon as it is exposed to the air these microbes which are constantly in the air, drop into the milk. They are alive, although invisible to the naked eye. If when they drop into the milk it is warm enough for them to get in their work so to speak, they fall upon the sugar in the milk and turn it into the acid. Their attempt to sour the milk can be overcome by keeping the milk at a low temperature in the refrigerator, but as soon as the milk is taken out of the refrigerator and left out long enough to become warm, the microbe begins to work and the milk cannot be made sweet again. If the milk is boiled as soon or shortly after the cow is milked, the sugar in the milk is changed in such a way that the microbe cannot feed upon it.

[Illustration: A PERSIAN RUG WEAVER AT WORK.[3]]

[3] Pictures and descriptions by courtesy of Hartford Carpet Co.

The Story in a Rug

What Are Carpets and Rugs Made Of?

The choicest wool of the world is used in the manufacture of carpet. In order to give satisfactory service carpet must be made of wool that is of a tough quality and has a long fiber. Such wool is not produced in America, and the markets of the distant lands that supply it are practically exhausted to supply the American manufacturers. Most of the wool used comes from Northern Russia, Siberia and China. It is shipped in bales. When it arrives at the mill there is much to be done before the wool is ready for any process of manufacturing.

How Long Have People Used Carpets?

The art of weaving stands foremost among the ancient industries. It came into being in the sunrise lands of the East where color has endless charm and variety and where figure is made to serve the purpose of fact and fancy. The art of weaving rugs is older than Egyptian civilization. Stone carvings made when Egypt was yet unborn were reproduced in rugs.

At what period the loom was first used is impossible to tell. An ancient Jewish legend claims that Naamah, daughter of Tubal-Cain, was the inventor of the process of weaving threads into cloth. There are other indications that the ancient Hebrews were the first weavers. Mythology also tells of beautiful maidens weaving exquisite patterns for the gods. Most of us are familiar with the story of Jason who set sail on the Argo in search of the Golden Fleece, arrived at the kingdom of Aeetes, won the hand of Medea, the daughter of Aeetes, who eloped with him after he had secured the coveted fleece.

The first hands busy at the weaving craft undoubtedly were those of women. Chaldean gossip, repeated in history relates that Sardanphulees, an ancient Greek king, was often seen in woman's garb carding purple wool from which his wives wrought rugs for floor coverings for the palace. Homer shows Helen of Troy setting the tale of her people's war in the woof of her web, and also tells with Virgil of rugs that were laid under the thrones of kings or upon chariot horses. Ancient Hindu hymns show that these people made their textile fabrics studies of great beauty. The woman in the Proverbs of Solomon says: "I have woven my bed with cords; I have covered it with painted tapestry from Egypt." One learns from the writings of Pliny of the large money value of rugs in ancient times. He wrote at length of a vast rug displayed at a banquet of Ptolemy Philadelphius, the value of which was placed at a fabulous sum.

A later writer tells of the love of Cleopatra for rich rugs and tapestries that were woven in her palace or in the countries to the East. On the occasions of her meeting with Cæsar and Antony, the Egyptian queen enveloped herself in a superb rug which she had

woven especially for the purpose of showing her renowned beauty to the best advantage. Akhar, emperor of Hindostan, spread a knowledge of the art of weaving throughout India.

The earlier phases of the art of weaving may be traced through the land of the Pharaohs to Northern Africa, Southwestern Asia, and finally into the dawn of the Aryan civilization. The loom has not been materially changed, and it may be seen to-day as it was in the time when the priests of Heliopolis decorated the shrines of their gods with magnificent carpets and when Delilah wove the hair of Samson with her web and fastened it with a wooden pin. The ancient weavers attained high artistic standards in their fabrics. Pliny tells of Babylonian couch covers that had all the beauty of paintings and sold for great fortunes to the ancient Asiatic kings.

In all ages fine rugs have been used for religious purposes. Early writings describe the use of rugs on the holy cars of pilgrimage to Mecca, at the tomb of the prophet at Medinah and throughout the mosques of the Orient. The abbot Egelric gave to the church at Croyland, before the year 892, two large rugs to be laid before the high altar on great festivals. At later periods rugs were used for similar purposes in the cathedrals of Southern Europe.

The Oriental people ever have been devoted to symbols and naturally wove them into their fabrics. Their textiles were made to reproduce mythological stories in which the fauna and flora of a country figured prominently. There was the symbolism of form, color and animal life, of trees and flowers, of faith, and earthly and heavenly existence. The symbols were made to illustrate the conflict between light and darkness, the evolution of life, the decay of death and the immortality that awaits the blessed in paradise.

What Do the Designs in Rugs Mean?

Since many of the figures of ancient rug-weaving are retained in modern rug designs, the following list of meanings of ancient Oriental symbols used in rug-weaving may be interesting as a key to the stories that are said to appear in many rugs of Oriental design:

Asp--intelligence Bat--duration Bee--immortality Beetle--earthly life Blossom--life Boat--serene spirit Butterfly--soil Crescent--celestial virgin Crocodile--deity Dove--love Eagle--creation Egg--life Feather--truth Goose--child Lizard--wisdom Palm tree--immortality Sail of vessel--breath Wheel--deity Lion--power Ass--humility Butterfly--beneficence of summer Jug--knowledge Ox--patience Hawk--power Lotus--the sun Pine-cone--fire Zigzag--water Leopard--fame Sword--force Serpent--desire Bird--spirit Owl--wisdom Pig--kindness

Such are the traditions that the makers of modern rugs must live up to. The art of the centuries has been revealed in the rugs of many nations, and the rug-maker of to-day must uphold the standards of an art that undoubtedly takes rank with the great arts. Where a valuable painting goes into the home of one millionaire, thousands of rugs made from an original design of unquestioned art and beauty go into homes the country over to give warmth, comfort and beauty, delighting housewives and imparting a sense of coziness and elegance.

According to students of the art of weaving, the perfection of this art was attained about the sixteenth century, after many centuries of slow growth. Since then weaving as an art has been broadened and given a wider scope by means of processes invented for a cheaper production of rugs in all the beauty of their original designs. But there also has developed a modern school of rug and carpet designing that in itself represents no mean standard of art. Many of the less expensive grades of American rugs and carpets, for example, are of designs created by artists of this modern school of weaving designs whose work is of a high degree of artistic excellence.

[Illustration: HOW OUR GRANDMOTHERS MADE RAG CARPETS

MAKING THE OLD RAG CARPET.]

A quarter of a century ago many homes had rugs woven by the housewives with their spinning-wheels, or no floor coverings, except crude cloths made of rags. These homes, of course, were those of families in moderate circumstances, which to-day can have their attractive and comfort-giving rugs of the less expensive grades of tapestry carpet, Axminster or of the various other grades of carpet manufactured at a range of prices within the financial reach of people of modest means.

It is only a step from the ancient weaving of rugs, with all the color, glamor and romance that attached to rug-weaving in the ancient days, to the manufacture of rugs in America to-day. There is no romance attached to the making of rugs and carpets in America, except the romance of industrial achievement; but the American rug-maker is as careful of the quality and beauty of his product as was the ancient weaver, and the best standards of ancient weaving have been realized in the manufacture of rugs and carpets in

America to-day.

Why Did the Ancients Make Rugs?

It is only a rug, several yards of woven threads, a design that few can understand--a simple thing, to be sure; yet what a lot of history and memories and traditions it carries! Merely a strip of carpet, with strange figures, beautiful though meaningless, a product of modern invention like many another, some may think. But the story of a rug may go back through many centuries to ancient times of opulent splendor, when wars were waged and kingdoms created and shattered for the beauty of a woman; when gorgeous palaces were raised and great spectacles of art were shown to inspire the world for thousands of years.

Only a rug, but a relic of a rich and glowing past! For in those distant days of war and pageantry, an era more classic than our own, history and romance were woven into the rug. The patterns and designs told great stories of wars and loves that swept nations away and created great new empires and related vivid accounts of intrigue and tragedy that determined history and inspired the immortal works of poets and dramatists. The rug in the ancient times was also used for religious symbolism, and sacred doctrines were inscribed in the woven figures.

Of all the arts none has been as close to the lives and history of the peoples of the earth as the art of weaving. Songs and stories of these peoples and their national achievements have been immortalized through their woven fabrics. Generations have learned of the great deeds of their forefathers through the historical accounts woven into rugs. And in the days of the early Greeks, Hebrews and Egyptians and on through the succeeding centuries until the middle ages the rug was used as a symbolical part of state, religious and romantic ceremonies.

What Makes Some Rugs so Valuable?

The reason many rugs are valued at so high a price in money is largely due to the skill of the artist or designer, just as a painting becomes valuable because the artist who painted it has succeeded in producing a remarkable result. The question of rarity also enters largely into the value of rugs. The great artist weavers of the past who worked for love of their art rather than for the money they might secure by disposing of their masterpieces, are dead, and they have had no successors. Then, also, the rug becomes valuable by reason of the amount of time and labor put into it. Many valuable rugs take years to produce, because the artist must do all his work by hand practically and tie his different colored yarns together just so, or the pattern will not come right. These knots may occur every inch or sometimes even less than an inch, and there will be thousands of hand knots in one rug.

[Illustration: MAKING TURKISH RUGS.]

[Illustration: THE OLDER THEY ARE THE MORE HIGHLY PRIZED

The above is a typical Chinese rug, containing symbolical emblems.

This is an antique and is of a class that sells sometimes as high as $5,000, its rarity of design, beauty in colors, and scarcity enhances its value.]

[Illustration: This is an American machine-made interpretation of a Chinese rug. The ground is a rich gold coloring, the figures being in ecru, dark blue, terra cotta and light blue. It is a beautiful rug, and one of the finest examples of loom-tufted goods ever produced.]

[Illustration: WHERE THE BEST PERSIAN RUGS ARE MADE

This antique Persian was made in the district of Kurdistan, in Western Persia. The general effect is handsome, although the design is crude. The ground is of a deep rich red, and top colors of dark blue and ecru.

The most valuable Persian rugs come from Kurdistan, Khurasan, Peraghan and Karman. The most highly prized come from Kurdistan. The pattern does not show a uniform ground of flowers or other objects, but looks more like a field of wild flowers in the spring, which is very appropriate as a design for anything that is to be walked upon. It is astonishing what wonderful artistic ability is displayed by some of the members of these wild nomadic Persian people. The carpets and rugs are woven on a simple frame on which the warp is stretched. The woof, or cross threads, consist of short threads woven into the warp with the fingers and without the use of a shuttle. Then a sort of comb is pressed against the loose row of cross threads to tighten it. The weaver sits with the back of the rug towards him, so that he depends entirely on his memory to produce a perfect pattern.]

[Illustration: This rug is an American copy of a typical Kurdistan. It is marvellous how well the effect in colors and design are reproduced in this domestic rug.]

[Illustration: HOW WE IMITATE POPULAR DESIGNS BY MACHINERY

This Tabriz reproduction has all the characteristics of the genuine rug in both design and color. The ground is of a soft rose with figures olives, ivory and deep blue.]

[Illustration: This is a copy of an old piece of a rug in the Kensington Museum, London, which is 500 to 600 years old. The design is very interesting on account of the symbolical figures which cover the ground.]

[Illustration: WOOL-PICKING MACHINE.]

The Making of Carpets

How Are Modern Rugs and Carpets Made?

The best way to learn of this is for us to take a brief visit to one of the largest carpet factories, where we will assume we have already arrived.

There is a sharp whistle, then an outlet of steam, the clang of a bell and a locomotive rolls around the curve of the spur-track into the factory yard. Attached to it are several freight cars that only the day before received their cargoes at the New York docks fresh from steamships coming from foreign lands. Inside the yard, the engine comes to a stop alongside a warehouse. Sturdy men unlock the doors of the cars and begin pulling out bales of the imported wool.

This is the first step in the evolution of a rug. Between the arrival of the rough wool at the warehouse and the placing in the stock room of the finished rug, splendidly woven after an artistic design shown in attractive colors, many interesting processes are followed. It is sufficient to state that few people looking at rugs of the Saxony, or Axminster or Tapestry type realize the high degree of mechanical science and artistic perception that have been brought to bear in the manufacture of these rugs.

After the arrival of the wool there are many steps to be taken until the skeins of yarn receive their coloring treatment in the dye-house and, at the bidding of the great machine, assemble themselves in the beautiful designs that the artists have created. Though there are many details of work in the development of a rug, they have been so well mastered that the employes in charge of every stage of the rug's evolution give to their work a nicety of attention in little time that careful training and scientific understanding alone can supply.

The travel-stained covers of the bales are removed. The heavy bulk is broken and the tightly-compressed bales loosened. Then the wool is fed into the washing-machine, and after that goes into the picking-machine. The process of cleansing the wool is an elaborate one, for it is so full of dirt and grease that several waters and several operations are necessary to its final appearance in a white and fleecy condition. After the last washing the wool is lifted to a drying-room, where the heat from steam-coils is forced through it by means of blowers.

The wool now passes to the sorting-room, where the blends are carefully made before it goes to the machine which tears the wool fibers apart, and gets them in shape for the carding and combing processes. Next the wool is blown into a spinning mill. The wool is now ready to be converted into yarn. It passes through a picking-machine, which blends the different grades of the raw material, selecting the strands as to fiber and color. Then it is refined and purified.

[Illustration: CARDING MACHINE]

Through tubes the wool is forced to the carding-room by means of air pressure. In passing through the cards it is carefully weighed to secure evenness in the yarn. Leaving the carding machine, the wool is taken to the floor above, where the big spools of yarn reach the combing machine for the next process. This machine separates the long from the short fibers. The strands of wool are still thick and must go through another process before they are ready to be made into yarn. They are finally united and given sufficient strength to stand the weaving process. As the visitor sees the strands of yarn first appear on the machine they resemble rolls of smoke.

[Illustration: DYEING THE YARN]

~HOW THE YARN FOR CARPETS IS DYED~

The yarn next appears on rows of spindles in the mule-room, six hundred feet long, where the yarn is twisted and brought to its final stage. The yarn now is ready for the dye-house. Here the atmosphere is very dense. Clouds of steam rise from the many vats of boiling dyes. The yarn receives the coloring for which it is intended, or is bleached in an adjoining department, and then is transferred on poles to the drying-room, after passing through a steaming process which sets the color. Next it passes on an electric conveyor to the weave-shop.

Considerable skill is required in the weaving process. The assembling of the yarns and matching of colors require expert attention. The skeins of yarn are wound on spools, which are put in sets back of the looms, each color or set representing one "frame" of color in the rug. By the famous Jacquard motion of cards each color wanted in the surface of the rug is pulled up in its proper place, the other frame color laying in the back of the rug. The mechanical process is a remarkable sight. As the pattern forms itself from the mechanical devices, the onlooker is struck with the wonder of it.

[Illustration: HOW A CARPET IS WOVEN BY MACHINERY

WEAVING A RUG BY MACHINERY]

[Illustration: 10,000,000 YARDS OF CARPET PER YEAR FROM ONE FACTORY

This picture shows the plant of one of the largest carpet factories in the United States at Thompsonville, Conn. From the looms of these mills are annually produced ten-million yards of the twenty-five different grades of carpet manufactured by this concern.

Imagine a strip of carpet across the United States at its widest part, the Forty-second latitude--a strip of "Hartford Saxony", say, stretching from the Atlantic seaboard to the Pacific coast; and then another carpet strip the length of the United States, where this country is the longest--i. e., from the Northern boundary of the state of Minnesota to the Southern boundary of the state of Texas; then imagine one more strip stretching from Chicago to New Orleans, and finally a connection between the two latter strips at about the vicinity of St. Louis.

With a mental picture of this vast country thus stripped with carpet, you wonder if there is that much carpet in the world. It seems incredible that this great sweep of land could be measured with carpet--and yet enough material comes every year from the looms of one carpet factory alone in this country to strip the United States East and West, and North and South as indicated above.]

The weave is now completed; the rug comes out. But it is rough and has to be finished. It is passed through a machine that removes the roughness of the face as a lawn-mower cuts away the top-grass. The ends are finished, and the carpet is complete.

~SOME DESIGNS STAMPED ON YARN BEFORE WEAVING~

The pattern of tapestry carpet is obtained by printing the colors to appear in the design on the yarn which forms the face before the weaving is started, by means of large drums. After all rugs leave the weave-shop a force of skilled women examine them carefully to make sure that there are no defects. Every yard of the annual output of carpet and rugs is inspected five times before it leaves the factory.

[Illustration: EXAMINING AND REPAIRING]

[Illustration: PACKING FOR SHIPMENT]

Why Do I Yawn?

When you yawn, you do so because you have not been breathing quite properly and for some reason or other your blood supply has not been getting sufficient oxygen through the air which has been taken into your lungs. Nature's way, in this instance, is to call for a big intake of air all at one time, and since it is important at such times that a large quantity of air should be supplied to the lungs at once, nature has so arranged matters that certain muscles shall cause you to open your mouth wide and take in as much air as you can at one time, and also has arranged so that it is almost impossible to keep from yawning when the demand for it is once made. The yawn is controlled by a part of our nerve structure which looks after the breathing apparatus.

The satisfaction we feel after a wholesome yawn is due to the fact that having replied to nature's demand that we bring in more air, our blood secures the oxygen which it needs and we feel the effect of better blood in our arteries at once.

A peculiar thing about the process of yawning is that one person in a room yawning will quite likely set all or nearly all the others to yawning also. There seems to be no explanation of this excepting that when a number of people are in one room and one of them begins to yawn, the others do so, not because they perceive the first yawn so much as the probable fact that the air in the room has become so poor that there is not enough good air for all the people in it, breathing normally, and many of them are forced to yawn at about the same time.

Where Do Living Things Come From?

This is a big subject, but a very interesting one. To understand it fully we must begin at the very beginning of the world.

God made first of all the rocks, the mountains, the sun, the moon, the stars, the soil, and put the water in the lakes, rivers and oceans. This took a long time, but they had to be there before the living things could begin to be.

What is Inorganic Matter?

This thing we have spoken of is called inorganic matter, which means "without life," and everything in the world which has no life is called inorganic matter. These things do not die, and for that reason do not have to be replaced. The form and appearance of inorganic matter and its location is often changed by man or other causes, but even when man burns the coal which he has dug up out of the ground in the furnace, no part of it is destroyed. Some of it is turned into smoke and gas and some of it is turned into ashes, while every other particle which went to make up the coal originally is still in existence. It remains as inorganic matter in some form or other.

Where Did Life Begin on Earth?

After the inorganic things had been made and the earth was ready for life, the different kinds of living things which we find on the earth began to exist. These are called organic objects, which means objects "with life." The first living things to appear were the bushes, the grass, the garden vegetables, the flowers, trees, and all the kinds of life which we ordinarily think of as growing things.

This division of living things makes up what we call the vegetable kingdom, and in a general way of classing it is the kind of life which cannot move about from place to place and which has not a sense of feeling, or any of the other senses, seeing, hearing, tasting or smelling.

After this division of life had been established the world was ready for the other and more important form of life--the fishes, the birds, cats, dogs, horses, cows, with others that we call domestic animals, and also the lions, tigers, elephants and others which constitute the division of wild animals.

This kind of life was given some or all of the five senses, but not all classes of animal life possess all these senses. Some of the lower forms of animal life, like the oysters, clams, in the fish family, cannot see, hear, smell or taste. They can only feel; others are able to do more of these things, and many have all of the five senses.

When Did Man Begin to Live?

Man was not created until all the other living things on earth had been started, and he was given additional powers so that he might become the ruler of all the other living things, principally because he was given a brain with power to think, reason and originate.

Why Must Life Be Reproduced?

Life must be reproduced because living things die. They have power to live only for a certain length of time. The other life in the world is used to provide food for man, and if there were no way of reproducing life it would not be long before man had eaten all the vegetables and the animals too, and would himself then starve to death.

To avoid such a calamity God put into each living thing, both vegetables and animals, a power to cause other things of the same kind as itself to grow. This is called the power of reproduction. With this power each kind of living thing can bring other specimens of the same kind into the world and each kind of living thing can do this without aid from any other kind of life.

The trees, the flowers, and other kinds of vegetable life would reproduce themselves without the aid of man, as would also the fishes and other kinds of animal life. Man, however, just to have things conveniently at hand, uses his power over other life to cause his vegetables to grow near where he lives, and keep the animals which he wishes to use as food in some place where he doesn't have to hunt for them every time he wishes meat for his table. This, however, he does only with the animals which he has domesticated or tamed. When he wants meat from the animals which are still wild he must hunt for them as he used to do.

Each kind of life has the power, however, to reproduce only its own kind. If you plant a peach stone you will sooner or later have a peach tree which will bear peaches, and these peaches from the young tree will look and taste just like the peach whose pit or stone you planted. There may be other kinds of fruit trees all about, and also trees which do not bear fruit. All of the trees secure the food upon which they live and grow from the same soil. Even the grass under your peach tree eats the same things as your peach tree, but it remains always true that things in the vegetable kingdom will grow only to be like the thing from which it came.

Have Plants Fathers and Mothers?

The little trees grow up to be exactly like their fathers and mothers (for they have fathers and mothers), which is something all living things must have. These are not the same kind of fathers, or mothers either, that a boy or girl has, exactly, but they are parents just the same. So far as the trees, flowers and plants are concerned we call the parents father and mother natures, which is a term used merely to keep you from confusing vegetable life fathers and mothers with the regular kind.

In the vegetable kingdom you cannot always see these father and mother natures, which enable them to reproduce their kind of life, but everything in the vegetable and also in the animal kingdom has them.

How Do Plants Reproduce Life?

In the spring we put seeds into the ground and later on plants grow up where the seeds were planted, and later the flowers come. The seeds contain the baby plants, which come to life, and after bursting the covering of the seed, unfold and grow up into plants if placed in the ground, where they can obtain the proper amount of warmth and moisture to give them a start.

Why Do Plants Have Seeds?

To get at this subject in the best manner we must study first how plants produce seeds and what happens. The power in a plant to make another plant like it grow comes from the flower. Ordinarily we think of the flowers as beautiful to look at and delightful to smell, but the flowers do not grow for the mere purpose of being beautiful, but are for a more useful purpose--to develop a seed which, when planted, will produce another plant. The machinery for producing a perfect seed is in the flower or blossom. Every flower has a definite plan of construction. The leaves and colors vary, but the plan for a perfect flower is always there. The petals which are generally colored are called the _crown_. When you pluck off the petals you see a number of green leaves at the bottom where the petals were attached. These form what is called the _calyx_, and help to hold the petals in place. Inside the flower are little stems which grow to the petals. These are called _stamens_. Every one of these little stems is hollow, and if you split one open you will discover a _fine powder_. This powder is called _pollen_, and is the "father" nature of the plant. In the calyx, the part we had left after we plucked off the petals, is the "mother" nature of the plant. The main part of the mother nature is the stem of the flower called the _ovary_, and this is where the seeds grow. These seeds in the ovary, however, will not become perfect seeds unless some of the pollen from the "father" nature of the plant touches them and fertilizes them.

At the proper age of the flower some of this pollen powder passes into the ovary and fertilizes the seeds and makes them good seeds. This is only one kind of flower, however. In this kind the father and mother natures are in the same flower. In other kinds of plants the father and mother natures are found on different parts of the same plant.

Why Does an Ear of Corn Have Silk?

The corn plant is one of this kind. You know what it looks like--a tall plant, generally six or seven feet high. The ears of corn grow out of the side of the corn stalk. The ear is covered with husks and out of the end of the ear hangs a bunch of brown silk threads which we term corn silk. Up at the top of the plant you will see the tassel, but you may not have known that this is the flower of the corn plant. The tassel or flower in this case contains the "father nature" of the corn plant, and the ear of corn contains the "mother nature." The husks on the outside of the ear of corn protect the grains of corn on the ear inside and keep them tender. The ear of

corn is really the ovary of the corn plant, because that is where the seeds grow. You will guess, of course, that the grains of corn on the ear are but seeds of the plant. Were you to examine one of these ears of corn on the plant when it had just started to form you would find no kernels on the cob, but only little marks which indicated where the grains of corn are expected to grow, but if you want to know, then, how many grains of corn were expected to grow on the ear, you could easily tell by counting the little silk threads which you see on the cob and which stick out over the end. There will be a thread of silk for each grain of corn that is expected to grow.

Every grain of corn must receive some of the pollen powder from the tassel or father nature at the top of the corn plant or it will not develop into a nice large, juicy kernel.

How Does the Pollen Touch the Grain of Corn?

Before the kernels of corn grow the tassel is in bloom. The wind blows and shakes the pollen powder off of the tassel and the powder falls on the ends of the silk which stick out of the little ear of corn to be. Each thread of silk then carries a little of the powder down to the spot on the ear where it is attached and thus the grain of corn receives the fertilizing necessary to develop it into a ripe seed. If you leave the ear of corn alone the kernel will eventually become yellow and hard and can then be planted and will produce other corn plants. Man, however, finds the ear of corn a delightful food, if taken at a time when the seeds are fully grown but not yet ripened into perfect seeds. At this stage the grains of corn would not grow up again if planted, because they have not yet become perfect seeds.

Do Father and Mother Plants Always Live Together?

We come now to the kinds of plants on which the “father” and “mother” natures are on different plants of the same kind. At times they will grow side by side, at other times they will be in the same field, but very often they grow at quite a distance from each other. In some instances the nearest father tree will be even miles away from the mother tree of the same kind. But in any event the pollen from the father nature must reach the mother nature of the plant or tree before a perfect seed can be produced. In cases of this kind the father nature will be on one tree or plant and the ovary or mother nature on another. The wind helps out nature in some of these cases by blowing the pollen of the father plant to the ovary of the mother plant. In many other instances the bees and insects help.

Why Do Flowers Have Smells?

Where the bees do this it is because the bee has been visiting the flowers in his search for honey. They do not fly from flower to flower for the purpose of uniting the mother and father natures of plants, but they help the flowers incidentally while getting the honey for which they are searching. In gathering his honey the busy bee will go all over the father flower and get his legs all covered with pollen powder. Sooner or later he comes to a mother flower of the same kind of plant or tree from which he has father pollen on his legs, and, still bent on gathering honey, he incidentally rubs the pollen powder on to the ovary of the mother flower and the fertilization takes place. The wonderful thing about this is that the father pollen of one kind of a plant will not fertilize the mother nature of another kind of plant. To illustrate this, if a bee carrying pollen on his legs from a walnut blossom visits the mother blossom of a hickory tree the pollen of the walnut would not affect the hickory blossom, but would still have the proper effect on the first walnut mother blossom he visited.

This is how life in general is reproduced among the plants and trees. Life in the vegetable kingdom has no sense of feeling or any of the other senses, but this kind of life is still true to its own nature and is a wise thing in the plan of creation, because, since all seed will produce only plants like those from which the seed came, man can control the growth of the vegetables and fruits he needs as food. He knows when he plants corn that he will get corn in return, because perfect seed never makes a mistake. It would mix things up terribly for man if this were not so, because man might then plant one thing and find another thing growing. It would be a sad thing to plant wheat and find thistles growing.

In order that seeds may grow they must be planted under conditions that suit the kind of vegetable life in the seed. Man has to study and learn what these conditions are.

If a seed is planted too deeply the sun may not have a chance to warm the ground to that depth, and if it is planted too near the surface it may become too warm and be killed by the sun. When planted under the proper conditions the seed soon begins to grow. It grows upward toward the sun to get light and air, and it sends roots down into the ground to get food and moisture.

The life in the vegetable kingdom is soon able to take care of itself.

How Are Fishes Born?

The next step in the study of the reproduction of life brings us to the animal kingdom. The first thing we discover in this section is that in the animal kingdom father and mother natures are almost always separated. In plants and trees these parent natures are sometimes in the same flower, often separated, but on the same plant, and in other instances on different plants miles apart. What we must remember, then, is that in the case of plants it is given more or less to the chance of wind or other circumstances to bring the parent natures together.

In the animal kingdom there are a few cases where the mother and father natures are found in the same living object, as in the oyster and clam families, one of the lowest forms of animal life. These have but one of the five senses--that of feeling. This class of animals--the cold-blooded animals--includes the fishes, and in most members of this class the father and mother natures are separated and in different bodies. Step by step from now on we enter higher forms of animal life, and through each step we find a greater difference between the father and mother natures, and in the animal kingdom we speak of the father and mother natures as "_male_ and _female_." In the animal kingdom, too, what we have previously called the seed is known as the _egg_. Seeds and eggs are the same so far as their usefulness is concerned, but we say eggs in the animal kingdom to distinguish from seeds in the vegetable kingdom.

Fish have eggs, then, and it is from the eggs that little fish are born into the world and grow to be of eatable size. You recognize the eggs of the fish in the "roe," which is eaten as food. Not all fish eggs are used as food, however.

In the fish world the eggs are developed in the body of the female fish. Each little round speck in a "shad roe" is one egg, and there are many thousands in a single "roe." Each egg will produce a little fish, under favorable conditions. These eggs develop in the body of the female fish in winter. In the spring, which is the time in which most living things are born, and, therefore, the time for hatching out fish eggs, all of the fish swim from the deep water where they live in winter to the places where the water is shallow and warm, and in these shallow waters the female fish expels the eggs from her body where the sun can get at them and hatch them by warming them. After the female fish has thus laid the eggs, the male fish swims over the eggs as they lay in the water, and expels from his body over them a fluid which is white in appearance and which fertilizes the fish eggs. If any of this fluid fails to reach some of the eggs it is not possible for the sun to bring them to life.

When the eggs are laid and fertilized the mother and father fishes swim away and they never see their children or recognize them as such, even if they meet them later in life. The parent fish do not act like other fathers and mothers, and they do not need to, because as soon as a baby fish is born he is able to find his own food and needs no help from father or mother to teach him how to find it or enable him to grow into a real fish.

Of course, many of the tiny fish are eaten by other fish and not all the eggs which the mother fishes lay hatch into live fish, because, if they did, the waters would be so crowded with fish that there would not be any room for the water. A single female fish will lay millions of eggs in a year, and if each egg developed into a fish there would be far too many.

This order of animals, which includes turtles, frogs, etc., is the cold-blooded class of animal life. They have only part of the five senses. They all can feel and some of the fishes can see and hear, but a great many of them, particularly those kinds which live on the bottom of the ocean, cannot either see or hear, and some members of the fish family cannot even swim.

The thing to remember about fishes in connection with the reproduction of life is that the mother fish must select a place which is favorable to deposit the eggs, but after that her responsibility ceases. The father merely fertilizes the eggs, and then his responsibility ceases. The little fish look out for themselves as soon as they are born and never know what it is to have a father or mother to look after them.

When we study the next higher form of animal life we find that the young ones have to be looked after, and that this becomes more necessary as we ascend the scale of animal life until we reach man, the most intelligent of all animals and yet the most helpless of all at birth.

How Birds Are Taught to Fly.

The next step brings us to the birds. Before they can look after themselves the little birds must learn how to search for food and the kinds of food good for them. They have to learn the habits of their kind of life. The higher you go in the study of animal life the greater seem to be the dangers which surround the young animals and the longer it takes to teach them how to look after themselves and what to do for themselves.

The bird family includes not only the robins, larks, sparrows and pigeons, but also the ducks, geese, and chickens, etc. We are all more or less familiar with birds' eggs, and if not we know what a hen's egg looks like. The eggs of the bird family are laid in nests, which is the first sign of home building in the animal kingdom.

The birds are the first of the large class of warm-blooded animals. The egg here represents again the reproductive power. The eggs, too, form in the body of the female bird, but are laid in a nest which the parent birds build together. Now this is the first step away from the fish family. The fish looks for a suitable place to lay the eggs and then goes off and leaves them. The birds, however, have to make a nest in which to deposit the eggs. The fish, as you remember, depended upon the warm sun shining on the shallow water to hatch out the eggs, thus depending on an outside force to supply the necessary warmth. In the bird family the mother bird must cover the eggs with her own body and keep them warm until they hatch out. Then, too, the father and mother birds feed the young until they are strong enough to fly and find food for themselves, and so the mother and father birds look after their babies until they are old enough to look after themselves. When this time arrives the old birds cease to bother about the young ones altogether. The fishes never act like parents after the baby fishes are born, because the little fish are able to look after themselves right away. The parent birds are a good deal like fathers and mothers for a time, but only so long as it takes them to teach their little bird children to look out for themselves. Then they forget the children completely.

It requires but a few days and no parental care to hatch out a family of baby fishes and no attention at all after birth. It requires several weeks and much patience for the parent birds to hatch out their eggs, and it involves care and attention for several weeks to teach baby birds to take care of themselves.

This being a father or mother in the animal kingdom becomes a greater responsibility in every step as we get closer to man, and when we reach man we find him to be the most helpless offspring of all at birth, and that it takes more time, care and attention to bring up a human child to maturity than any other animal.

What Makes the Hollow Place at One End of a Boiled Egg?

This hollow place on the end of the boiled egg (sometimes it shows on the side) is the air which is put inside of the egg when it is formed so that the little chicken will have air to breathe from the time it comes to life within the egg until it becomes strong enough to break the shell and go out into the world. There is also food in the egg for him. When you boil the egg this pocket of air within the shell, which would have been used up by the chick if the egg had been set to hatch instead of being cooked for breakfast, begins to fight for its space and pushes the boiling egg back and forms the hollow place.

The purpose of the air in the egg is a good thing to remember when we come to study the higher forms of animal life from the standpoint of how they reproduce themselves.

The mammals are the next higher form of animals. The babies of this class of animals must be fed for several weeks or months before they are ready to come into the world.

A little chicken is ready to come out of the egg almost as soon as it comes to life, and, therefore, needs only a little air and food before it is strong enough to peck its way out, but the babies of mammals begin to live months before they are ready to come into the world, and they need a great deal of air and food during this time. This class includes the dogs, horses, cows, cats and all other animals in the Zoo and in the woods. The name mammals means the same as "mamma," and indicates an animal which must be fed from the body of a female mammal even after it is born.

In this class the eggs are retained within the body of the female animal instead of being laid in a nest or some other place, as in animals of lower classes, after being fertilized by the male animal, so that the baby animal may secure its food and air from within the mother's body after the life within the egg is begun.

The mother's body supplies the necessary warmth to develop the life of the little animal in the egg, just as the birds supplied this with their bodies. In the bird class it only takes a few hours to give the little bird sufficient strength to peek his way out, but in the mammal class it is a long time before the baby animal is strong enough to come out into the world, and even after it is born the

babies of mammals require a great deal of care and attention before they are able to look out for themselves. During this period the animal secures all of its food from the breast of the mother animal.

Another reason why the eggs of mammals are retained within the bodies of the females is the need for protecting the young animals from enemies. In the animal kingdom each kind of animal preys upon another kind. They attack and devour each other and are constantly in danger. If, then, mammals laid eggs in nests and sat upon them to hatch them out, the mother animals sitting on the nests would be continually in danger of attack from their enemies. They would either have to flee and subject the nest and its contents to the danger of destruction or else stay and fight, and perhaps be destroyed. But by carrying her egg within her body the mother mammal is able to move about from place to place and protect her baby.

Is Man an Animal?

Men, women and children belong to the "mammal" class of animals. The offspring of the human family is the most helpless of all animals at birth. The young of most kinds of mammals can stand on their legs shortly after being born, but the human baby requires months before it can stand up. A baby horse can also walk within a few hours, but human children do not begin to walk until they are more than a year old.

Why Cannot Babies Walk as Soon as Born?

The human baby has a great many more things to learn than a horse baby before it is safe for him to go about alone. It takes time for the brain to develop, and if a baby could walk before the brain had even partially developed it would only get into trouble.

This, then, is what we have learned about the reproduction of life and the reasons for its being different in different classes of life. First, we had the division of organic life into the vegetable and animal kingdoms. Life in the vegetable kingdom has none of the five senses, for plants cannot see, hear, feel, smell or taste. They cannot move from place to place, but remain where they grow until destroyed or removed. On the other hand, all animal life has at least one of the five senses--feeling. The oysters and clams belong to this class. Starting with this level of life in the animal kingdom we find that as we go on up through the different classes we find each class able to do things which make it superior to the class below it, until we reach the human mammal, who can do most of all. And, further, that since each class as we go up in the scale of life has greater ability to do things than the class beneath it, so in each case the task of the parents in preparing their offspring for their kind of life becomes greater, and the period during which the offspring is learning becomes longer and longer until we reach the human family, in which we find that parents have the greatest responsibility, and the children are the most helpless of all animals, but that in the final result man has a right, on account of his superior qualities, to be the ruler of the other creatures of the world.

What Are Ball Bearings?

Some years ago a gentleman in trying to find some way to reduce the friction, which is constantly developed to a certain extent, even when the axle is oiled, discovered that if between the axle and the inside of the hub a circle of steel balls were arranged, so that the hub of the wheel did not touch the axle at all, but rested on the little balls which in their turn touched the axle, that a great deal of the friction was eliminated. This proved to be a wonderful invention, and when this combination is arranged and oiled, there is hardly any friction.

Why a Gasoline Engine Goes

[Illustration: FIG. 1.]

As you know, gasoline is a very inflammable fluid, and will explode if placed too close to fire.

This explosive quality is the basic principle of the gasoline engine. By admitting a small quantity of gasoline vapor into an enclosed cylinder, and exploding it by means of an electric spark, repeating this operation continuously, the engine is given a regular rotary motion.

Look at Fig. 1. Starting from the gasoline tank, the fluid is fed into the 'carburetor', which is a sort of atomizer. Here the gasoline is mixed with air, and broken up into a very fine spray, in which condition it will explode readily.

The engine will not start of itself. Its fly-wheel must first be turned by hand, or by some other outside force, until the first explosion takes place. After this its action is automatic.

As shown in Fig. 1, the fly-wheel is being turned, and is drawing the piston down the cylinder, which in turn sucks gasoline vapor, (shown by little arrows) through the 'intake valve'. This 'intake valve', and the 'exhaust valve' on the opposite side of the cylinder, are opened and closed at the proper time through the action of the gears shown in the illustration.

Passing to Fig. 2, the fly-wheel in turning has drawn the piston to its lowest point, and is now shown forcing it up the cylinder. This compresses the gasoline vapor in the cylinder to a density at which its explosion produces the greatest amount of power. The intake and exhaust valves are both closed.

~WHAT CAUSES THE EXPLOSION IN A GAS ENGINE~

Fig. 3 shows the explosion. The cylinder has been filled with compressed gas, and the piston has again started on its downward travel. The spark plug, set in the top of the cylinder, makes a spark every time an electrical current passes through it. A switch on the engine permits the current to pass to the spark plug only when the engine is at this position in its action. (Fig. 3.) The consequent explosion drives the piston downward with great force, turning the fly-wheel, which by its weight continues the rotary motion after the downward impulse of the piston has been expended.

Fig. 4 shows the fly-wheel, still turning, forcing the piston up and thus expelling the burned gases from the cylinder through the exhaust valve, held open for this purpose. From this position the engine goes again to that of Fig. 1, and through 2, 3, and 4, continuously, exploding every second revolution, and giving a regular rotary motion to the fly-wheel.

[Illustration: FIG. 2.]

[Illustration: FIG. 3.]

[Illustration: FIG. 4.]

The illustrations show a one-cylinder motor, but these engines can be built with two or more cylinders, arranged to explode at different times, thus giving very smooth action to the fly-wheel and main shaft.

Aeroplanes, almost all automobiles, various pumps and other machinery are driven by gasoline engines. The rotary motion can readily be transmitted by chains or gears to the propellor of an aeroplane or motor boat, or the wheels of an automobile. It is only in the past few years that the gasoline engine has reached its present high state of perfection.

[Illustration: THE BEGINNING OF AN AUTOMOBILE

CRANKCASE SHOWING BEARINGS.

The heart of the automobile is the engine. It is built around the crankcase, which is its foundation or base.]

[Illustration: CRANKCASE WITH CRANKSHAFT AND FLY-WHEEL ADDED.

The crankshaft serves the same purpose in an automobile as the pedals do on a bicycle.

The fly-wheel on the end helps it to keep turning at an even speed.]

[Illustration: Gasoline vapor is exploded in the cylinders. This pushes the piston down, and as the piston is connected to the crankshaft it starts the crankshaft turning.

The piston and the rod that connect it to the crankshaft are just like the feet and limbs of any one riding a bicycle.

Cylinders showing piston in place and connected to crankshaft.]

[Illustration: The gears or "cog-wheels" are for running the fan, the pump and other parts.]

[Illustration: THE HEART OF THE AUTOMOBILE

Cylinder added to crankcase.

The cylinders are next bolted down to the crankcase, the pistons and crankshaft having been connected, as shown in Fig. 3. A cover is placed over the gears to keep them clean.]

[Illustration: An oil pan or reservoir is attached to the bottom of the crankcase to hold oil for the engine.]

[Illustration: The carburetor furnishes the gasoline vapor for the cylinders. It is connected to the engine by a crooked pipe called the intake manifold.

After the gasoline has been exploded a valve opens and allows the burned gases to escape through another pipe, called the exhaust manifold.]

[Illustration: Oil is poured in the spout which is at the left of the carburetor. It runs down into the reservoir and is pumped up through the engine a little at a time.

Oil pump and filler added to motor.]

[Illustration: THE POWER PLANT OF AN AUTOMOBILE

The electric generator makes electricity to be used for starting the engine and lighting the car.]

[Illustration: The magneto gives an electric spark, which explodes the gasoline in the cylinders.

The water pump keeps water flowing around the cylinders to prevent them from getting too hot. This water comes back to the pump through the radiator at the front of the car. Wind blows through the radiator and cools off the water. The tire pump on up-to-date cars is run by the engine. It does not pump except when the gears, which are shown in the picture, are pulled together.]

[Illustration: An electric motor starts the engine by turning the fly-wheel. This makes it unnecessary to get out and crank the car by hand.]

[Illustration: SECOND STAGE OF CONSTRUCTION

The transmission is added.

The transmission makes it possible to reverse the car. It also enables the driver to go into high-speed gear when on level roads and low-speed gear for starting and for pulling hills.]

[Illustration: Double-drop pressed steel frame.

The frame on which the car is built.]

[Illustration: Addition of semi-elliptic and three-fourths-elliptic springs to frame.

Large springs are placed at the front and rear of the frame. They make the car ride smoothly.]

[Illustration: Adding the front axle.]

[Illustration: READY FOR THE WHEELS

Showing addition of full-floating rear axle.]

[Illustration: Completed engine and transmission is next fastened to the frame and connected to the rear axle by the drive shaft.]

[Illustration: Showing addition of gasoline tank and gas lead to carburetor.]

[Illustration: Showing how steering gear is connected.]

[Illustration: WHAT THE COMPLETED CHASSIS LOOKS LIKE

Wheels are next added to chassis.]

[Illustration: Completed chassis with radiator added.

The water which keeps the engine from getting too hot is pumped around the cylinders and then through the radiator. The wind blows through the little openings in the radiator, and cools off the water. Then the water is pumped around the cylinders again.]

[Illustration: The steps and fenders are next attached.]

[Illustration: THE MARVELLOUS GROWTH OF TWENTY YEARS

The finished car.]

[Illustration: GASOLINE AUTOMOBILE.

The first American-built automobile, now in Smithsonian Institute, Washington, D. C., where this photograph was taken. The rude carriage that was a curiosity twenty years ago and less--the vehicle that vied with the two-headed calf and the wild man of Borneo at the county fairs--was the beginning of the greatest transportation aid since the birth of civilization. Because of it our standards of living have become higher. It has broadened the horizon of all of us.

Built by Elwood Haynes, in Kokomo, Indiana, 1893-1894. Equipped with one-horse-power engine. Successful trial trip made at speed of six or seven miles an hour, July 4, 1894. Gift of Elwood Haynes, 1910. 262,135.]

[Illustration: When an automobile passed you twenty years ago.]

[Illustration: HOW AUTOMOBILES HAVE IMPROVED

LEFT SIDE VIEW

RIGHT SIDE VIEW

A new exhibit in the Smithsonian Institute, officially known as "Exhibit Number 56,860," is attracting a great deal of attention from visitors to the National Museum. It consists of a complete Haynes six-cylinder unit power plant, and has been given a position at the side of the original Haynes "horseless carriage," where the striking contrast shows the remarkable improvement that has been made in motor design and construction during the past twenty-two years.

The most important features of the power plant are shown clearly and comprehensively by having sections cut away from the various parts, so that the visitors to the Institute are enabled to see the mechanical construction, and the relation of the component devices.

On the right side of the engine, the intake and exhaust manifolds are shown in their natural position. A full vertical section of the Stromberg carburetor gives a good idea of how the gasoline is mixed with the air and supplied to the cylinders. The Leece-Neville generator has its casing cut away to give a view of the windings and cores. Numerous windows have been cut into the crankcase to disclose the crankshaft construction and the oil reservoir. The transmission gears are also shown in this manner.

Most of the electrical equipment is shown clearly on the left side of the motor. Here an interesting feature is the full vertical section of the American Simms high-tension dual magneto. A half section has been removed from the rear cylinder, and the piston as well, to give a glimpse of the interior construction. A large portion of the Leece-Neville starting motor casing has been cut away. The cover-plate on the switch controlling the starting motor has been replaced with a glass cover to display the method of completing the circuit from the battery to the motor. A skeleton selector switch is mounted at the rear of the transmission case, instead of its usual position on the steering wheel. The electric gear-shifting mechanism is made visible by using a glass plate for the top cover-plate on the transmission.]

Why Does the Heart Beat When the Brain Is Asleep?

Under ordinary conditions the heart beats are controlled by certain nerve cells which are located within the heart itself, and these cause the heart to beat even while the brain is asleep. This explains why the heart beats when the brain is asleep, and the fact that the brain when asleep does not exercise its functions, shows how necessary this arrangement and the control of ordinary heart beats is. If this were not so, we should not be able to live while asleep. It is just like the management of a great business in this sense. The general manager of a great business has control of the entire works, but there are occasions when he must be thinking of only one thing in connection with the business, and so he must have his organization so complete, that the parts which he cannot be thinking about at the time will do their work just the same. So he surrounds himself with competent assistants, who look after certain departments while he is busy or away or asleep, and if anything goes wrong while he is away, he calls on special forces to set things right. Now, the brain is the general manager of the whole body and has these nerve cells in the heart as a sort of

assistant manager to look after the heart beats in ordinary conditions, and to keep the heart going while he is asleep. But, by reason of his office as general manager, the brain has a special way of sending orders to the heart through special nerves which run from the brain down each side of the neck to the heart. There are two pairs of these special nerves. One pair, if set in motion, will make the heart beat faster, and the other pair will make the heart beat more slowly.

Why Do Our Hearts Beat Faster When We Are Running?

When you start running, the brain knows at once that your legs and other parts of the body will need more blood to keep them going, and so the brain sends down orders through his special nerves which make the heart beat faster, to get busy, and they do. Then when you stop running, your heart is beating faster than necessary--there is really an oversupply of blood being pumped through your system for the time being, and that makes you uncomfortable, until the brain sends word through the other set of nerves to the heart to slow down the heart beat. It is better to stop running gradually, to give the heart a chance to get back to its normal beat gradually also.

Why Do I Get Out of Breath When Running?

This is also caused by your brain in its efforts to keep up your supply of good blood. We breathe to take air into the lungs, where the blood which has once been through the arteries and comes back on its return trip to the heart, is exposed to the air in the lungs, before going back into the heart. The air which we take into our lungs purifies the once used blood and makes it into good blood again. When you run the heart pumps blood into your arteries faster to enable you to run. Thus also, the arteries send much more blood back to the heart through the veins, and this must be purified by the lungs before going back into the heart. To attend to purifying this extra amount of spoiled blood the lungs need more air, and thus you are made to breathe in more air for the purpose. Unless you are in good training--your wind in good condition as we say--it is almost impossible for you to supply the lungs with enough air for the purpose, but whether you can do it or not, the lungs call upon you for more air, and cause you to try to get it, and that is what makes you get out of breath.

Why Does My Heart Beat Faster When I Am Scared?

The natural tendency of a scared creature is to run or fly. The effect of being scared has the same effect on the brain that your starting to run has. The brain is always as quick as you are, and knowing that when you are scared your actual or natural inclination is to run, it is merely getting you in shape so that you can move or run fast.

Why Does Cold Make Our Hands Blue?

Your hands appear blue when cold because the veins which are near the surface are filled with impure blood which is purplish in color. Your hands become cold because there is not sufficient circulation of warm red blood going on to keep them warm. The blood in circulating through your body sends warm red blood through the arteries, and this is returned to the heart through the lungs by way of the veins. The veins carry only used-up blood or what is left of the good red blood when the arteries are through with it. Its color is a purplish blue.

When your hands are blue it means that circulation of good red blood has practically stopped--the red blood is not flowing from the heart through the arteries in sufficient quantity and there is no color in the arteries, as the blood from the arteries has practically all gone into the veins. The veins are full to purplish blue blood, and this makes the hands look blue, because there are a great many veins in the hands close to the surface.

Why Do I Get Red in the Face?

Now, when you rub your cold blue hands together, you start the circulation going again, and that brings the red blood into the arteries, giving you the healthy red color again. When you run hard to get red in the face because you are causing an unusual amount of red blood to flow through your whole body by your violent exercise. Some people with an extraordinary amount of circulation are red in the face all the time. This is because of the presence of a great deal of blood in the arteries, or because the walls of their arteries are so much thinner than others that the red blood shows through more easily.

Is Yawning Infectious?

Yawning is infectious to the extent that other habits are. The desire to yawn which comes to us when we see some one else does so comes under the heading of suggestion. The power of suggestion is greater than many of us realize. We are great imitators of each other. When one of us is downhearted, we are apt to become happy and glad simply by being with other people who are happy and glad. If enough people one at a time tell a perfectly well man that he looks sick, he will actually feel ill, provided he does not suspect a game is being played on him. So a good actor carries his audience with him. He can make them laugh or cry almost at will, and if he yawns, his audience will begin yawning.

Often, however, there is no acting connected with the yawning of the first person. Then the yawn is caused because the person is not sending enough good air into the lungs for purifying the blood, and the yawn is only nature's way of making us take an exceptionally deep breath of air in at one time. This lack of sufficient good air in the lungs may not be due to the poor breathing, but to the amount of bad air in the room. In such cases it is quite likely that other people in the room yawn when one of them starts it because they all begin to feel the need of more good air at about the same time.

What Makes Me Want to Stretch?

The necessity or desire to stretch comes to us because certain parts of the body are not receiving the proper amount of blood circulation and it is these parts that we stretch at such times. If you have ever been to a ball game, you know, of course, that it has become customary for the crowd, no matter how large, to stretch its legs and arms during the last half of the seventh inning. In fact, that has come to be a fixture at ball games and is universally known as the "stretch inning." Now, it is not so much the result of a desire to encourage the home team as the natural following out of nature's laws that originally started this practice. The end of the seventh inning at a ball game generally means that the crowd has been sitting quite still for the greater part of an hour and a half, just long enough for the circulation to become poor in parts of the body, and the custom of stretching at a ball game thus comes from the necessity of getting a little more speed into the action of the heart to increase the blood supply.

In other words, the stretching constitutes a mild form of exercise. You will notice the ball players themselves do not stretch themselves in the last half of the seventh inning. They are getting enough exercise without that.

It is natural, however, for us to stretch as we wake up from sleep after having lain quietly in one position for one or more hours. It is nature's way of causing the heart to work faster.

What Happens When I Stretch?

What happens is simply this. When you stretch your arms and legs, you squeeze the arteries and veins which are a part of your arms and legs, much as happens when you pull on a piece of rubber tubing. The tubing becomes flat instead of perfectly round, and it is not so easy to send water through a flat tube as through a round one. Just so with the heart. It is the heart's business to send blood through the arteries at all times, and when you make them flat the heart's job becomes just a little harder, and it goes to work beating just a little faster to overcome this extra difficulty. By that time you are through stretching and the heart is busy pumping blood a little faster than ordinarily, and that is what makes you feel so good after you have stretched.

Why Can We Think of Only One Thing at a Time?

If you are asking the question intelligently, you must know that to think means to concentrate, and in that sense we can only think of one thing at a time, because it takes all of that part of the brain which is used for thinking for just one thing. To give close attention to any one subject means to turn the entire brain force practically in one direction. To let other things pass through the mind at the same time may appear not to interfere with the one thought, but they do, and our conclusions suffer accordingly.

You can be doing something with one part of your body, while engaged in thinking of one thing, but only such things as are more or less mechanical as the result of habit, such as walking, or moving the arms--things which the parts have done so often that actual attention by the brain is not absolutely essential. Take for instance, the fact that a man in deep thought on one subject will sometimes walk up and down the room or along the sidewalk. He can do this walking and still think concentratedly, but if he stubs his toe on the leg of a chair or on a rough place in the walk, his thought is broken, because the brain immediately takes itself out of the thought and pays its attention to the toe that was stubbed.

Why Do I Turn White When Scared?

Simply because, when you are scared or frightened, the blood almost leaves your face entirely. Under normal conditions, the red blood which is flowing through the arteries of your face, gives the face a reddish tinge, and your face becomes white when you are frightened, because then the blood leaves the face. It is quite singular, but when you are really frightened, whatever the cause may be, the human system receives such a shock that the heart just about stops beating all together. When your heart stops beating of course the flow of the blood from the heart stops and then there is no supply of fresh red blood coming through the arteries under the skin of your face. Therefore you look white--the color your face would be if no blood ever flowed through your arteries and veins. Some people have faces so white they look as though they were scared all the time. This is not because they have no blood flowing through the veins and arteries in their faces, but because their supply of blood is less than other peoples, and sometimes because the walls of their arteries and veins are much thicker than the average that the color of the blood does not show through. There are also many people who have so much blood in their systems all the time, and the walls of whose arteries are so thin, that they look at all times as though they might be blushing.

What Makes Me Blush?

Anything that will make your heart send an extra supply of blood into the arteries and veins which supply your face with blood, will make you blush. Embarrassment will do this. So will anger generally, although sometimes people get so angry that the blood is driven out of their faces. In this case they are so angry that their heart has stopped beating, practically.

What Occurs When We Think?

When we think the mind is acting on sensations; it is receiving, in conjunction with memories of sensations it has previously received. Sensations as they reach the mind arouse the mind to activity and, as soon as the sensation is received, the mind begins to compare the new sensation with sensations received at previous times, and by putting things together reaches a conclusion.

When you are thinking you are really trying to call upon memory to help you. You know the thought of one thing calls up another, and this leads to something else. This association of ideas is the faculty which enables us to think consecutively and accurately. It is the business of the mind to receive the sensations that enter it and arrange them in their proper places. That memory of past sensations is the important part of thinking, is proven by the fact that when we have forgotten a thing we are unable to think what it was.

Can Animals Think?

For this reason if animals have memory they should be able to think. It is now believed that many animals have to a certain extent the power to remember.

A dog will recognize his master even though he has not seen him for years. We might think he does this by his highly developed power of smell, but if his master has come from a direction opposite to that from which the dog first sees him, he could not have tracked him by his smell. A dog will recognize his master from quite a distance, so he must have to a certain extent the ability to remember or the power of association of ideas, which amounts to the same thing. Again, a horse that once belonged to the fire department, even though now hitched to a milk wagon, will have the impulse to run to the fire when he hears the fire gong. And an old war horse will prick up his ears as he used to when he hears the bugle call.

Why Do I Sneeze?

You sneeze sometimes when you look up at the sun or at a bright light. There does not seem to be any real good explanation of why looking at a bright light should make you sneeze. It is due to the connection there is between the nerves of the eyes and the nose. You generally blink if you look at a bright light suddenly, and the blinking process stirs the nerves inside of the nose to make you sneeze.

You know, of course, that the start of the sneeze is inside of your nose. The nose is, besides being the organ of smell, the channel through which we take air into the lungs, when we breathe properly. The nose is lined with membranes, back of which are a net of

very small nerves which are extremely sensitive. The membranes are placed there to catch and hold the impure particles of matter which come into the nose when we take in a breath of air, and sneezing is only one effective way of cleaning out the nose. It is brought on only when some particularly difficult job of nose-cleaning has to be done. Pepper up the nose will make you sneeze quickly, because pepper produces a very great irritation inside the nose, and the nose goes to work at once to get rid of it in the quickest possible manner as soon as the pepper comes in. Other things have the same effect. Sometimes a cold in the head causes you to sneeze. The sneeze in that event is merely nature's effort to clean out the nose when other efforts have failed.

There are many suggestions for stopping a sneeze before it takes place, after you feel it coming on, such as putting the finger on each side of the nose, and many others. But a half sneeze does not remove the cause of the sneeze, so it is much better to sneeze it out, and many people enjoy the after effects of sneezing so much that they take snuff into the nose to produce it.

What Happens When I Swallow?

The muscles of your throat act in the form of a ring when food passes into your throat. The food does not drop directly into your stomach. In other words, the action is not quite the same as when you drop a stone out of the window. When you do the latter, the stone hits the sidewalk or whatever is below at the time, with a smash. It would hardly do to have our food drop into the stomach, so the muscles of the throat are arranged to contract in rings which push or squeeze the food downward, and the food is passed from one ring of muscles to the other. It is just like pushing a ball down into the foot of a stocking that is apparently too small for it to drop down. You put the ball in the top of the stocking and then by making a ring of your fingers around the stocking you can push the ball down. When you swallow, you start the muscles of your throat to making these rings. The upper ring squeezes the food on to the ring below it and so on down to the stomach.

What Makes the Lump Come In My Throat When I Cry?

The "lump" which comes up into your throat when you cry is caused by a sort of paralysis of the rings of muscles in your throat. The muscles of your throat can make these rings or waves upward also, but it is more difficult upward than downward--probably because of lack of practice, as we say. When you have put something into your stomach that makes you sick and causes you to vomit, the throat muscles take the matter from your stomach and bring it back to the mouth in the same way, except, of course, that this action begins at the bottom.

Sometimes when you cry, or lose control of yourself in some other way (you know, of course, that in crying you always lose control of yourself, don't you) practically the same effect is produced as when you have something in your stomach that should come out. Crying, or the thing that happens sometimes when we cry, makes the throat muscles act just as if we were vomiting, and as the action is an unnatural one, when the ring or wave reaches the top of the throat, we feel the lump or ball as we call it. We feel the lump because the throat has been made to go through the motion of eliminating something in an unnatural way, just as your arm will hurt if you pretend to have a ball or a stone in it, and in throwing the imaginary ball or stone, you put the same force into your movements as you would if you had an actual ball or stone in your hand and were seeing how far you could throw it.

Why Do We Stop Growing?

We eventually stop growing because certain of the cells of the body lose their ability of increasing in size and producing other cells. It is one of the marvels of the construction of the human body that this is so and one of the wisest provisions also. At first the cells of the body crave lots of food and increase in size, divide and then the parts go on growing until they become of a certain size, when they again divide and each part goes on growing, etc., and thus we grow. A growing boy needs more fond than a mature man, because he needs some of it to grow with, while the man only has to keep what growth he has going, i. e., alive.

We say this limit of growth is a wise provision of nature because if there were no limit to the size we might become, we would not know how large to build houses, barns, etc., or else we would have to build them so large to start with that we would be lost in them for a long time. We would constantly be forced to change these things and there would be no basis to reckon from. Dogs might be as big as elephants and then they would be of no use to us, or of what use would a dog as big as an elephant be to a boy of five years. You see it would not do at all to have this rule changed.

Why Do We Grow Aged?

We age directly in accordance with the lives we lead. You can bend a wire back and forth a number of times at the same point without breaking it, but eventually it will break. Just so with the human body. You can use each part of it for its own purposes a number of times, but eventually the break will come. Or, you can fail to make a part of it perform its regular functions, and it will die--the break will come. The human body is the most wonderful machine in the world, but even it will eventually wear out. Every time you move your arm, leg or some other part of your body, you destroy some tissues. The body replenishes and builds up those tissues again for a certain time. When you bend a joint in your body, the body oils the joint naturally, but as you grow older, or rather, as you use the different parts of your body more and more, it brings nearer always the time, when the body cannot, of its own accord, build up again the tissues you have destroyed. That is why some people become very old at forty and others are still comparatively young at seventy. It requires a great deal of care and attention and the elimination of all abuse of the body to keep us young when we are old. The use of drink, lack of sufficient sleep and other abuses prevent the body from restoring the tissues which have been destroyed. Worry and sorrow age us very rapidly, because these things affect the nerves. If the nerves are not quiet we cannot get any rest and without rest we grow old very rapidly.

What Causes Wrinkles?

Wrinkles come to us in several ways. An easy way to cause wrinkles is to scowl and frown and get into the habit of doing this. When you scowl or frown you pucker up the skin on your forehead into wrinkles and if you continue the habit the skin on your forehead makes the wrinkles permanent. You have given your skin the wrinkle habit. This acts just the same way as your arm would, if you tied it up in a sling and held it close to your side for a very long time--a number of weeks. When you took the sling off you would find your arm useless--a dead arm. It had developed the habit of doing nothing.

In old people, however, wrinkles come more naturally. There it is the case of the skin not receiving the proper nourishment and attention to keep the circulation of the blood right. When people become old they are apt to lose the fat which has accumulated under their skins. If they had taken just the right amount of exercise all of their lives and kept their circulation perfect in all parts of the body, there would have been no fat there. But when the fat accumulates, it makes the skin grow larger, and then when the fat disappears and people get thin again, the skin is too large and makes the wrinkles.

Does Thunder Sour Milk?

Milk will sour in any kind of warm and moist temperature and, because just before and during a thunderstorm the air is generally quite warm and moist, it is only natural that it should turn sour. It is wrong, however, to say or think that thunder makes milk sour. Thunder is only a noise and noise cannot do anything but make itself heard. The fact that it is generally warm and moist, however, when it thunders, coupled with the fact that these conditions of the air sour milk very rapidly, have led people to connect the two in their minds and caused them to fall into the error of believing that the thunder is responsible for the change in the milk.

What Makes the Rings in the Water When I Throw a Stone Into It?

Every movement has a beginning. When a movement on the earth is once started it keeps on going until something stops it. If nothing stops it it will go on forever.

When you shout you start air waves going in every direction, which keeps on going until stopped by something which has the power to break up their waves.

When you throw a stone into the ocean you start a series of ripples or waves which spread out in every direction and if you dropped your stone into the exact middle of the ocean--half way from each side--in a perfectly calm sea undisturbed by other forces, your ring of ripples would go on getting larger until it landed on the beach or shore on each side of the ocean at the exactly the same time and there the beach or shore would stop it.

The original ring of ripples is caused by the fact that when you drop a stone into the water it disturbs the water where it goes in and the water moves away from the stone to the sides, and as the stone goes down, over and up above it, and the whole body of the water is disturbed in such a way that makes the ripple appear on the surface and spread out in every direction. As the stone goes down into the water further and further the disturbance is repeated and ring after ring appears on the surface.

Of course there are many disturbances in the water at all times. Many things may happen to break up your little ring of ripples before they touch the sides of the ocean--a ship--a fish--the wind--or one of many other things, and because this is true you would have difficulty in sending the waves made by your little pebble across the ocean, but you can take a dishpan from the kitchen and after filling it with water drop pebbles into it as nearly the middle as possible, and you will see the ripples or waves your pebble makes spread out from the point where the pebble entered the water in all directions.

Why Are There Many Languages?

Different languages developed in different parts of the world because there was no inter-communication between people in different communities, and each was really developing a language for itself. In doing so they developed their language without knowing that other communities were working out the same problems for themselves. So they first developed their own sign and gesture language and later on their word or sound language and kept on using it. While they may thus have developed the use of some of the same signs and sounds or combination of sounds to express one thing perfectly understandable to themselves, these sounds or combinations of sounds might mean something entirely different to another community, where that particular sound or combination of sounds may have been hit upon to mean something entirely different.

Of course, not all languages were developed in this way. There are, you know, a great many languages used in the world. Some of them are offshoots of others, where part of a community moved to another part of the world, taking their language with them, but developing it further along new lines, and using new combinations of sounds for new words. Then also, there are many words which mean the same thing in different languages and are spoken with practically the same sounds. This is due to the movement of people from one nation to another and bringing their own words with them, so to speak. In many instances a stranger would come to another nation, and use his own word for expressing a certain thing and that would eventually be taken up and used as a better word, and the old word dropped. It is strange that this should be true, but this accounts for the fact that many words are the same in sound and meaning in numerous languages.

What Makes a Match Light When We Strike It?

The match lights when we rub it along a rough substance, because the rubbing produces sufficient heat on the end of the match to set fire to the head, as we call it, which is made of chemicals that light more easily than the stick of wood, which is the rest of the match. The fire thus started is hot enough and burns long enough to set fire to the wooden part of the match.

To explain this more fully, let me say this. Rub your finger quickly along your coat sleeve or along the seat of your trousers, long a favorite place for men to strike matches, pretending that your finger is a match. You find the end of your finger becomes warm, don't you? Not warm enough to set your finger on fire, of course, but if you had the same combination of chemicals on the end of your finger that there is on the match, you would set the chemicals afire and this would burn your finger, just as it sets fire to the wooden part of the match.

It took a great many years to discover the combination of chemicals of which the head of the match is made. Before that discovery was made it was far from easy to light the light in the evening as it is now. It must have been a serious thing to let the fire go out in the furnace in those days.

What Makes the Kettle Whistle?

The kettle whistles only when the water boils and the steam or gas which is the form the water turns into when boiling is trying to escape through the spout of the kettle. You see, when the water starts boiling, the inside of the kettle is at once filled with steam and more is coming out of the water all the time. This steam must get out some way, so it rushes for the spout of the kettle, and because so much of it is trying to get out of a comparatively small opening at once there is quite a pressure and this results in making the whistle out of the spout of the kettle. It is just the same process as when you whistle yourself. To whistle you fill your mouth with air and force it out through your lips, which you have closed excepting for a small opening, by the pressure you can bring to bear with the roof and sides of your mouth, and if you have learned to make your lips into the proper shape and apply the pressure steadily you can sound a very long note and make different notes by making the opening in your lips large or small. The kettle spout has only one size of opening so the sound is practically the same at all times though louder at sometimes than at others. This is caused by the varying pressure at which the steam in the kettle is being forced out.

What Makes the Water From a Fountain Shoot Into the Air?

The water from the fountain shoots into the air because water anywhere will run down if given a chance. To produce a fountain you must have a source of water supply for the fountain which is higher than the openings of the fountain out of which the water shoots. The water comes out of the holes in the fountain for the same reason that it comes out of the faucet in the kitchen or bath room. In the latter case the water comes from the waterworks reservoir in which the level of the water is much higher than the opening in the faucet in your home. Being higher the water in the reservoir is trying to get away through the pipes all the time and all the pipes leading from the reservoir are full of this water trying to get away. Just as soon as you turn the valve in the faucet the water comes out and runs down into the bowl.

If you were to turn the opening of the faucet up instead of down as it is, the water would shoot up instead of down. Not very much, it is true, but it would act much like the water from the fountain. The reason it does not shoot up high in the air like a fountain is because the opening in the faucet is the same size as the opening in the little pipe which leads the water from the street into the house. If you would turn the opening of the faucet up and attach to it a pipe which made the opening much smaller (the size of the opening in the fountains), you would see the water shoot into the air just as it does from the fountain. When you reduce the size of the opening you increase the pressure of the water coming from the pipes in proportion to the reduction you have made in the size of the opening.

Water from the fountain will not, however, shoot as high as the level of the water in the reservoir because, as soon as it leaves the pipes, it encounters the pressure of the air outside the pipes and the law of gravitation which pulls all things toward the center of the earth.

It is not natural for water to shoot into the air as it does in a fountain. The only way water can go naturally is down, and it only goes up a little way from a fountain because of the pressure of the water in the pipes behind the openings in the pipes in the fountain.

What Keeps a Balloon Up?

A balloon stays up in the air, because of the air in it, together with the weight of the balloon, is less than an equal bulk of the air in which it floats.

In former days of ballooning the balloons were filled with hot air and were then found to rise and stay up until the air inside of the balloon became of the same temperature as that in which it floated. When this stage was reached, the balloon itself would fall because the material of which it was made was denser than air.

Today balloonists fill their balloons with gas which is lighter than air, even when as cool as the air in which they rise and are thus able to stay up a long time.

You, of course, have seen many of the red, white and blue paper balloons which are sent up on the Fourth of July. You will remember that father, or whoever it is that is sending them up, lights the oil-soaked knot of cloth that is attached to the balloon immediately below the opening at the bottom. He first lights this and then holds the balloon for a time with his hands.

Soon, however, you will remember that the balloon starts upward with father still holding it. This is because the air inside the balloon is becoming heated. You will notice also that at first he has to hold out the sides of the top of the balloon with his hands or has some one help him do this, but that even so the balloon does not stand out round and full as it should. When the balloon starts to rise, however, you will notice that it is round and full. This is because the air in the balloon has become heated and is expanding. Soon the balloon is tugging to get away and father lets go and it rises and sails away with the wind. As long as the fire below it burns, and if the wind does not upset it so as to make the paper part catch fire, the balloon will stay up; but, when the fire burns out, the balloon will come down.

The balloon merely rises because the air inside, and held there by the covering of the balloon, is warmer air and lighter than the air on the outside.

Why Did People of Long Ago Live Longer Than We Do Now?

When reading of people who lived long years ago and especially when reading about the length of their lives, we are told that in the old days people lived longer than they do now. Some of the early historical records speak of single individuals who lived hundreds of years. There is great doubt as to whether these statements are founded on fact. In thinking about this we must first take into consideration that these records of long ages were recorded at a time when man had no accurate ideas of the actual passage of long periods of time such as a year. They did not have our calendar as a basis for figuring at all. Learned men now tell us that the actual age of men who lived at the time these records of great ages were recorded probably lived shorter lives than we do now, and that what they record as a period of one year was probably a much shorter period than one year.

It is true beyond the question of a doubt that the people of today live longer on the average than people who lived ten, twenty or more years ago.

In other words, the average period of life has increased steadily. This is due to the fact that we have taken great care of our bodies; have improved the conditions in which we live, and made them more sanitary; have learned to fight and check and eradicate diseases, which only a few years ago we could not prevent people dying of when they once contracted them, and we know from the records which we keep that actually people live longer on the average today than only a few years ago, and it is safe to say that they live longer now on the average than at any time in the world's history.

Is There a Reason for Everything?

The world is so constructed that there must be a reason or cause for everything. There are so many forces in the world that man has not yet been able to locate the original cause of every one of them. Concerning other things, he sees the effects without having any knowledge of the forces which are their cause. Other things he has never even bothered to inquire about, but simply takes them for granted. But every force, which means, of course, everything in the world, must have had a beginning and therefore something or a combination of things must have caused it to begin, and the thing or things that caused it to be is the reason for its being. Every little while someone makes a discovery of some new force, and then we suddenly realize that this force has been in existence all the time although not known to man, and we discover through this the reason for many other things being as they are.

The other thing or side of the question is also true. We cannot have a cause without an effect. You cannot do anything without causing something to happen and producing an effect on one or more other objects either animate or inanimate. You cannot move your hand without creating some disturbance in the air. When you make a noise, low or loud, you produce sound waves. When you burn a stick of wood, you create smoke, ashes and gases of various kinds. You change the whole nature of what was the piece of wood, and yet no particle of what made the stick of wood is ever destroyed or lost, but appears in some other thing in the air or on or in the earth.

What Makes an Echo?

An echo is caused when the waves of air which you create when you shout are thrown back again when they are stopped by something they encounter and are turned back without changing their shape. Any kind of a sound wave will make an echo in this way.

You see, you can have no sound of any kind without sound waves. You could not make a sound if there were no air. Now, when you shout, you start a series of sound waves that go out from you in every direction and they spread away from you in circles just like the rings of ripples that are caused when you drop a stone into a pool of water. You can prove this to yourself easily by having one, two, three or more of your friends stand around you in a large circle. You can place them as far away from you as your shout can be heard if you wish. When you shout, each of your friends will hear the shout at the same time, provided, of course, they are at equal distances from you.

Sometimes these sound waves as they go away from you in circles strike objects that turn the waves back unbroken just as they came to them. The waves will bounce back just like a rubber ball from a wall against which it has been thrown and this is the echo. However, some things that the sound waves strike break up these waves entirely and others partially.

No doubt you have sometimes noticed when you shout you hear a distinct echo and that at other times, standing in the same place, you cannot hear any echo, although you shout in the same way. This is explained by the fact that at times conditions of the air are such that no echo is produced while at other times a perfect echo results.

What is a Whispering Gallery?

The possibilities of an echo have to be taken into account by the architects and builders of all public buildings, such as theaters, halls and churches, where anyone is to speak or entertain others. Unless they are very careful the walls and ceilings may be so arranged that when any one sings or speaks in the room, there is such an echo that it interferes with the music or speaking. It sometimes happens also that through some peculiarity in which the walls and ceiling of a building are constructed there will be certain places in the room where an echo can be heard, even a whisper, and which cannot be heard in other parts of the room at all. This is likely to occur in rooms where there is a dome-shaped ceiling. There will be certain spots in the room hundreds of feet apart, where if you stand on one spot and another person is on another definite spot clear across the room, the tiniest whisper can be heard, while the people in between cannot hear at all. This is called a whispering gallery. Of course, loud talking would produce the same effect. A whispering gallery is a gallery with an echo which can be heard from certain positions. There are a number of famous whispering galleries of the world. In the room beneath the great dome of our Capitol at Washington is an almost perfect whispering gallery. There are quite a number of points at which you can stand and hear the whispers across the room which is more than a hundred feet. These whispering galleries come accidentally, of course. It would be difficult to deliberately construct a building in such a way as to produce a whispering gallery.

Why Do We Get a Bump Instead of a Dent When We Knock Our Heads?

When you knock your head against a sharp corner, or if some one hits you on the head with anything with a sharp edge, you do receive a dent in your head, but it does not last. In other words, the head has one of the qualities of a rubber ball. You can press your finger against the sides of the rubber ball and push it in, but when you take your finger off the ball resumes its shape. Just so with your head--it resumes its shape after a blow.

After doing this, however, a bump or lump is formed. I will endeavor to tell you how the bump is formed or rather what causes it to form. You cannot knock your head against anything that is harder than your head without causing some injury to the parts which received the bump. Now, what happens then is just what happens to any other part of your body when it is injured whether as a result of a bump, a cut or a bee or mosquito sting.

As soon as the injury occurs the brain starts the “repair crew” to work. The result is that first a great supply of blood is rushed to the injured part with the result that the blood vessels are filled up and extended with blood. Certain parts of the blood cells find their way through the walls of the blood vessels at the part of the injury and other fluids from the body are piled up there, so to speak, to form a congestion. This “piling up or congestion” distends the skin and raises the bump. On the head where the layer of muscular structure is thinner and where there is less space between the bones of the skull and the outside skin, the bump will be larger and more noticeable, because a good deal of blood and other fluids are piled up in a comparatively small space, and so the skin gets pushed out further to accommodate this great congestion, whereas in other parts of the body the bump may be quite as large but not so noticeable.

[Illustration: HOW MEN GO DOWN TO THE BOTTOM OF THE SEA

PUTTING ON THE SUIT.

Socks, trousers and shirt in one, and a copper breastplate.]

[Illustration: PUTTING ON THE IRON-SOLED SHOES.

They are purposely made heavy, to help the diver sink.]

The Deep Sea Diver

What Does the Bottom of the Sea Look Like?

It looks very much like the land on which we live. There are mountains and valleys, rocks and crags, trees and grass, just the same as we see on land, except, of course, that there are no human beings to be seen. Instead of birds flitting about the tree-tops, fish swim about them, and where the squirrel and rabbit bound through the woods on land, the great king crab and sea turtle drag their unwieldy forms on the ocean’s bottom. Some of the scenes at the bottom of the sea are like fairyland, and in tropical waters are

often as beautiful and spectacular as those we see in theatrical pantomimes. Delicately tinted sea-shells, great trees of snow-white coral, sea foliage of every tint and shape, and deep dark caverns, in which lurk the devil-fish and other odd looking fish.

The Diver's Outfit.

The armor of to-day consists of a rubber and canvas suit, socks, trousers and shirt in one, a copper breastplate or collar, a copper helmet, iron-soled shoes, and a belt of leaden weights to sink the diver.

[Illustration: ADJUSTING THE TELEPHONE.

This enables the diver to talk at all times to those above him.]

[Illustration: PUTTING ON THE HELMET.

It is made of tinned copper, with three glass-covered openings, to enable the diver to look out.]

[Illustration: TELEPHONING FROM THE BOTTOM OF THE OCEAN

TESTING THE TELEPHONE.

Every precaution is taken to see that everything is in order before the diver goes down.]

[Illustration: THE FINAL TEST.

The least error in the adjustment may mean death to the diver.]

The helmet is made of tinned copper, with three circular glasses, one in front and one on either side, with guards to protect them. The front eye-piece is made to unscrew and enable the diver to receive or give instructions without removing the helmet. One or more outlet valves are placed at the back or side of the helmet to allow the vitiated air to escape. These valves only open outwards by working against a spiral spring, so that no water can enter. The inlet valve is at the back of the helmet, and the air on entry is directed by three channels running along the top of the helmet to points above the eye-pieces, enabling the diver to always inhale fresh air. The helmet is secured to the breastplate below by a segmental screw-bayonet joint, securing attachment by one-eighth of a turn. The junction between the water-proof dress and the breastplate is made watertight by means of studs, brass plates and wing-nuts.

A life or signal-line and also a modern telephone enables the diver to communicate at all times with those above him.

The cost of a complete diving outfit ranges from $750.00 to $1,000.00. The weight of the armor and attachments worn by the diver is 256 pounds, divided as follows: Helmet and breastplate, 58 pounds; belt of lead weights, 122 pounds; rubber suit, 19 pounds; iron-soled shoes, 27 pounds each.

The air which sustains the diver's life below the surface is pumped from above by a powerful pump, which must be kept constantly at work while the diver is down. A stoppage of the pump a single instant while the diver is in deep water would result almost in his instant death from the pressure of the water outside.

The greatest depth reached by any diver was 204 feet, at which depth there was a pressure of 88½ pounds per square inch on his body. The area exposed of the average diver in armor is 720 inches, which would have made the diver at that depth sustain a pressure of 66,960 pounds, or over 33 tons.

The water pressure on a diver is as follows:

20 feet 8½ lbs. 30 feet 12¾ lbs. 40 feet 17½ lbs. 50 feet 21¾ lbs. 60 feet 26½ lbs. 70 feet 30½ lbs. 80 feet 34¾ lbs. 90 feet 39 lbs. 100 feet 43½ lbs. 120 feet 52½ lbs. 130 feet 56½ lbs. 140 feet 60¾ lbs. 150 feet 65½ lbs. 160 feet 69¾ lbs. 170 feet 74 lbs. 180 feet 78 lbs. 190 feet 82½ lbs. 204 feet 88½ lbs.

The dangers of diving are manifold, and so risky is the calling that there are comparatively few divers in the United States. The cheapest of them command $10.00 a day for four or five hours' work, and many of them get $50.00 and $60.00 for the same term of labor under water.

The greatest danger that besets the diver is the risk he runs every time he dives of rupturing a blood-vessel by the excessively compressed air he is compelled to breathe. He is also subject to attacks from sharks, sword-fish, devil-fish, and other voracious monsters of the ocean's depths. To defend himself against them, he carries a double-edged knife as sharp as a razor. It is the diver's sole weapon of defense.

Just how far back the art of submarine diving dates is a matter of conjecture, but until the invention of the present armor and helmet, in 1839, work and exploration under water was, at best, imperfect, and could only be pursued in a very limited degree.

Feats of Divers.

~THE GREATEST DIVING FEAT~

Millions of dollars' worth of property has been recovered from the ocean's depth by divers. One of the greatest achievements in this line was by the famous English diver, Lambert, who recovered vast treasure from the "Alfonso XII," a Spanish mail steamer belonging to the Lopez Line, which sank off Point Gando, Grand Canary, in 26½■ fathoms of water. The salvage party was dispatched by the underwriters in May, 1885, the vessel having £100,000 in specie on board. For nearly six months the operations were persevered in before the divers could reach the treasure-room beneath the three decks. Two divers lost their lives in the vain attempt, the pressure of water being fatal. The diver recovered £90,000 from the wreck, and got £4,500 for doing it.

One of the most difficult operations ever performed by a diver was the recovering of the treasure sunk in the steamship "Malabar," off Galle. On this occasion the large iron plates, half an inch thick, had to be cut away from the mail-room, and then the diver had to work through nine feet of sand. The whole of the specie on board this vessel--upward of $1,500,000--was saved, as much as $80,000 having been gotten out in one day.

It is an interesting fact that from time to time expeditions have been fitted out, and companies formed, with the sole intention of searching for buried treasure beneath the sea. Again and again have expeditions left New York or San Francisco in the certainty of recovering tons of bullion sunk off the Brazilian coast, or lying undisturbed in the mud of the Rio de la Plata.

[Illustration: The last look just before going down.]

[Illustration: Coming up after a successful trip.]

At the end of 1885, the large steamer Imbus, belonging to the P. & O. Co., sank off Trincomalee, having on board a very valuable East-India cargo, together with a large amount of specie. This was another case of a fortune found in the sea, for a very large amount of treasure was recovered.

Another wreck from which a large sum of gold coin and bullion was recovered by divers, was that of the French ship "L'Orient." She is stated to have had on board specie to the value of no less than $3,000,000, besides other treasure.

A parallel case to "L'Orient" is that of the "Lutine," a warship of thirty-two guns, wrecked off the coast of Holland. This vessel sailed from the Yarmouth Roads with an immense quantity of treasure for the Texel. In the course of the day it came on to blow a heavy gale; the vessel was lost and went to pieces. Salvage operations by divers, during eighteen months, resulted in the recovery of £400,000 in specie.

Humorous scenes do not play much of a part on the ocean's bottom, and the sublime and awe-inspiring are far more in evidence there than the ludicrous, yet even beneath the waves there are laughable scenes at times. A diver had been engaged to inspect a sunken vessel off the coast of Cuba. Arriving on the scene he discovered a number of native sponge-divers, who descend to considerable depths, diving down from their canoes to the sunken vessel trying to pick up something of value. They paid little attention to the arrival of the wrecking outfit, and did not notice the diver descend, until suddenly what seemed to them to be a horrible human-shaped monster, with an immense head of glistening copper and three big, round, glassy eyes, came walking around the vessel's bow and made a big salaam to them. That was enough. They shot surfaceward like sky-rockets, climbed frantically into their canoes and hurriedly rowed away.

What Happens When Anything Explodes?

By explosives are meant substances that can be made to give off a large quantity of gas in an exceedingly short time, and the shorter the time required for the production of the gas the greater will be the violence of the explosion. Many substances that

ordinarily have no explosive qualities may be made to act as explosives under certain circumstances. Water, for example, has caused very destructive boiler explosions when a quantity of it has been allowed to enter an empty boiler that had become red hot. Particles of dust in the air have occasioned explosions in saw mills, where the air always contains large quantities of dust. A flame introduced into air that is heavily laden with dust may cause a sudden burning of the particles near it, and from these the fire may be conveyed so rapidly to the others that the heat will cause the air to expand suddenly, and this, together with the formation of gases from the burning, will cause an explosion.

It must not be thought, however, that fine sawdust or water would ordinarily be classed as explosives. The term is generally applied only to those substances that may be very easily caused to explode.

The oldest, and most widely known, explosive that we possess is gunpowder, the invention of which is generally credited to the Chinese. It is a mixture of potassium nitrate, or saltpeter, with powdered charcoal and sulphur. The proportions in which these substances are mixed vary in different kinds of powder, but they usually do not differ much from the following:

Sulphur 10 per cent. Charcoal 16 per cent. Saltpeter 74 per cent.

The explosive quality of gunpowder is due to the fact that it will burn with great rapidity without contact with the air, and that in burning it liberates large volumes of gas. When a spark is introduced into it, the carbon, charcoal, and sulphur combine with a portion of the oxygen contained in the saltpeter to form carbonic acid gas and sulphurous acid gas, and at the same time the nitrogen contained in the saltpeter is set free in the gaseous form. This action takes place very suddenly, and the volume of gas set free is so much greater than that of the powder that an explosion follows.

In the manufacture of gunpowder all that is absolutely necessary is to mix the three ingredients thoroughly and in the proper proportions. But to fit the powder for use in firing small arms and cannon it is made into grains of various sizes, the small sizes being used for the small arms with short barrels, and the large sizes for cannon. The reason for this is that if the powder is made in very small grains it all burns at once, and the explosion takes place so suddenly that an exceedingly strong gun is required to withstand the explosion, while if larger grains are employed the burning is slower and continues until the projectile has traveled to the muzzle of the gun. In this way the projectile is fired from the gun with as much force as if the explosion had taken place at once, but there is less strain on the gun.

What Causes the Smoke When a Gun Goes Off?

Powder of this latter kind always produces a considerable quantity of smoke when it is fired, because there is a quantity of fine particles formed from the breaking up of the saltpeter and from some of the charcoal which is not completely burned. This smoke forms a cloud that takes some time to clear away, which is a very objectionable feature. In order to get rid of it, efforts were made to produce a substance that would explode without leaving any solid residue, and that could be used in guns. These efforts were finally successful, and there are now several brands of smokeless powder in use.

What is Smokeless Powder Made Of?

The most satisfactory forms of smokeless powder are all made from guncotton or nitrocellulose. This substance, which is made by treating cotton with a mixture of nitric and sulphuric acids, is a chemical compound, not a mixture like gunpowder; and when it is exploded it is all converted into gases, of which the chief ones are carbonic acid gas, nitrogen, and water-vapor. To cause the explosion of guncotton it is not necessary to burn it, but a mere shock or jar will cause it to decompose with explosive violence. Of course, such a violent explosive as this could not be used either in small arms or in cannon, but guncotton can be converted into less explosive forms which are suitable for use in guns, and the majority, of smokeless powders are made in this way. The methods used in producing the smokeless powders are kept secret by the various countries that use them.

What is Nitroglycerine?

Another very powerful explosive, which is closely related to guncotton, is nitroglycerine. This compound is made by treating glycerine with the same sort of acid mixture that is used in making guncotton. It explodes in the same way that guncotton does and yields the same products. It is an oily liquid of yellow color, and on account of its liquid form it is difficult to handle and use. The difficulty in handling nitroglycerine led to the plan of mixing it with a quantity of very fine sand called infusorial earth. When mixed

with this a solid mass called dynamite is formed, which is easier to handle and more difficult to explode, but which has almost as much explosive force as nitroglycerine.

A more powerful explosive than either nitroglycerine or guncotton is obtained by mixing them together. When this is done the guncotton swells up by absorbing the nitroglycerine and becomes a brownish, jelly-like substance that is known as blasting gelatin. This is generally considered the most powerful explosive obtainable.

What Makes Nitroglycerine and Guncotton Explode So Readily?

Let us now consider for the moment what it is that makes guncotton, nitroglycerine, and blasting gelatin explode so readily. The explanation is found in the presence in them of nitrogen. As you remember from what you learned about air, nitrogen is an extremely inactive element. It has no strong tendency to combine with other elements, and when it does enter into combination with them the compounds formed are almost always easily decomposed. In the compounds that have just been described a shock causes a loosening of the bonds that hold the nitrogen, and the whole compound goes to pieces just as an arch falls when the keystone is removed.

What Is Silver?

Since the earliest time recorded in history, silver has been the most used of the precious metals, both in the arts and as a medium of exchange. Even in the prehistoric times silver mines were worked and the metal was employed in the ornamental and useful arts. It was not so early used as money, and when it began to be adopted for this purpose, it was made into bars or rings and sold by weight. The first regular coinage of either gold or silver was in Phrygia, or Lydia, in Asia Minor. Silver was used in the arts by the Athenians, the Phœnicians, the Vikings, the Aztecs, the Peruvians, and in fact by all the civilized and semi-civilized nations of antiquity. It is found in almost every part of the globe, usually in combination with other metals. The mines in South America, Mexico, and the United States are especially rich. Silver is sometimes found in huge nuggets. A mass weighing 800 pounds was found in Peru, and it is claimed that one of 2,700 pounds was extracted in Mexico. The ratio of the value of silver and gold has varied greatly. At the Christian era it was 9 to 1; 500 A.D. it was 18 to 1; but in 1100 A.D. it was only 8 to 1. In 1893 it was as high as 2,577 to 1. The subject has entered largely into American politics as a disturbing element, and in 1896 the Democratic party, in its national convention, declared for the free coinage of the metals at 16 to 1. The Republican party adhered to the gold standard and declared against the free coinage of silver. Each party reaffirmed in 1900 this plank in its platform. In both years the Democrats were defeated.

What Is Worry?

Worry is a feeling of fear, but is never of the present. It is always about something that may happen or that has happened. It is generally in the future, sometimes in the past, but never in the present.

An animal that knows neither future nor past cannot worry. Babies, living only as they do in the present, cannot worry. All creatures, excepting human beings, live only in the present and therefore they do not worry, for such creatures cannot remember what happened in the past or guess what is going to happen.

A human being after arriving at a certain age is given such powers that his mind can go back to the past and cast itself forward into the future as he thinks it will be, because he has imagination. As a matter of fact we live less in the present than in the past or future.

Why Do We Worry?

We worry because we are able through a power called self-consciousness to place ourselves through our minds for the time being. Either--back somewhere in the past without carrying our physical bodies with us; for if we could take our bodies with us, we would be in the present again, and then worry is impossible; or, we use our imagination and project the future entirely apart from our bodies, for we cannot project our bodies into the future, and if we could we would again be in the present. We worry over going to have an operation performed which may or not be dangerous, but quite necessary. We may still think we worry when the operation begins, but as soon as that occurs the time becomes the present, and though we may fear, we cannot worry in the present.

[Illustration:

Back View of Shield

Longitudinal Section through Shield & Tunnel

Diagram showing method of tunnel construction by shield and compressed air.

Scale; ½■ inch · 1 foot

Jacobs & Davies Inc. 30 Church St. N.Y.

Oct. 15. 1910.

FIGURE 1.]

The Story in a Tunnel

How a Tunnel Is Dug Under Water.

Fig. 1. On the left is a cross section showing, in diagram, the back view of a shield. The heavy black circle is the "tail" or "skin." The small circles within the tail are the hydraulic rams which at a pressure of 5,000 pounds to the square inch force the shield forward. The square compartments within the shield are the openings through which the men pass to dig away the ground. In the middle of the shield is shown the swinging "erector" which picks up the iron lining plates and puts them in position.

The view on the right is a longitudinal section of the tunnel showing the shield and the bulkhead wall across the tunnel with the air locks built into it. The front of the shield ahead of the doors is made with a sharp edge called the "cutting edge" and this makes it easier for the shield to advance in case all the ground in front has not been removed. This view shows how the tail overlaps the last portion of the iron lining.

Some distance behind the shield comes the concrete bulkhead wall with the air locks contained in it. There are two shown in the view. The upper one is the emergency air lock, always kept ready so that in case of an accident the men have a means of escape even though the lower part of the tunnel is filled with rushing water or mud. The lower air lock is for the passage of men and materials during ordinary working. This view also shows that all the tunnel ahead of the bulkhead wall is under compressed air while the finished tunnel behind the bulkhead wall is under the ordinary or normal air pressure. When the tunnel is finished the air locks and bulkhead walls are removed.

[Illustration: FRONT VIEW OF A DRIVING SHIELD

This shows the front of one of the shields used on the Pennsylvania Railroad tunnels crossing the North River at New York. The cutting edge is clearly seen and the various compartments, each with its door, which divide up the front of the shield. These shields weighed about 200 tons each.]

HOW TUNNELS ARE BUILT.

These notes describe very generally the way in which tunnels are built through mud and gravel under parts of the sea or large rivers in such a way that the men who build them are protected and as safe as the carpenter who is building a house.

The way these tunnels are built is called the "shield" way because the machine used is called a shield. It is given this name because it shields the tunnel builders from the water and the mud which are ready at every moment to overwhelm them and kill them.

The shield was invented in 1818 by a great Engineer, Marc Isambard Brunel, who was a Frenchman living in England. The idea of the shield came to him as he saw how the sea worm which attacks the wooden piles of docks along the shore bores the holes it makes in the wood. The head of this worm is very hard and can bite its way through the hardest woods. As it goes through the wood its body makes a hard shelly coating which lines the holes which its head has made and prevents the hole from getting filled up. This is the general idea of a tunnel built by a shield.

The first shield was used by Mr. Brunel to make a tunnel across the Thames River at London, England. This is still the biggest tunnel ever built by a shield, although not the longest, and is still used by railroad trains. This tunnel was begun in 1825 and was finished in 1843, and provides a history of almost unexampled and not-to-be-excelled courage in attacking difficulties and skill in defeating them.

Since the days of Brunel many great improvements have been made in the shield and in the way of working it but the same idea is still there.

[Illustration: HOW THE SHIELD IS PUSHED FORWARD

This shows the rear end or tail end of one of the smaller shields, used on the Hudson and Manhattan Railroad tunnels under the North or Hudson River at New York. It shows the skin, the hydraulic jacks within the skin and the piping and valves for working them. It also shows the doors leading to the front or "face." The erector is not shown, but the circular hole in the middle shows where it would be attached.]

[Illustration: This shows one side of an air lock bulkhead wall with the air lock in place. The boiler-like appearance of the lock is clearly visible, as well as the door and the pressure gauge to tell the air pressure inside the lock.]

[Illustration: This is a rear view of one of the Pennsylvania Tunnel shields, taken after a length of tunnel had been completed. All the details of construction are shown, but in this case the erector is clearly seen also. The valves which control the erector and the rams which push the shield forward are seen near the top of the shield. The rods across the tunnel are turn-buckles used to keep the iron lining from getting out of shape in the soft mud. These are removed later. The floor and tracks in the bottom are temporary and are used for bringing materials to and from the shield.]

After the days of Brunel's shield another great help was given to tunnel builders by the invention of the use of compressed air to hold back the water which saturates the ground in which the tunnel is being built.

~WHO INVENTED THE COMPRESSED AIR METHOD~

The first real invention of compressed air for this purpose was made by Admiral Sir Thomas Cochrane who, in 1830, took out a patent for the use of compressed air to expel the water from the ground in shafts and tunnels and, by this means, to convert the ground from a condition of quicksand to one of firmness. This patent covers all the essential features of compressed air working.

As suggested above, the thing which compressed air does in a tunnel is to push the water out from all the spaces which it fills in the ground, so that the men who are digging away the ground for the tunnel are working in firm dry ground instead of a mixture of earth and water which will run into and fill the hole they dig as soon as it is dug.

Whenever a tunnel is being built below a body of water through ground which is porous, or in other words through any ground except solid rock or dense clay, the water fills every crevice and space in the ground and is exerting a pressure of about half a pound per square inch above the ordinary pressure of the air, (which is 15 pounds to the square inch) for every foot of depth below the surface of the water; so that supposing the tunnel is 40 feet below the water the water has a pressure of nearly 20 pounds per square inch on every square inch of the surface of the tunnel. This pressure causes the water to flow violently into any hole or opening that is made in the ground, and, unless the water is prevented from moving by some means or other, the opening made would be very quickly filled with water and also with ground as the rush of water will carry the sand, gravel or mud with it.

By Cochrane's invention the whole tunnel is filled with air under a pressure equal to the pressure of the water. This compressed air therefore balances the pressure of the water and holds it back from moving, and if the pressure of the air is made slightly greater than that of the water the water is driven back from the tunnels for a short distance so that when the tunnel is being dug the ground instead of being wet is quite dry.

This explains the principles of the shield and compressed air way of making a tunnel.

The following describes very shortly how these principles are put to actual use.

Most tunnels which are built by shield and compressed air under rivers or arms of the sea are lined with cast iron plates to protect the railway or roadway which is in the tunnel.

The tunnel is a circular tube, or shell, and the plates have flanges on all sides which are bolted together. This shell is put into place, plate by plate, by means of the shield which not only protects the workmen and the work under construction, but which helps to build the iron shell. In fact it corresponds to the sea worm which bores through the wood and lines the hole with a shell. In the case of the tunnel the shell is made of iron. The shield itself consists of a steel tube or cylinder slightly bigger in diameter than the tube or tunnel it is intended to build. The front edge of this shield is made up of a ring of sharp edged castings which form what is called the "cutting edge." Just behind the cutting edge is a bulkhead or wall of steel, in which are openings which may be opened or closed at will. Behind this bulkhead are placed a number of hydraulic jacks or presses arranged around the shield and within it, so that by thrusting against the last erected ring of iron lining the whole shield is pushed forward. The rear end of the shield is a continuation of the cylinder which forms the front end, and this part, called the "tail," always overlaps the last few feet of the built up iron shell.

[Illustration: This is a photograph of a model of the Pennsylvania Tunnels to New York City, made for the Jamestown Tercentenary Exposition of 1907. It is given because it illustrates, as no photograph of actual work could do, the relationship between the shield, the tunnel itself and the air lock. This view shows the rear part of the shield on the extreme left, with the erector picking up an iron plate. It shows a man bringing a car with two of the iron plates up to the shield. Behind this man comes the bulkhead wall with the emergency air lock in the top and the ordinary air lock for passing in and out at the bottom. It also shows the upper platform to the emergency lock along which the men can get to the emergency lock in case of an accident.]

[Illustration: This is another view of the same model, but showing the front view of the shield. The doors on the air locks are clearly shown.]

[Illustration: This is a photograph taken in one of the Pennsylvania tunnels under the Hudson River. It shows the soft mud, through which the tunnel is being built, flowing in a thick stream through one of the doors of the shield. The mud under the Hudson, where these tunnels are, is so soft that often the shield was pushed through the mud with all the doors shut, so that no mud came into the tunnel and no digging had to be done, but the shield pushed its way bodily through the mud, the rings of iron lining being built up behind as usual. Generally, however, a certain amount of mud was brought in and had to be removed. This photograph shows how it looked.]

~HOW THE SHIELD CUTS THROUGH THE GROUND~

The diagram, Fig. 1, shows more clearly what is meant. From an inspection of Figure 1 it is clear that, when the openings in the shield bulkhead are closed, the tunnel is protected from an inrush of either water or earth; the openings in the bulkhead may be so regulated that control is maintained over the material passed through. After a ring of iron lining has been erected within the tail of the shield, the shield doors are opened and men go through them and dig out enough earth for the shield to go ahead. The rams are then thrust out thus pushing the shield ahead. Another ring of iron is built up within the tail for which purpose an hydraulic swinging arm, called the "erector," is mounted on the shield face. This erector picks up the plates and puts them into position, one by one, while the men bolt them together. Excavation is then carried on again and the whole round of work repeated, gaining every time the jacks are rammed or thrust out a length equal to the length of one ring of iron lining. In carrying out this work in ground charged with water the shield is assisted by introducing compressed air as described before. To use the compressed air thick bulkhead walls of masonry are built across the tunnel behind the shield and into the space between the shield and the bulkhead wall air is pumped, compressed to the same pressure as that of the water in the ground, or in other words the pressure of the air in pounds per square inch is about half the number of feet the tunnel is below the water surface. This dries the ground and simplifies enormously the difficulty of working in it. The diagram, (Fig. 1) shows a bulkhead wall across the tunnel. In order to pass from the ordinary air outside the bulkhead into the compressed air inside it, all the men and the materials have to pass through the "air locks" which are built into the wall. They are called air locks because they are like the locks on a canal which raise the water from a lower to a higher level or lower it from a higher to a lower level as the case may be. The difference is that an air lock enables one to pass from air at a low pressure to one of a higher, or vice versa. An air lock is made like a large boiler with a door at each end. If we wish to enter the compressed air we enter the lock from the outside. The door at the end has been tightly closed to prevent the compressed air from rushing out. We close the door behind us and are now tightly shut in the boiler-like lock. We now open a valve and compressed air begins to flow quickly into the air lock and the air gets hotter and hotter, due to the compression of the air. Very likely an intense pain begins to make itself felt in the ears but by swallowing hard and blowing the nose it may be relieved. It is caused by the air pressure being greater on the outside of the ear drum than on the inside. If the delicate ear passages are choked, because of a cold or some such reason, it is unsafe to go further or the ear drum may burst. When the pressure in the air lock has reached that in the working chamber, the door leading to the shield may be opened and we can pass to the working space and note the work going on. There is no especial bodily sensation to be felt except a slight exhilaration and it is curious to find that one

cannot whistle. On leaving the compressed air we enter the air lock by the door we left; a valve is turned and the air begins to escape and the pressure in the air lock begins to go down. As it does so the air becomes colder and colder and the whole lock is filled with a wet fog due to the chilling by expansion of the air. The air has to be allowed to escape very slowly, as bubbles of air and gas otherwise form in the blood vessels and tissues of the body giving rise to the very painful complaint known to tunnel builders as "the bends," and in very serious cases to paralysis and even death. The higher the air pressure the more slowly must one come out into the ordinary air.

[Illustration: MAKING THE JOINTS WATER TIGHT

This shows the erector building up the iron lining in one of the Pennsylvania tunnels at New York. It shows clearly how the iron plates are bolted together to make the rings of iron lining.]

[Illustration: The last, or closing, plate of each iron ring is called the "key," and is much shorter than the others. This photograph shows the shield erector on one of the Pennsylvania tunnels picking up and putting into place a key plate. This picture gives an idea of the mud and dirt and wet in which the men who work in tunnels have to do their work.]

[Illustration: Wherever possible, every space and crevice outside the iron lining is filled with cement forced, in a liquid state, through the iron lining by compressed air. This photograph shows the operation of "grouting," as it is called. The man at the left is in control of the grouting. He has the hose, through which the grout is forced, screwed to a pipe which passes through a hole made for the purpose in the iron lining plates and called a "grout hole." The two men in the middle of the picture are attending to the "grouting machine" by which the work is done. Water and cement are fed into the small boiler-like tank, the tank closed and compressed air admitted thus blowing the liquid cement through the hose and behind the iron lining. When no more grout can be forced behind the iron lining all the space has been filled. The man on the right is the engineers' inspector taking note of how much grouting is done, and seeing that the work is properly carried out.]

[Illustration: This shows the process by which the iron lining is made perfectly water-tight, so that, when the compressed air is taken off, no water at all can get into the tunnel. Two operations are shown here. One is called "grommetting the bolts," the other is called "caulking the joints." The two men on the left, hanging on to the wrench, are tightening up the bolts as tight as they can after having put on, underneath the washers at the head and nut of each bolt, a ring of spun yarn dipped in red lead and oil or tar or some such water-proof material. A few of these "grommets" may be seen at the feet of the third man from the left. The other four men are caulking the joints between the iron plates by driving into the joints a mixture of sal ammoniac and iron borings. This sets as hard as iron and if properly done makes a perfectly water-tight joint.]

[Illustration: THE REMARKABLE ACCURACY OF ENGINEERING

Usually when crossing, with a tunnel, a wide river or estuary the tunnel is started from each shore and the shields are pushed through the ground until they meet somewhere about the middle of the river. This shows two of the Pennsylvania tunnel shields which have met far below the Hudson River. The white arrow shows where each shield ends. The platform of one shield on which the man stands corresponds exactly with the platform of the other shield. As may be imagined, it takes very careful and skillful engineering and surveying work, both before the work is begun and while it is being carried out, to enable tunnel shields to meet like this. This part of the art of tunnelling would take an article to itself.]

When the shield has been pushed across the entire length of the water way which has to be tunnelled, and the whole of the iron tube or shell is in place, a thick lining of concrete is placed inside the iron shell to protect it and make the tunnel stronger. As an added safeguard wherever the tunnel is in rock, gravel, strong clay or other ground which is not so soft that it does not close tightly in on the outside of the tube, liquid cement is forced by compressed air through holes made in the iron plates for this purpose. This liquid cement enters every pore or crevice in the surrounding ground and when it has set hard it still further protects the iron with a coating of cement. Pieces have been cut out of the iron lining of a tunnel built under the river Thames at London, England, in 1869, which showed that the iron at all places was as good as the day it was first put in forty years before, and iron put in the lining of the Hudson River Tunnel about 1878 when removed after thirty years was in perfect condition.

[Illustration: SHIELD AT END OF JOURNEY

Sometimes, however, shields are not driven to meet one another, but end their journey at some shaft or in some other tunnel previously built, after having gone through thousands of feet of all kinds of ground, from the hardest rock, which had to be blasted out foot by foot before the shield could advance, through hard pan, gravel, boulders, piles, rip-rap, made ground and mud so soft

that it flows like melted butter. Naturally, after an experience like this a shield does not look as spick and span as when it started in life. This photograph shows one of the shields of the Hudson and Manhattan Railroad in New York just reaching the end of its journey, battered and bent but still in the ring.]

[Illustration: This shows a piece of curved tunnel near Morton Street, on the Hudson and Manhattan Railroad, and is given because of the clear showing it gives of the iron lining. The track and floor are only the temporary roads for use during construction.]

[Illustration: Sometimes it is necessary to make borings of the ground below the tunnels. In some of these bore holes vast quantities of water are found at a much higher pressure than the tunnel compressed air. This picture shows a spouting bore hole in one of the Pennsylvania tunnels during construction.]

[Illustration: The last thing to do before laying the track is to put the concrete inside the iron lining. This picture shows this work going on and the wooden forms or ribs for holding up the concrete while it is setting.]

[Illustration: THE LAND END OF A GREAT TUNNEL UNDER THE HUDSON

This view is given to show how complicated an underground structure may have to be made to take care of the requirements of traffic. This view shows the three great reinforced concrete caissons sunk through the earth at Jersey City in order to contain the switches and crossings required to form the New Jersey connections of the uptown and downtown tunnels of the Hudson and Manhattan Railroad.

These caissons were sunk under air pressure by excavating below them just as though they were tunnels turned up on end. In sinking these caissons the material passed through was water-logged made ground, and the hulls of two sunken canal boats were encountered and had to be cut into pieces small enough to be taken out through the locks.

The usual passenger rushing at high speed in the trains between Jersey City and Newark and New York has little idea of the very complicated structure necessary to allow of his doing so.

The information in this article was supplied by Jacobs & Davies, Inc., Consulting Engineers, 30 Church Street, New York, the Engineers for the Pennsylvania Railroad, Hudson River Tunnels, the Hudson and Manhattan Railroad, and many other tunnels in various parts of the world.

The illustrations were kindly supplied by the Pennsylvania Railroad and the Hudson and Manhattan Railroad.]

~DANGERS OF TUNNEL BUILDING~

This account of tunnelling by shield and compressed air is very short and gives no more than a bare statement of the principles and chief methods of such work. Nothing has been said of the engineering difficulties involved in the design of such work, nor of the delicate surveying work necessary if one should hope to start two shields a mile or two apart and have them meet as shown in Fig. 13 like two great glass tumblers placed rim to rim after having travelled through thousands of feet of every kind of ground. Nothing has been said of the men who work on this most arduous form of subterranean navigation, how they cheerfully face the dark and the water ever threatening above them and the unseen but not less deadly ally, and yet foe, the compressed air, with its dreaded result, the bends, or the men on the surface who keep the air compressors running without pause or stop day in and day out until the work is done so that their comrades below may work in safety. Nothing has been said of the curious accidents that are liable to occur as when the air pressure in the tunnel gets too high, overbalances the water pressure and blows a hole through the river-bed and forms a geyser in the river above. It gives no account of the special difficulties which arise when special conditions are found; for example, when the lower part of the tunnel is in rock and the upper part is in soft material. In fact it is nothing more than a bare outline but it hoped that some, who may not be clear in their minds as to how tunnels are built, may learn some of the first principles of this most romantic kind of work from this bald narrative.

Why Do My Teeth Chatter?

Your teeth chatter because when you are cold in a way that makes your teeth chatter the little muscles which close the jaw act in a series of quick little contractions which pull the jaw up, and then let it fall by its own weight. This is repeated many times and, as the action is quick, the chattering occurs. It is a peculiar thing that this occurs in spite of the will or brain, when, as a matter of fact, these muscles which operate the jaws are especially under the control of the brain. The chattering is really a spasm caused by the cold, and all spasms act independent of the will. Cold seems to act on the jaw muscles a good deal like some poisons which cause

spasms.

Where Did All the Water in the Oceans Come From?

No, it did not come from the rivers which empty themselves into the oceans, because the oceans were there before the rivers existed. Part of it comes from the rivers now, but only a little in comparison to all the water there is in the ocean. I will try to tell you simply how all the water got into the ocean.

There was a time when there was no water on the earth at all. That was when the earth was red hot, just as it is to-day on the inside, and at that time all the water we have to-day was up in the air in the form of gases. Strange as it may seem to you, if you take two gases, one called hydrogen and the other oxygen, and mix them the right way, they will turn into water, and if you had the right kind of chemical apparatus you could take water and turn it into these gases again. When, then, the earth was still all red hot, all of our water was up in the air in the form of these two gases. Then, later on, when the amount of heat on the earth was just right to make these gases mix together, the water came down out of the air in great quantities, and there was so much of it that it completely covered the whole earth and no land was visible. Later on, for various reasons, mountains were thrown up on the earth's surface by great earthquakes, and every time a mountain or a high place was formed there had to be a hole or low place some place else, and the water ran into these low places and stayed there, and that uncovered more of the land, because there wasn't enough water to fill all the holes and cover the land too, and that is what makes our continents and islands and all of the land we see. There is now about three times as much earth covered with water as there is land. Of course, the sun is always picking up water through what is called evaporation, which means that it is taken into the air in the form of gases. Later it comes down again in the form of rain and falls into the oceans or on the land, where it sinks in, finally finding a stream or river, and sooner or later gets back into the ocean again.

Why Don't the Water in the Ocean Sink In?

This is due to the fact that there is a kind of substance at the bottom of the ocean which the water cannot penetrate, in spite of the tremendous pressure which the great body of deep water exerts. In all places where the bottom of the ocean has a covering which water can sink into it does so, but there are such a few places where this is possible, by comparison, that the amount that gets out that way is not noticeable. This water, if it can keep on going, will eventually reach the inside of the earth, where it is red hot, and is turned into steam.

Where Does the Water in the Ocean Go at Low Tide?

To get to the answer of this you must know something about the tides. The tide is caused by the pull of the moon on the waters in the ocean. The moon revolves about the earth once each day and has the ability to draw up the waters in the ocean toward it, as we have seen in our study of the tides.

Now, when it is high tide in one place it is low tide in another. The moon does not make more water, but only pulls it toward it from side to side. When it is low tide where we are the water has simply moved as a body toward the place where it is high tide.

The tides act a good deal like a see-saw, except that they move from side to side instead of up and down. When one end of the see-saw goes up the other end goes down, and when the "down" end comes up the other end goes down. So the answer to your question really is that at low tide the water which made it high tide a few hours before has gone to some place where it is at that moment high tide.

Why Does the Ocean Look Blue at Times and at Other Times Green?

Sometimes when we look at the ocean from the pavilion or while on the sand of our favorite bathing beach the water in the ocean looks very beautifully blue, and on other days will look dark green from the same point. Why is it? If you will stop to think that at night when there is no moon or other light the water in the ocean looks black, I think you will soon be on the right track to answer the question yourself.

When the sky is blue--the kind of blue we like to see in the sky when we are at the beach--the water in the ocean is blue, because the sea reflects the color of the sky, and when the sky is overcast and gray the color reflected by the sea will be gray also.

But, say you, sometimes the water in the ocean is dark green, and yet the sky is never green. Quite true, and I will try to tell you what produces the green color. This happens sometimes where the water is shallow, either near the shore or out further where there is a sandbar or other shallow place. Sometimes at such points the sunlight strikes the water at such an angle that the rays go clear to the bottom and are reflected from that point--the bottom--to our eyes. In such a case the light will be changed through a combination of the color of the bottom at that point and the color of the sky itself at the time to make the color green as it is reflected to our eyes from the bottom.

Why Does Water Run?

Water runs because it has not enough of anything in it to make it stick together.

In school language we call this sticking-together-thing "cohesion." The principle of cohesion makes all the difference there is, so to speak, between solids, liquids and gases. A brick, a stone, a stick of wood, or a piece of iron and all other solid substances have a certain amount of this property of cohesion, and the particles stick together, enabling us to build buildings and other things which become permanent structures. These solid substances are either naturally cohesive or else man, as in the case of the brick, has brought together certain things with little or no cohesion and made them stick together permanently. In the case of the brick, he takes a quantity of clay, which is cohesive only to a certain degree, bakes it in an oven and it becomes hard enough--more cohesive--so that he can pile one on top of the other and make a building. Then he puts sand, mixed with other things--lime and water--between the bricks to hold the bricks together, and makes a structure that will last. Two bricks have no natural cohesion for each other and, therefore, they can only be held together by something that has cohesion within itself and also for the bricks. The lime, sand and water make mortar which is cohesive when properly mixed, while in themselves neither lime nor sand have much cohesive property, and water has none at all.

Liquids have little or no cohesion. Water has none, or very little. Syrup has a good deal more, but will run over the edge of a piece of bread and butter if you are not careful.

Gases have no cohesive properties at all and, therefore, fly all over the place, through any opening they can find, either at the top of the room or under the crack of the door. They are always trying to get to some place else and will keep moving as long as not confined. Gases can move in any direction.

Liquids, however, while they are inclined to be constantly on the move, can only go in one direction--down hill, and they go down fast or slow if there is a chance, in proportion to the amount of stick-together properties they have. Liquids can never go up of their own accord, excepting in the process of evaporation, and then only when changed into gases. A lake of water will dry up completely by evaporation unless fed by streams of water constantly flowing in, because evaporation is constantly taking place wherever water is exposed to the air.

What Makes the Water Boil?

What we call boiling in the water we see when water is put over a hot fire long enough to make it boil, is the changing of the water from what we generally regard it--a liquid--into gases. Water consists of two gases--hydrogen and oxygen--in fact, two parts of hydrogen gas and one part of oxygen gas when mixed will always make pure water. Now, then, if liquid water is heated to a certain point or temperature it turns into the two gases, oxygen and hydrogen, and comes to the top of the water, which still remains in liquid form, in the form of a bubble and explodes into the air--not a very loud explosion, but still an explosion. The process of turning liquid water into gases is a gradual one, and that is why the water does not all turn into one large bubble at once and explode away. If you keep the fire going long enough, all the water in the vessel will explode away into the air, a few bubbles at a time. If you hold a cold plate over the vessel as the bubble explodes you can catch some of these gases in the form of bubbles on the under side of the plate, which are again liquid water. When the water becomes hot enough it turns into bubbles and as bubbles rise that is what makes the boiling you see. When the same gases then come together again in a certain proportion under proper temperature they turn into liquid water.

At What Point of Heat Does Water Boil?

The boiling point of water is the temperature at which it begins to pass into the form of gases. This varies in different altitudes. At the sea level the boiling point is at 212° Fahrenheit. On the top of mountains, for instance, water would boil at a much lower

temperature. It would be possible to go high enough in a balloon so that the water would fly from the pan in the form of gas without making the water hot. Also, a mile below the level of the sea it would take many more degrees of heat to make the water boil. It is said that high up in a balloon you could not boil an egg hard in a pan of boiling water if you kept it in the boiling water for an hour or more, whereas we know that an egg will be hard-boiled if we keep it in boiling water down where we live for more than five minutes.

The degree of heat at which water passes away into the form of gases is regulated by the pressure of the air on the water and other things about us. At the average level in the United States where people live the pressure of the air on everything is fifteen pounds to the square inch, and at this pressure water boils only after it reaches a temperature of 212° Fahrenheit. As we go up the mountains the pressure becomes less and less as we go up. At the top of Mount Blanc, which is 15,781 feet high, water boils at 185° Fahrenheit. If we took a balloon from the top of the mountain we would come to a height where there was no air pressure at all.

What Do We Mean by Fahrenheit?

The name Fahrenheit is used to distinguish the kind of scale most commonly used on thermometers in Great Britain and the United States. Gabriel Daniel Fahrenheit, a native of Dantzic, made the first thermometer on which this scale was used, and it is named after him. In this scale for thermometers the space between the freezing point and the boiling point is divided into 180 degrees--the point for freezing being marked 32 degrees and the boiling point 212 degrees.

Why Can't We Swim as Easily in Fresh Water as in Salt Water?

Our bodies are heavier than fresh water, i. e., a bulk of fresh water equal to the size of our body would weigh less than our body, so that the first tendency is to sink to the bottom if we find ourselves in fresh water. If man had not learned to swim that is what he would always do, sink to the bottom; but having learned how to keep from sinking, he is able to swim in fresh water. However, we find that an amount of salt water equal to the bulk of a man in size is heavier than an equal amount of fresh water, although such a bulk of ordinary salt sea water will still weigh less than the man. A man will sink in salt water also if he has not learned to swim or float, but he can keep up with less effort in salt water, and also swim in it more easily. In a nutshell, then, the answer to this question is that salt water is heavier than fresh water. You can make salt water so full of salt that it becomes heavier than a man. Great Salt Lake in Utah is so salty that one cannot sink in it for this reason. You could drown yourself in it, of course, by keeping your head under water, but whether in shallow water or deep water you would not sink in Great Salt Lake.

Why Do We Say Some Water Is Hard and Other Water Soft?

What we call hard water contains certain salts which soft water does not contain. This salt in hard water is lime or some other salts which the water has picked up out of the ground as it passed through either coming up or going down. On the other hand, we can guess after having been told this much that if we can find any water that has not passed through the ground, and, therefore, not had a chance to pick up any salts, we will have soft water. From that point it is easy to guess, then, that rain water must be soft water, and so it is. The water in the cisterns, which is rain water, is soft water, and the kind we get out of the wells is hard water.

We do not like to wash either our faces or our clothes in hard water, especially when it is necessary to use soap, because when we use soap with hard water the soap undergoes chemical change which prevents its dissolving in the water. Therefore, you cannot easily do a good job of washing in hard water. On the other hand it is easy to dissolve the soap in pure rain water or soft water and that is the kind we, therefore, prefer for washing.

How Does Water Put a Fire Out?

This is at first a puzzling question, because back in your mind is the thought that since hydrogen and oxygen are necessary to make a fire burn, it seems strange that water, which is composed of oxygen and hydrogen, will also put it out.

A burning fire throws off heat, but if too much of the heat is taken from the fire suddenly the temperature of the fire is sent down so far below the point at which the oxygen of the air will combine with it that the fire cannot burn. We speak commonly as though water thrown on a fire drowns it. That is practically what happens. Scientifically what happens is that the water thrown upon the fire absorbs so much of the heat to itself that the temperature of the fire is reduced below the point where oxygen will combine with the carbon in the burning material and the fire goes out.

To answer the unasked part of your question at the same time I will say that hydrogen and oxygen when combined as water will put the fire out rather than make it burn, more because when these gases take the form of water they are already once burned, and you know that anything, substance or gas, which has already been burned cannot be burned again. It required great heat to make oxygen and hydrogen combine and form water, and it also takes great heat to separate them again. So they are really burned once before they become water.

Where Does the Rain Go?

Eventually almost all of the rain that falls runs into the rivers and lakes and later finds its way into the ocean, where it is again taken up into the air by the sun's rays. But many other things happen to parts of the rain which do not find their way into the ocean. In the paved street, of course, where the water cannot sink in, it flows into the gutter and thence into the sewer and on down to the river or wherever it is that the sewers are emptied. You see, it depends very much on what the earth's surface is covered with at the place where the rain falls. When it strikes where there is vegetation a great deal of it stays in the soil at a depth of comparatively few feet. If it is soil where trees and other plants grow a great deal of it is sucked up from the ground by this vegetation and given back into the air through the leaves and flowers. Some of the rain keeps sinking on down into the earth until it strikes some substance like rock or clay, through which it cannot sink, and then it follows along this until it finds something it can get through and collects in a pool and forms an underground lake, and may cause a spring to flow. Then there are also worms and other forms of animal life in the earth which use up some of the water. But it all gets back into the air eventually to come down some time again in the form of rain.

Why Does Rain Make the Air Fresh?

The main answer to this question must be that the rain in coming down through the air drives the dust and other impurities which are in the air before it, and so cleans the air and makes it absolutely clean. In addition to this it is now stated that since very often rain is produced by electrical changes in the air, and that these electrical changes produce a gas called ozone, which has a delightfully fresh smell, it is this ozone that makes us say the air has become fresh.

The air above our cities is almost constantly filled with smoke, containing various poisonous gases, and these are driven away by the falling rain.

Then, too, there is always a greater or less accumulation of dirt, garbage and other things in the cities which give off offensive smells constantly, but which we do not notice always because we become used to them. When the rain comes down it washes the streets and destroys these smells, and that makes the air fresh and delightful to take into the lungs.

In the country the air is more nearly pure all the time, because the things which spoil the air in the city are not present.

Is a Train Harder to Stop Than to Start?

The answer is yes. It is harder to stop a train than to start it, or rather it takes more power. The speed of a train depends upon the motive power. When a train is stopped and you wish to start it, you must apply enough motive power to start it going. There must be enough power to move the weight of the train and overcome the friction of the wheels on the track. It is, of course, easier to move a thing that weighs less than a heavier one. If you throw a ball ten feet into the air, it will perhaps not sting your hand when you catch it on its return; but, if you throw it one hundred feet into the air, it will sting your hands when you catch it. Besides, it will come down faster the last ten feet of the way than the ball which you threw only ten feet into the air. This is because when movement is applied to anything you add power to it. The ball which comes down from one hundred feet in the air acquires more power in falling and it takes more power to stop it. A train in motion has not only the power of the weight of the train behind it, but also the additional weight which the movement of the train has given it. Therefore, it takes more power to stop it than to start it. To stop a train you must apply the same amount of power as is in the moving train because the power to stop any moving thing must always be at least as great as the power which is moving it.

What Makes the Knots In Boards?

We find knots in the boards which we notice in a lumber pile or in any other place where boards happen to be, because the smaller limbs which grow away from the larger limbs of trees grow from the inside as well as the outside of the tree.

When you see a knot in a board it means that before the tree was cut down and the log sawed up into boards, a limb was growing out from the inside of the tree at the spot where the knot occurs.

You will also find that the wood in the knot is harder generally than the rest of the board. This is because more strength is required at the base of a limb and in the part of the limb which grew inside the tree than in other parts, for the limb must be strong enough to support not only the limb itself, but also the smaller limbs which grow out of it.

How Many Stars Are There?

Man may never know how many stars there are. The best we can do is to figure on the number that can be seen with the largest telescopes which have been invented, for, of course, you know there must be many millions of them which to us are invisible. We have counted the stars so far as we can see them; or, rather, so far as we can photograph them. Astronomers have found that a photographic plate exposed to the stars will show more of them than can be seen by the naked eye. This is because the materials on a photographic plate are more sensitive to the light of the stars than the human eye. By this method man has been able in a way to count the stars he can see. It adds up to more than a hundred million of them. Astronomers found this out by taking photographs of the heavens at night, devoting one picture to each section, until the entire heavens had been covered, and then counting them.

[Illustration: WHERE PAINT COMES FROM

MAKING LEAD BUCKLES--THE FIRST STEP IN PAINT MAKING.]

The Story in a Can of Paint

Paint such as is most frequently used is the material used for painting buildings, such as houses, barns, stores, and many others which we need not mention here. This paint is used on these buildings mostly for two very important reasons--one being to beautify the buildings, the other being to protect them from the ravages of the weather, much in the same way that your clothes protect you from the weather.

Paint such as we mention here may be regarded as the most simple and useful form. You have no doubt frequently seen the painter-man spreading paint on some building, or perchance, you have seen your father doing it, and have noticed that paint is a fluid substance looking something like cream, which is applied to the surface to be painted with a suitable brush and is brushed out smoothly. After the first coat is dry, other coats are put on in the same way until enough paint has been put on to thoroughly hide the unevenness of the lumber and making it of a uniform color.

This paint is made by simply mixing together dry powder, which is usually called pigment, with a thin, yellowish liquid which is called linseed oil. In the earlier days, the painter-man mixed this paint himself whenever he desired to use it. In these more modern times, he usually buys this paint already prepared.

Perhaps a little history of the preparation of the package of a can of paint which he buys may be interesting to you.

Let us imagine that the can of paint is white. In this case, the pigment which is used is a white powder and is made of either metallic lead or metallic zinc. The preparation of this fine white powder is very interesting and requires considerable time to perfect.

Let us consider the pigment known as white lead first. This is produced by causing metallic lead, which is of a bluish-gray color and very heavy, to change from its original form by a process which is known as “corrosion.” This corrosion is brought about by first taking the metallic lead, which at this stage exists in large pieces known as “pigs.” These pigs of lead are melted in a furnace and then molded into small, thin shapes which are buckles.

[Illustration: HOW WHITE LEAD IS MADE

FILLING THE STACK WITH LEAD BUCKLES.]

[Illustration: LEAD BEING TAKEN OUT OF THE STACKS.

The next step is to take an earthenware vessel, which resembles an ordinary stone crock, and first pour into it a small quantity of acetic acid, which is about the same as table vinegar. Then the crock or pot is filled up with the lead buckles.

Where this white lead is made in a large way many thousands of these pots are placed in a building, the sides of which are walled up tight, the spaces between the crocks being filled in with tan bark. After the floor has been covered with a layer of these crocks, the layer is covered with boards, in order to provide a foundation for setting in the next layer of crocks and tan bark. The layer of boards also serves as a floor to keep the tan bark from falling into the open crocks on the tier below. This procedure is followed with tier after tier until the building is completely filled.

Corrosion of the metallic lead in the pots now begins, because the tan bark generates some heat, becoming finally quite warm. This heat causes the acetic acid or vinegar to throw off vapor or steam, which attacks the metallic lead, causing it to decompose or corrode. This process goes on for many weeks (sometimes as much as fifteen or sixteen weeks), until those buckles of metallic lead have become a mass of white powder and nearly all trace of the original metallic lead has disappeared.]

[Illustration: A LEAD BUCKLE AFTER CORROSION.]

[Illustration: A LEAD BUCKLE BEFORE CORROSION.]

[Illustration: HOW OXIDE OF ZINC IS OBTAINED

WASHING THE LEAD. SCREENS COVERED WITH CLOTH REMOVE ALL FOREIGN MATTER.

After these many weeks have passed, the pots containing the white powder of carbonate of lead, as it is called, is taken out of the building where corrosion took place, and the white deposit is put through an elaborate system of refining, which is called "washing," and, in fact, is really washed in water, and is then dried in very large copper pans. After being dried it is in the form of large white cakes, resembling pieces of chalk. These cakes are then passed through a mill, which grinds them to very fine powder, which is packed in barrels ready to be shipped and used by the paint-maker.]

[Illustration: FURNACE WHERE THE SULPHUR IS ROASTED OUT OF THE ORE.

Now that we have followed through the process of making the white-lead powder, or pigment, let us take a little time to study the preparation of the other white powder, known to the paint trade as "oxide of zinc." This is prepared in a manner quite different from that of the white lead.

First the ore which is mined from the earth containing the metallic zinc is carefully selected by expert workmen and placed in a special kind of furnace, being mixed with hard coal, such as we use in our heating stoves.]

[Illustration: A ZINC SMELTER--THE MEN KEEP THEIR MOUTHS COVERED SO AS NOT TO INHALE THE VAPOR, WHICH IS POISONOUS

The burning of the coal causes an intensely high temperature, sometimes being several thousand degrees. This causes the zinc ore to be consumed as it were or to pass into a form of vapor. This vapor is carried through huge pipes which are several feet in diameter and extend for a long distance. While these vapors are passing through these pipes it becomes cooled. After becoming cooled it takes on the form of very fine white powder, coming from the pipes in much the same way that snow falls from the sky in the winter. This is collected and placed in barrels, after which it is ready for the paint-maker without further preparation.]

~WHERE LINSEED OIL COMES FROM~

Since we have followed the preparation of the two important white pigments used in making our can of paint, it is now important that we devote a little thought to the liquid which is to be used. This is called "Linseed Oil." Linseed oil is of a golden yellow color, resembling the appearance of thin syrup which we sometimes have on the table. This oil is taken from the seed of the flax plant. It might better be called "Flaxseed Oil," yet it is not commonly known by that name, but is nearly always referred to as "Linseed Oil." Flax is grown in many parts of the world, the most important places being the United States of America, Dominion of Canada, Ireland, India and the Argentine Republic. In the United States, the seed is sown early in spring, much the same as is done with other crops, and ripens and is harvested early in the fall of the year. The harvesting and separation of the seed from the plant or straw is done very much in the same way that other crops, such as wheat and oats, are harvested. The seed is then taken to market and is ready for the extraction of the oil, which is done by men who are known as "oil crushers."

[Illustration: PRESSING OIL OUT OF FLAXSEED.]

[Illustration: REMOVING OIL CAKE FROM PRESS.]

The oil is extracted from the seed by a very simple process. Usually the seeds are heated by steaming them, after which they pass through a mill, being ground to a coarse mass, which is then placed in very powerful machines called "Hydraulic Oil Presses," which squeeze the oil from the seed, leaving the remainder in the form of large cakes which are then ground to a mealy-like powder which is used as food for cattle and is very much prized.

The oil which has been extracted by this process is put into large tanks where it is clarified and is then ready for the paint-maker. This oil is often referred to as "Vegetable Oil" and it has one very peculiar and very important characteristic which makes it useful and necessary for use in paint. This property is that of drying or becoming solid, losing all tendency to stickiness after it has been spread out thinly and exposed to the air for a short time.

[Illustration: WHERE LEAD IS GROUND IN OIL.]

[Illustration: WHERE PAINTS ARE MIXED.]

Now that we have given attention to the preparation of the most important things used in the making of our can of paint, let us look a little to the manner in which they are put together, and the result.

The oil is necessary in making paint in order to make it fluid, so that the paint may be brushed on to the wood or other surface, and also so that the pigment or powdered material which has been put into the paint will have something to hold it to the surface. The oil or other liquid which may be used is usually called "Binder" by the paint man because it binds the pigment in the paint and to the surface on which it has been spread or applied.

In a large paint factory, the two white pigments, lead and zinc, are mixed with linseed oil in large machines known as "Mixers" into a smooth paste which is then run through other machines called "Mills," where the paste is ground very fine into large tubes where the paint is finished by mixing in enough more oil to make it of the proper thickness or consistency for brushing. In this state it can be used, but would not be entirely satisfactory because it would dry very slowly. For that reason, the paint-maker adds in a small amount of what is known as "Drier," which causes the paint to dry much more rapidly after it is spread out on any surface.

The paint-maker may also add in a small amount of thin liquid called "Turpentine," which also aids in the drying and the working of the paint. Turpentine is a very thin liquid which looks like water, and it is derived from the sap of one species of pine which grows abundantly in the southern portion of the United States. The sap is taken from the tree by tapping the tree or making an incision called a box, at certain seasons. After the sap is collected it is put through a heating process called "distilling," which separates the water-white liquid, called turpentine, leaving a large mass of heavy material which is commonly known as "Rosin." This turpentine is very useful to the paint-maker and the painter. It is also used for many other purposes.

~WHAT MAKES THE DIFFERENT COLORS OF PAINT~

The paint which we have described is the most simple kind and is white. There are many other kinds of paint used, being of many different colors. All of these different kinds require different treatment and preparation and would require many large books to explain even in a brief way.

The white paint which we have described may be colored or tinted to many different hues by adding suitable color pigments. These color pigments are of many kinds and are derived from many different sources. The vegetable kingdom is represented as well as the mineral and animal kingdoms. The linseed oil which we have already mentioned, is derived from the vegetable kingdom. This also applies to some few of the pigments. A very important instance which we might mention is a beautiful rich brown called "Vandyke Brown." This is made from decayed vegetation which is found in swampy districts. There are many pigments derived from the mineral kingdom. White lead and zinc oxide have already been described as useful. Among colored pigments coming from this kingdom, we might mention yellow ochre, sienna, umber, cobalt blue, and many others.

The animal kingdom supplies quite a number, one of which is a beautiful red known as "Carmine." This is taken from a small insect or fly which is found in certain tropical climates. The production of carmine is very expensive and the product is highly prized.

Another important development of the animal world is what is called "Bone Black." This is made by taking ordinary animal bones, putting them into a suitable furnace and burning them, which really produces bone charcoal, which is refined by powdering and washing, and finally produces a beautiful black, such as used for painting fine coaches and carriages.

Why Does a Dog Turn Round and Round Before He Lies Down?

Away back in the history of the animal kingdom, when the ancestors of our domestic dog were wild, they slept in the woods or open. When they were ready to lie down, they first had to trample the grass about them flat to make a place to lie down. This became a habit and one of the instincts of the animal which has been transmitted to the dogs of today who keep it up. It is an inherited habit quite useless to the dogs of to-day.

How Is Light Produced?

You already learned that a substance called ether is found in all substances, filling the spaces between the molecules. When the molecules are made to vibrate, the ether naturally also vibrates. As soon as the vibrations become sufficiently rapid, they produce the sensation of light. These vibrations also produce heat. In heated bodies the molecules are always found to be in vibration, and a body may become so hot that it gives off light. We notice this when iron becomes red hot. Heat and light are found together in bodies in many instances. In fact, most of the light we have comes from bodies which are hot. The sun is so hot, that it is surrounded by the gases of many substances that exist as solids on earth.

We have some bodies which produce light which is not accompanied by much heat. The glow-worm, or firefly, seems to make light with little or no heat; but we do not yet know how this is done. Almost all sources of artificial light require that heat be produced before light obtained. Only such vibrations of the ether which are sufficiently rapid produce enough light to enable us to see. For this reason, a piece of red hot iron, which is made luminous by heat and whose particles vibrate less rapidly produce little light.

What Makes Rays of Light?

Whenever the ether is made to vibrate rapidly enough at any point, the vibrations go in straight lines from the source of light in all directions. A single line of vibrating particles in the ether, is known as a ray. A number of rays, that issue from one point, are said to form a pencil. A pencil of light may be produced by holding near a candle a screen, with a hole in it. Sometimes rays of light are brought together in a point, as may be done by means of a burning glass, and one of these bundles of rays is known as a convergent pencil.

A bundle of rays that lie parallel to each other forms a beam. The rays that come to us from the sun are practically parallel and are called sunbeams.

Why Does a Nail Get Hot When I Hammer It?

When we are in the sunshine, or standing before a fire, we feel hot; when we take snow or ice in our hands, they feel cold. The thing which produces these sensations is called heat. When we feel heat, it is because heat is absorbed by our bodies, and when we feel cold, it is being thrown off by them.

To answer this question, we must see how heat may be produced. If we draw a cord rapidly through our fingers, they feel hot, and if we rub a coin briskly with a cloth or our hands, it becomes warm; if we take a nail and hammer it on a hard substance, it becomes too warm for us to hold. In these instances heat is produced by retarding or checking the motion of a body. When we draw a cord through our fingers, it moves less easily; we retard its motion by gripping it and this is what makes the heat we feel. When we strike the nail with a hammer, the motion of the hammer is checked by the nail, and the faster we pound with the hammer, the hotter the nail becomes. From these experiments we learn that whenever the motion of a substance is checked, or retarded, heat is generated, and the substance made hot.

In explaining this method of producing heat, it was at one time thought that all bodies contained a substance which produced the heat and that, when rubbed or hammered, this substance was thrown off. About the end of the 18th century, however, it was shown by Benjamin Thompson (Count Rumford), that substances when rubbed give off heat. From this we learned that heat is not a substance, because the quantity of any substance, present in a body, cannot be limitless. If it were a substance which produced the heat, the supply would sooner or later be exhausted, and rubbing could no longer produce heat.

Heat produced by rubbing, or by striking substances together, is caused as follows: If two substances are struck upon each other, the whole of those substances are checked, but the molecules of the substances are made to vibrate very rapidly, and these vibrations produce the heat we feel.

How Do We Obtain Heat?

We get most of our heat from the sun. If the heat from the sun did not reach us, no living thing would exist on the earth. No plants or animals could live; the oceans and rivers would be solid ice.

Another important source of heat, is chemical action. Chemical action is what causes fire. Even when it does not cause fire, it produces a great deal of heat. When we breathe to keep our bodies warm, it is a chemical action that occurs. Fire is the most important form of chemical action, as a source of heat.

Why Does a Glow-Worm Glow?

A glow-worm is a kind of beetle which may be found in the yards and hedges in the summer time. The name applies only to the female of the species which is wingless and whose body resembles that of a caterpillar somewhat and emits a shining green light from the end of the abdomen. The male of this species has wings but does not show any light as does the female and resembles an ordinary beetle. The male flies about in the evenings looking for the female and she makes her light glow in order that the male may find her. Glow-worms are found mostly in England. There are, however, some members of the same species of beetle common to the United States. We speak of them as fireflies or lightning bugs. The female of these also is the only one carrying a light, although unlike the glow-worm she has wings and can fly.

Why Do They Call It Pin Money?

This expression originally came from the allowance which a husband gave his wife to purchase pins. At one time pins were dreadfully expensive so that only wealthy people could afford them and they were saved so carefully that in those days you could not have looked along the pavement and found a pin which you happened to be in need of as you can and often do today.

By a curious law the manufacturers of pins were only allowed to sell them on January 1st and 2nd each year and so when those days came around the women whose husbands could afford it, secured pin money from them and went out and got their pins.

Pins have become so very cheap in these days that we are rather careless with them, but the expression has continued to live although today when used, it means any allowance of money which a husband gives a wife for her personal expenses.

Pins were known and used as long ago as 1347 A. D. They were introduced into England in 1540. In 1824 an American named Might invented a machine for making pins which enabled them to be manufactured cheaply. About 1,500 tons of iron and brass are made into pins every year in the United States.

Why Do People Shake Hands With the Right Hand?

In the days of very long ago when all men were prepared to fight at any and all times because one could not know whether another approaching was a friend or an enemy, all men went armed. This was before the day of guns when the sword was the great weapon of defense.

Upon occasion when one man approached another, each had to decide whether the other came on a peaceful mission or not.

People in those days were mostly right handed as they are now and when fighting carried their swords in their right hands.

If, then, a man wished to speak with a stranger or, as might easily be necessary, to one who may even be known to be unfriendly, he put out his right hand upon approaching to show that he had no deadly or dangerous weapon in it. The other man could see this and knew from the extended open hand that no harm was intended and that the approach was peaceful. If, then, he was willing to meet the other, he also extended his right arm with the hand open to show him who was approaching that his fighting hand was empty also; and when they met each would grasp the hand of the other so that neither one could change his mind and assume a fighting attitude without the other having an equal warning.

How Did the Custom of Clinking Glasses When Drinking Originate?

In the days of the Roman gladiators, before a duel with swords, it became the custom of each of the participants to drink a glass of wine before fighting. Just before the fighting commenced two glasses of wine were brought and the gladiators drank. These two

glasses of wine were provided by the friends of either one or the other of the gladiators. To guard against treachery, through some over zealous friend of the fighters furnishing poisoned wine was necessary. So before drinking and to show there was no treachery, the gladiators came close together and poured wine from one glass into the other back and forth until the wine in the glasses was thoroughly mixed. If the wine in one glass then had been poisoned, the poisoned wine would thus be in both glasses, and if there had been any treachery, both gladiators would be poisoned if they drank. The wine was poured from one glass to the other to show that there was no treachery.

This custom continued in use for a long time until the idea of drinking before a fight was abandoned. The custom, however, of showing friendliness in this way while drinking continued for a long time. Later it became a mere custom, however, to show a friendly spirit toward the one who was drinking with you, and when the danger of poisoned wine was past, the actual act of pouring the wine from one glass to another was changed to merely touching the glasses together. Thus today we have the friendly custom of touching glasses together long after the necessity of guarding against treachery while drinking has passed.

Why Cannot Fishes Live In the Air?

It is a curious thing isn't it that if a boy falls into the water, he will drown if he cannot swim or someone does not help him out, and that if a fish falls out of the water onto the land, he will drown also, even though he knows how to swim, better than anything else he does. A boy cannot secure the air which he needs to live on if he is under the water, because there is not enough air for him there and a fish cannot secure enough air for him to live on when he is on land where the air is plentiful, because, the boy takes his air from the air itself and the fish gets his air out of the water.

To live by breathing the air we find on or above the land, it is necessary to have lungs and fishes do not have lungs. In the case of the boy under the water he would have to have gills to enable him to make use of the air which is in the water to live by and he has no gills.

A fish can only live a little while out of the water, but even so he can live longer out of the water than a boy can under the water.

Lest you read sometime of the flying fish and think they must be able to live out of the water, I will tell you before you ask the question that the flying fish never stays out of the water for more than a few seconds at a time. His flying leaps amount to little more than long leaps from wave to wave. He swims along very fast in the water, coming right up to the surface and out into the air and the speed at which he has been swimming regulates the distance he will go when he shoots into the air, as he has no means of propelling himself through the air, but only into it. He has, however, wing-like fins, which he spreads out when in the air and which enables him to glide through the air and thus remain in the air longer.

What Makes a Fish Move in Swimming?

This is a puzzling question, I am sure. Of course, you at once cause several other questions as soon as you ask this one such as the following: Does the water in front of him move out of the way and then close in behind him? If so, where does it go in the meantime? Does the fish move the water forward or up or down or what does he do?

The answer is, of course, in the movements of the fish's tail. The fish in swimming is surrounded with water, top, bottom and all sides of him. The pressure of the water on the fish is the same at all points so that any motion made by him would have a tendency to make him move. As a matter of fact the tail in moving from side to side creates a current in the water from the head to the tail, or rather would produce an actual current if the fish remained perfectly still. Instead of making an actual current of water, the body of the fish is moved forward.

As to whether the water ahead of him opens up first and then the water behind him is a more difficult question to answer. To the appearance it would seem as if the water moved at both ends and sides at once, but according to scientific theory, the water at the head of the fish is displaced first.

Why Are Birds' Eggs of Different Colors?

This is a wise provision of nature to help the mother birds hide her eggs away from the eyes of her enemies. In the animal kingdom every kind of life is the natural prey of some other kind of animal. A bird will have enemies which try to catch her as food. A bird cannot fight back, so must fly away when danger threatens, in order to save her life. This means that she must leave the eggs in

the nest for the time being. At certain times she must also leave her nest and search for food for herself. In order that the eggs so left alone may have a better chance of not being discovered, nature has arranged matters so that the eggs take the color very much of the surroundings in which they are laid. Eggs of some birds are spotted or look like pebbles, because the mother bird lays them in the sand. Some of them are green, almost the color of the materials from which the bird builds the nest, and so the colors have a real, and to the birds, a valuable purpose.

Why Does a Hen Cackle After Laying an Egg?

The hen cackles because she is glad. She is glad because she has just accomplished something, which she was put on earth to do. If you study the life on the earth carefully with this in mind, you will discover that all kinds of life give expression in some form of gladness, when they have performed the things they are on earth for. It's the hen's way of expressing herself and letting the chicken world know. The dog wags his tail when he is pleased; boys and girls jump up and down when they are pleased, whether they have been doing anything commendable or not. No doubt also the actual laying of the egg causes some discomfort to the hen and the corresponding feeling of gladness would come naturally after the discomfort disappeared.

Why Will Water Run Off a Duck's Back?

The reason that water runs of a duck's back, is that the feathers of ducks are oily and, as water and oil will not mix, the water runs off instead of soaking in. The feathers on a duck are so thick on the body of the duck, top and bottom, that even if it were not for the oil which is on the feathers the water would have some difficulty in soaking through the feathers. But the main reason why the feathers on a duck's back cause water striking them to run off is that the duck has an oil gland which is constantly producing grease or oil and which the duck uses in giving his feathers a thin coating of oil to make them slick with oil and when any water strikes the duck it runs off. Other birds which live in the water a great deal have this oil gland for the same reason.

THE STORY IN A STEEL RAIL

[Illustration: A Blast Furnace.

Molten iron is brought from the blast furnaces to the open-hearth furnaces, and dumped into a receptacle called a mixer, the capacity of which ranges from 400 tons to 1000 tons, depending upon the number of furnaces to be served.]

[Illustration: One-thousand-ton Mixer.]

Pictures in this story by courtesy of Bethlehem Steel Co.

[Illustration: INSIDE OF OPEN HEARTH FURNACE

Charging Side of an Open-hearth Furnace.

An open-hearth furnace consists of a long, shallow hearth, suitably enclosed in fire-brick, and bound together with steel binding. The furnace is heated by burning gas and air, which have previously been preheated, so that a temperature is obtained in the furnace ranging from 2900 to 3050 degrees Fahrenheit.]

[Illustration: Pouring Side of an Open-Hearth Furnace.

The open-hearth process consists of the purification of iron by oxidizing out the impurities and burning out the carbon of the iron until a tough and ductile steel is produced, which can be made of any desired composition by the addition of the necessary quantities of alloys just previous to tapping and pouring. The impurities in the iron are oxidized by the slag lying on top of the metal, and the burning out of the carbon, which is a very slow operation, is hastened by the addition of iron ore, the oxygen of which combines with the carbon of the iron and passes off is a gas going up the stack.

When an open-hearth furnace is ready for a charge, a variable amount of scrap, say 30 per cent of the total weight of material used for the heat, is charged into the furnace. With this scrap is charged sufficient lime or limestone to make the slag, as well as some iron ore to assist in reducing the carbon of the iron. In about two or three hours the required amount of molten iron is brought from the mixer in ladles, and poured into the furnace on top of the scrap, lime and ore.]

[Illustration: MOLTEN STEEL BEING POURED LIKE WATER

Molten Steel Being Poured Into Ladle.

When the scrap has all been melted, a test is taken to determine the amount of carbon remaining in the bath. Iron ore is added from time to time until the carbon in the bath has been reduced to the desired point, and the metal is sufficiently hot to pour. At this point "recarburizers" (consisting of Ferro-Manganese, Ferro-Silicon, and pig-iron, or coal) are added to get the required composition. The tap hole at the back of the furnace is opened, and the steel is allowed to run out into a ladle, the slag coming last and forming a blanket over the steel in the ladle.]

[Illustration: Crane Carrying Ingot and Soaking Pit Furnaces.

The ladle is picked up by an electric crane and carried over cast-iron moulds, which are set on cars, the steel being poured into the moulds, resulting in steel ingots. A sufficient amount of time is allowed for the steel to become chilled or set, when the cars are pushed under an electric stripper, where the moulds are removed from the ingots. After the ingots leave the stripper they are taken to the scales and weighed, and after weighing are put into the soaking pits. The pits get their name from the part they play in the heating of the steel for rolling. When the steel ingot is stripped the outside of the ingot is cool enough to hold the inside, which is still in a liquid state, and the steel is put into the soaking pits to allow the inside to settle into a solid mass, after which the ingot is reheated for rolling. The length of time in the soaking pits depends upon the size of the ingot, as the larger the ingot, the greater length of time is required to set.

When the steel is ready for rolling it is taken from the pits by overhead electric cranes, and placed into a dump buggy at the end of a roller line, which leads to the blooming mill. The dump buggy derives its name from the fact that when the ingot is placed into same in an upright position, the buggy, in order to place the ingot into a horizontal position on the roller line, dumps over, in the same way as if one were to rock too far forward in a rocking-chair, the dump buggy operating on the same principle.]

[Illustration: GETTING READY TO MAKE A RAIL

Blooming Mill and Engine.

The ingot travels down the movable-roller line to the blooming-mill rolls, which roll it down from a piece 19 inches by 23 inches to what is known as an 8 inch by 8 inch bloom, which is the size usually used in the manufacture of rails. The blooming mill derives its name from the fact that after an ingot is rolled in same it is no longer called an ingot, but a bloom.

After leaving the blooming mill the bloom travels along another roller line to the shears, where it is cut into two or three pieces, the number of pieces depending on the size of the rail which is to be rolled. The blooms are then lifted over the roller line at the shears by a transfer crane, and placed on a traveling roller line which connects with the rear of the reheating furnace. This furnace is about 35 feet long, and is so constructed that when the bloom is pushed in at the rear of the furnace, another bloom drops from the front or discharge end of the furnace.]

[Illustration: THE INGOT BECOMES A RAIL

The Ingot Becomes a Rail.

The bloom dropping out, being sufficiently hot to roll into rails, travels along another roller line to the roughing or first set of rolls. Here the bloom is given five passes in the rolls, and is then transferred to the strand or second set of rolls, where it receives five additional passes; after this operation it is transferred to the finishing or third set of rolls, in which it is given one pass. The bloom has now been converted into a rail, and the rail travels on another roller line to the hot saw, where it is cut into 33-foot lengths, this being the standard length in this country for all rails. The rails when hot are cut by the hot saw to lengths of about 33 feet 6½■ inches, the allowance of inches being made for shrinkage in cooling. It is difficult to believe that steel shrinks to this extent, but this is a fact, and while the rails are cooling on the hotbeds they have the appearance of being animated, as they move first one way and then the other. After the rails are on the hotbed a sufficient length of time to cool, they are taken from the hotbed and placed on a traveling roller line, which takes them to an endless chain conveyor. The statement that rails are put on hotbeds for cooling seems paradoxical, but the hotbeds are so called because the rails are placed on them while hot, and are left there until they have cooled.

The endless-chain conveyor places the rails on another bed, from which they are picked up by an electric crane and distributed to the straightening presses, where all burrs (which have been caused by the hot-sawing operation) are removed before the rails are straightened. After straightening they are transferred to drill presses, where they have holes drilled into them for the accommodation of the splice bar, after which they are placed on the loading docks.]

[Illustration: After being carefully examined by the railroad company's inspectors they are picked up from the loading docks by electric magnets attached to a crane, and are placed in cars ready for shipment.]

Who Made the First Felt Hat?

The felt hat is as old as Homer. The Greeks made them in skull-caps, conical, truncated, narrow- or broad-brimmed. The Phrygian bonnet was an elevated cap without a brim, the apex turned over in front. It is known as the "cap of liberty." An ancient figure of Liberty in the times of Antonius Livius, A.D. 115, holds the cap in the right hand. The Persians wore soft caps; plumed hats were the headdress of the Syrian corps of Xerxes; the broad-brim was worn by the Macedonian kings. Castor means a beaver. The Armenian captive wore a plug hat. The merchants of the fourteenth century wore a Flanders beaver. Charles VII, in 1469, wore a felt hat lined with red, and plumed. The English men and women in 1510 wore close woolen or knitted caps; two centuries ago hats were worn in the house. Pepys, in his diary, wrote: "September, 1664, got a severe cold because I took off my hat at dinner"; and again, in January, 1665, he got another cold by sitting too long with his head bare, to allow his wife's maid to comb his hair and wash his ears; and Lord Clarendon, in his essay, speaking of the decay of respect due the aged, says "that in his younger days he never kept his hat on before those older than himself, except at dinner." In the thirteenth century Pope Innocent IV allowed the cardinals the use of the scarlet cloth hat. The hats now in use are the cloth hat, leather hat, paper hat, silk hat, opera hat, spring-brim hat, and straw hat.

What Is the Hottest Spot on Earth?

The hottest regions on earth is said to be along the Persian Gulf, where little or no rain falls. At Bahrein the arid shore has no fresh water, yet a comparatively numerous population contrive to live there, thanks to the copious springs which break forth from the bottom of the sea. The fresh water is got by diving. The diver, sitting in his boat, winds a great goat-skin bag around his left arm, the hand grasping its mouth; then he takes in his right hand a heavy stone, to which is attached a strong line, and thus equipped he plunges in, and quickly reaches the bottom. Instantly opening the bag over the strong jet of fresh water, he springs up the ascending current, at the same time closing the bag, and is helped aboard. The stone is then hauled up, and the diver, after taking breath, plunges in again. The source of the copious submarine springs is thought to be in the green hills of Osman, some 500 or 600 miles distant.

Where Do We Get Ivory?

Ivory is a hard substance, not unlike bone, of which the teeth of most mammals chiefly consist, the dentine or tooth-substance which in transverse sections shows lines of different color running in circular arcs. It is used extensively for industrial purposes and is derived from the elephant, walrus, hippopotamus, narwhal, and some other animals. The ivory of the tusks of the African elephant is held in the highest estimation by manufacturers; the tusks vary in size, ranging from a few ounces in weight to 170 pounds. Holtzapffel states that he saw fossil tusks on the banks of rivers of Northern Siberia which weighed 186 pounds each. Ivory is simply tooth-substance of exceptional hardness, toughness, and elasticity, due to the firmness and regularity of the dentinal tubules which radiate from the axial pulp-cavity to the periphery of the tooth.

How Did Trial by Jury Originate?

~WHY JURIES HAVE TWELVE MEN~

A jury consists of a certain number of men selected according to law and sworn to inquire into and determine facts concerning a cause or an accusation submitted to them, and to declare the truth according to the evidence. The custom of trying accused persons before a jury, as practised in this country and England, is the natural outgrowth of rudimentary forms of trial in vogue among our Anglo-Saxon ancestors. The present system of trial by jury is the result of a gradual growth under the English Common Law. There is no special reason why twelve is the usual number chosen for a complete jury except the necessity for limiting the

number. In a grand jury the number according to law must not be less than twelve nor more than twenty-three, and twelve votes are necessary to find an indictment. The ancient Romans also had a form of trial before a presiding judge and a body of judices. The right of trial by jury is guaranteed by the United States Constitution in all criminal cases, and in civil cases where the amount in dispute exceeds $20. A petit or trial jury consists of twelve men, selected by lot from among the citizens residing within the jurisdiction of the court. Their duty is to determine questions of fact in accordance with the weight of testimony presented and report their finding to the presiding judge. An impartial jury is assured by drawing by lot and then giving the accused, in a criminal case, the right to dismiss a certain number without reason and certain others for good cause. Each of the jurymen must meet certain legal requirements as to capacity in general and fitness for the particular case upon which he is to sit, and must take an oath to decide without prejudice and according to the testimony. A coroner's jury or jury of inquest is usually composed of from six to fifteen persons, summoned to inquire into the cause of sudden or unexplained deaths.

Can Animals Foretell the Weather?

Certain movements on the part of the animal creation before a change of weather appear to indicate a reasoning faculty. Such seems to be the case with the common garden spider, which, on the approach of rainy or windy weather, will be found to shorten and strengthen the guys of his web, lengthening the same when the storm is over. There is a popular superstition that it is unlucky for an angler to meet a single magpie, but two of the birds together are a good omen. The reason is that the birds foretell the coming of cold or stormy weather, and at such times, instead of searching for food for their young in pairs, one will always remain on the nest. Sea-gulls predict storms by assembling on the land, as they know that the rain will bring earthworms and larvæ to the surface. This, however, is merely a search for food, and is due to the same instinct which teaches the swallow to fly high in fine weather, and skim along the ground when foul is coming. They simply follow the flies and gnats, which remain in the warm strata of the air. The different tribes of wading birds always migrate before rain, likewise to hunt for food. Many birds foretell rain by warning cries and uneasy actions, and swine will carry hay and straw to hiding-places, oxen will lick themselves the wrong way of the hair, sheep will bleat and skip about, hogs turned out in the woods will come grunting and squealing, colts will rub their backs against the ground, crows will gather in crowds, crickets will sing more loudly, flies come into the house, frogs croak and change color to a dingier hue, dogs eat grass, and rooks soar like hawks. It is probable that many of these actions are due to actual uneasiness, similar to that which all who are troubled with corns or rheumatism experience before a storm, and are caused both by the variation in barometric pressure and the changes in the electrical condition of the atmosphere.

Nearest Approach Ever Made to Perpetual Motion in Mechanics.

An inventor has patented a double electric battery which seems to come exceedingly near to perpetual motion. Instead of using the zinc battery, he professes to have hit upon a solution which makes a battery seven times as powerful as the zinc battery, with absolutely no waste of material. The power of the battery grows gradually less in a few hours of use, but returns to its original unit when allowed to rest a few hours. He has two batteries so arranged that the power is shifted from one to the other every three hours. A little machine has been running for some years in the patent office at New York. Certain parts of the mechanism are constructed of different expansive capacities, and the machine is worked by the expansion and contraction of these under the usual variations of temperature. In the Bodleian Library at Oxford there is an apparatus which has chimed two little bells continuously for forty years, by the energy of an apparently inexhaustible "dry-pile" of very low electrical energy. A church clock in Brussels is wound up by atmospheric expansion induced by the heat of the sun. As long as the sun shines this clock will go till its works wear out. Mr. D. L. Goff, a wealthy American, has in his hall an old-fashioned clock, which, so long as the house is occupied, never runs down. Whenever the front door is opened or closed, the winding arrangements of the clock, which are connected with the door by a rod with gearing attachments, are given a turn, so that the persons leaving and entering the house keep the clock constantly wound up.

Do Plants Breathe?

Plants, like animals, breathe the air; plants breathe through their leaves and stems just as animals do by means of their respiratory organs. When a young plant is analyzed it is found to consist chiefly of water, which is all removed from the soil; there is about 75 per cent or more of this fluid present, and the rest is solid material. Of this latter by far the most abundant constituent is carbon, almost every atom of which is removed from the atmosphere by the vital action of minute bodies contained in the green leaves. The carbon is taken into the plant as carbonic acid gas. Plants also absorb oxygen, hydrogen, and nitrogen from the atmosphere in different quantities through their leaves, and also by means of their roots. These new products stored are in turn used in building up

the different organs of the plant. Plants give off used-up moisture through their leaves, just as animals perspire through the pores of their skins. Calculations have been made as to the amount of water thus perspired by plants. The sunflower, only 3½■ ft. high, with 5,616 square inches of surface exposed to the air, gives off as much moisture as a man.

What Depth of Snow Is Equivalent to an Inch of Rain?

Newly fallen snow having a depth of about 11½■ inches is equivalent to one inch of rain. A cubic foot of newly fallen snow weighs 5½■ pounds and a cubic foot of fresh or rain water weighs 62½■ pounds or 1,000 ounces. An inch of rain means a gallon of water spread over every two square feet, or about a hundred tons to every acre. The density of snow naturally varies a good deal according to the speed with which it falls. Temperature, also, has much to do with its bulk. In cold, crisp weather, when the thermometer registers several degrees of frost, snow comes down light and dry; but in moist, cold weather, when the temperature is only just below thirty-two degrees, the snow falls in large, partially thawed flakes, and occupies much less space where it falls than that which reaches the earth during the prevalence of a greater degree of cold.

How Are the Stars Counted?

Stars are counted by means of the telescope and photography. The Astronomer-Royal for Ireland, Sir Robert S. Ball, in one of his lectures mentioned a photograph which had been obtained by Mr. Isaac Roberts representing a small part of the constellation of the Swan. The picture is about as large as the page of a copy-book, and it is so crowded with stars that it would puzzle most people to count them; but they have been counted by a patient person, and the number is about 16,000. Many of these stars are too faint ever to be seen in the greatest of telescopes yet erected. Attempts are now being made to obtain a number of similar photographs which shall cover the whole extent of the heavens. The task is indeed an immense one. Assuming the plates used to be the same size as that above mentioned, it would require at least 10,000 of them to represent the entire sky. The counting of stars by the telescope was first reduced to a system by the Herschels, who introduced “star-gauges,” which were simply a calculation by averages. A telescope of 18 in. aperture, 20 ft. focus, and a magnifying power of 180, giving a field of view 15 in. in diameter, was used for the purpose. The process consisted in directing this instrument to a part of the sky and counting the stars in the field. This, repeated hundreds of times, gave a fair idea of the average number of stars in a circle of 15 in. diameter in all parts of the sky. From this as a basis it is possible to reckon the number of stars in any known area.

How Is the Volume of Sound Measured?

Sound arises from vibrations giving a wave-like motion to the surrounding atmosphere, the wave gradually enlarging as it leaves the source of disturbance, while at the same time the motion of the air particles becomes less and less. The simplest method of determining the number of vibrations of a sound is by means of Savart’s apparatus. This consists of two wheels--a toothed or cog-wheel and a driving-wheel. They are so adjusted that the cog-wheel is made to revolve with great rapidity, its teeth hitting upon a card fixed near it. The number of revolutions is indicated by a counter attached to the axis of the cog-wheel. Suppose that sound is traveling in the air at the rate of 1,000 ft. per second, and that Savart’s wheel is giving a sound produced by 200 taps on the card per second, it follows that in 1,000 ft. there will be 200 waves or vibrations, and if there be 200 waves in 1,000 ft. each wave or vibration must be 5 ft. in length. The velocity of sound through air varies with the temperature of the latter, but is usually reckoned at 1,130 ft. per second.

At What Rate Does Thought Travel?

Thought travels 111 feet per second, or about a mile and a quarter per minute. Elaborate experiments have been made by Professors Heimholtz, Hersch, and Donders, to ascertain the facts on this question, the result of which was that they found the process of thought varied in rapidity in different individuals, children and old persons thinking more slowly than people of middle age, and ignorant people more slowly than the educated. It takes about two-fifths of a second to call to mind the country in which a well-known town is situated, or the language in which a familiar author wrote. We can think of the name of the next month in half the time we need to think of the name of the last month. It takes on the average one-third of a second to add numbers containing one digit and half a second to multiply them. Those used to reckoning can add two to three in less time than others; those familiar with literature can remember more quickly than others that Shakespeare wrote “Hamlet.” It takes longer to mention a month when a season has been given than to say to what season a month belongs. The time taken up in choosing a motion, the “will time,” can be

measured as well as the time taken up in perceiving. If it is not known which of two colored lights is to be presented, and you offer to lift your right hand if it be red and your left if it be blue, about one-thirteenth of a second is necessary to initiate the correct motion.

What Is the Largest Tree In the World?

In San Francisco, encircled by a circus tent of ample dimensions, is a section of the largest tree in the world--exceeding the diameter of the famous tree of Calaveras by five feet. This monster of the vegetable kingdom was discovered in 1874, on Tule River, Tulare County, about seventy-five miles from Visalia. At some remote period its top had been broken off by the elements, or some unknown forces, yet when it was discovered it had an elevation of 240 feet. The trunk of the tree was 111 feet in circumference, with a diameter of 35 feet 4 inches. The section on exhibition is hollowed out, leaving about a foot of bark and several inches of the wood. The interior is 100 feet in circumference and 30 feet in diameter, and it has a seating capacity of about 200. It was cut off from the tree about twelve feet above the base, and required the labor of four men for nine days to chop it down. In the center of the tree, and extending through its whole length, was a rotten core about two feet in diameter, partially filled with a soggy, decayed vegetation that had fallen into it from the top. In the center of this cavity was found the trunk of a little tree of the same species, having perfect bark on it, and showing regular growth. It was of uniform diameter, an inch and a half all the way; and when the tree fell and split open, this curious stem was traced for nearly 100 feet. The rings in this monarch of the forest show its age to have been 4,840 years.

Where Did the Term Yankees Originate?

This is a word said to be a corruption of Yengees, the Indian pronunciation of English, or of the French “Anglais,” when referring to the English Colonists. It was first applied to the New Englanders by the British soldiers as a term of reproach, later by the English to Americans generally, and still later to the people of the North by the Southerners.

How Far Does the Air Extend?

It is, perhaps, generally known that enveloping the earth is a layer of air fifty or more miles in thickness. Just how thick this layer is we do not know, but we do know that it extends many miles from the earth. You may assure yourselves of this in a very simple manner by watching the shooting stars that may be seen on any clear night. These are nothing but masses of rocks that give off light only when they have been made red-hot by friction with the air in their rapid flight. The fact that we often see these stars while they are still many miles from the earth proves to us that the air through which they are passing extends to that height.

What Makes Us Feel Hungry?

Hunger is a peculiar craving which we are accustomed to say comes from the stomach. It is the business of the stomach to change such food as we take into it in such a way that the rest of the organs of the body which we have for the purpose can make blood out of it. When you feel the sensation of hunger, it means that the blood-producing system is calling on the stomach to furnish more blood-making material. The stomach prepares the food for blood production by mixing with it certain juices which the stomach is able to supply. As soon as the stomach is then called upon to supply more blood-making material, it goes to work on what is in the stomach and begins mixing things. If, however, there is nothing in the stomach, the craving which we call hunger is produced. It is, therefore, then not altogether the stomach which makes us hungry, but the parts of our body which actually turn the food into blood after the stomach has prepared it.

To prove this it is only necessary to say that the sensation of hunger will stop if food which is easily absorbed and, therefore, does not need the preparation which the stomach generally gives, is introduced into the system through other parts of the body, as, for instance, by injecting it into the large intestine, which is a part of the body, the food passes through after it leaves the stomach ordinarily.

What Makes Us Thirsty?

Thirst is a sensation of dryness and heat which is generally communicated to us through the tongue and throat. The sensation of thirst can be artificially produced by passing a current of air over the membranes which cover the tongue and throat, but thirst is naturally due to a shortage of water in the body. The human body requires a great deal of water to keep it in condition, and when

the supply becomes low a warning is given to us by making the membranes of the tongue and throat dry.

In connection with thirst, however, as in the case of hunger, where the warning is given by the stomach, thirst will be appeased by the introduction of water, either into the blood, the stomach or the large intestine, without having touched either the tongue or throat, which proves that it is not our tongue or throat that is thirsty, but the body itself.

What Is Pain and Why Does It Hurt?

Pain is the result of an injury to some part of our bodies, or a disturbed condition--a change from the normal condition. Pain is caused by nerves in the body. The network of nerves coming in big nerves from the back bone or spinal chord branches out in all directions, and near the surface of the skin they spread out like the tiny twigs of a tree, covering every point of the body. Some parts of our bodies are more sensitive than others. That is because the nerves are then nearer the surface or else there are more nerves in that part. The heel is perhaps the least sensitive part of the body, as the nerves do not lie so near the surface there.

Pain is not a thing which you can make a picture of or describe in words. Pain is a sensation of the brain caused by a disturbance of conditions in some part of the body. If you cut your finger, you cut certain veins or arteries and also the tiny nerves in the finger. The nerves immediately let the brain know that they are injured, and the brain sets to work to have the damage repaired. But there is a congestion right where the cut is. The veins being cut, the blood which would ordinarily flow through them back to the heart, pours out into the cut and the inside of your finger is thus exposed to the oxygen of the air, and the action of the air on the exposed part helps to make the pain. It is not your finger, however, that hurts. It is the shock that your brain gets when you cut your finger that hurts.

A pain in your stomach is a pain caused by something else than a cut. If the stomach could always digest everything or any amount of stuff you put in it, you would not have a stomach pain. But sometimes you put things into your stomach through your mouth, of course, that the stomach cannot handle. Or, it may be a combination of a number of things that cause this unusual condition in your stomach. The stomach makes a special effort to get rid of this troublesome substance and generally succeeds eventually, but while the fight is going on, it pains or hurts you.

Pain is the result of a disturbance of the nerves. It is just the opposite of gladness. We sometimes are so glad we feel good all over. Pain is just the opposite. You can prove that pain is not a real thing but only a sensation. Perhaps you have had toothache. You go to the dentist and he kills the nerve or takes it out. After that you cannot have the toothache in that tooth again, because there is no nerve there to telegraph to the brain, even though the cause of the hurt still exists. You cannot feel pain unless the brain knows about the injury.

What Is the Horizon?

Of course you know what the horizon is. It is easiest to see the horizon at sea when out of sight of land. There, when you look in any direction from the ship to the place where the sea and the sky meet you see a line which, if you follow with your eye as you turn completely around, makes a perfect circle. It looks as though it marked the boundary of the earth. On land it is not easy to see as much of the horizon at one time, because of buildings and trees and hills in the woods and elsewhere, but if the land were perfectly smooth like the sea and there were no trees or buildings or hills in the way, you could see just as perfect a circle on land as on sea. This proves that the horizon is a movable circle. On land it is where the earth and sky appear to meet, and on water it is where sky and water appear to meet.

How Far Away Is the Horizon?

The actual distance of the horizon away from us depends altogether upon the height above the sea level from which we are looking as far as we can. The horizon is always as far away as we can see. At the seashore, where we are practically on a level with the water, we cannot see so far as when we are up on a bluff or hill overlooking the sea. The higher we go up straight from a given point the greater the distance we can see up to a certain point and the farther away the horizon will appear. The height of the person looking, of course, figures in this, because when you are at sea level it is only your feet really that are at sea level (if you are standing up straight) and the distance of the horizon is measured from the eye of the person looking. A boy or girl of ten would be, say, a little over four feet high, and the eyes of such a person would be about four feet above the level of the sea. At that height the horizon would be about two and a half miles away. If the eyes are six feet above sea level the distance of the horizon will be about

three miles, so that practically every one sees a different horizon, that is, one that appears at a different distance. A hundred feet above the level of the sea the horizon will be more than thirteen miles away, while at 1000 feet altitude it would be 42 miles away, and if you could go a mile into the air the horizon would appear 96 miles from where you are. The higher you go the farther away the circle which apparently marks the joining of the earth and sky appears.

Why Can We See Farther When We Are Up High?

Remember that the earth is round and you will probably be able to answer the question yourself. This one, like most questions boys and girls ask, only requires a little thought. The earth, of course, as we have learned long ago, is a globe. When you look out on the land or the sea from a high place you can see more of the earth's round surface before the curve of the earth's surface takes things beyond the range of vision. If you are on a bluff 100 feet high at the seashore and looking toward a point where a ship is coming toward shore, you will be able to see the ship much sooner than if you were at the sea level. In exact words, you actually see more of the earth's surface the higher up you are, because, as you go up your position in relation to the curvature of the earth's surface changes.

What Makes Lobsters Turn Red?

When a lobster is taken out of the lobster trap with which the fisherman traps him, he is green, but when he comes to the table as a choice morsel of food his shell is red. We know that he has been boiled and we know that he goes into the boiling water green and comes out red. This change in the color of the shell of the lobster is the result of the effect of boiling water on the coloring material in the shell. When the lobster is put in the boiling water the process of boiling produces a chemical change in the color material in the lobster's shell. There is no particular reason why the lobster should turn red, excepting that that is the effect boiling water has on the coloring matter in the shell.

Why Do We Have to Die?

Death must come to all things that have life. All matter in the world is either living (animate) or dead (inanimate). Inanimate things do not change. They remain always the same. We can change the form and size of inanimate things, and particles of them even help to make up the bodies of the living things, but what they are made of always remains what it was.

Death is one of the things that must occur if we are to continue to have more life. The whole plan of living things includes the ability to reproduce themselves. Every kind of life has the power to produce life like itself and this process of reproduction is continuous. If there were no death, then the world would soon be crowded with living things to the point where there would be neither room nor food.

[Illustration: WHERE WINDOW GLASS COMES FROM]

Pictures herewith by courtesy of Pittsburgh Plate Glass Co.

Making Plate Glass

What Is the Difference Between Plate Glass and Window Glass?

How is plate glass made? These questions are asked very frequently. The two products are wholly unlike each other; and we wish to show wherein lies the difference. We shall tell how plate glass is made; and we hope to make it clear that great care, time and expense are involved in its manufacture.

The raw materials may be said to be virtually the same in plate glass as in window glass; the main difference being that in plate glass greater care is exercised in selecting and purifying the ingredients. Window glass is made with a blow-pipe. The work requires skill on the part of the operator; but the process is quite simple and rapid. And the result is, naturally, a comparatively ordinary and indifferent product. On the other hand, the superb quality of plate glass is owing to the elaborate method of producing it.

Commercial plate glass was first made in France somewhat more than two hundred years ago; although glass in one form or another has been in use for many centuries. Apparently glass was known in Egypt fully four thousand years ago.

[Illustration: MINING SILICA]

The materials used are silica (white sand), carbonate of soda (soda ash), and lime. Other materials, as arsenic and charcoal, are used in small proportions, but the main ingredients are the first three named.

Probably it is little imagined that in the production of plate glass, mining is involved in two or more forms (namely silica and coal), also the quarrying of limestone, the chemical manufacture of soda ash on a large scale, the reduction and treatment of fire clay to its right consistency, an elaborate and expensive system of pot making; and the melting, casting, rolling, annealing, grinding and polishing of the glass.

In special uses, as in beveled plates and mirrors, two more elaborate processes must be added--beveling and silvering--all of which are performed under the direction of experts aided by a large amount of labor and expensive machinery.

Pots of fire clay take so important a part in the successful manufacture of plate glass that the subject deserves especial notice. The different clays after being mined are exposed to the weather for some time to bring about disintegration.

~THE CLAY MUST BE TRAMPLED WITH BARE FEET~

At the proper stage finely sifted raw clay is mixed with coarse, burned clay and water. This reduces liability of shrinkage and cracking. It is then "pugged," or kneaded in a mill; kept a long time (sometimes a year) in storage bins to ripen; and afterwards goes through the laborious process of "treading." Nothing has thus far been found in machinery by which the right kind of plasticity can be developed as does this primitive treading by the bare feet of men. The clay must be treaded, not once or twice, but many times. The building of pots is a slow, tedious and time-killing affair; but this is most essential.

~HOW MELTING POTS ARE MADE~

Without extreme care, some elements used in the making of the pots might be fused into glass while undergoing the intense heat of the furnace; or they might break in the handling. The average pot must hold about a ton of molten glass, and the average furnace heat necessary is about 3,000° Fahrenheit. The work is not continuous. Each workman has several pots in hand at a time, and passes from one to another adding only a few inches a day to each pot, so that a proper interval for seasoning be given. After completion, comes the proper drying out of the pots; and this is another feature in which the greatest scientific care is required. No pot may be used until it has been left to season for at least three months, and even a year is desirable. And after all this trouble, the pot has but 25 days of usefulness. The pots form one of the heavy items of expense in plate glass manufacture; and upon their safety great things depend.

[Illustration: POT MAKING.]

[Illustration: MIXING THE CLAY.

TRAMPLING THE CLAY.]

[Illustration: SKIMMING THE POT.]

[Illustration: CASTING PLATE GLASS.]

~HOW THE HUGE PLATES OF GLASS ARE CAST~

The pot, having been first brought to the necessary high temperature, is filled heaping full with its mixed "batch" of ground silica, soda, lime, etc. Melting reduces the bulk so much that the pot is filled three times before it contains a sufficient charge of metal. When the proper molten stage is reached the pot is lifted out of the furnace by a crane; is first carefully skimmed to remove surface impurities, and then carried overhead by an electric tramway to the casting table. This is a large, massive, flat table of iron, having as an attachment a heavy iron roller which covers the full width, and arranged so as to roll the entire length of the table. The sides of the table are fitted with adjustable strips which permit the producing of plates of different thicknesses. The pasty, or half-fluid glass metal is now poured upon the table from the melting pot, and the roller quickly passes over it, leaving a layer of uniform thickness. The heavy roller is now moved out of the way, and then by means of a stowing tool the red hot plate is shoved into an annealing oven. All of these stages of the work have to be performed with remarkable speed, and by men of long training and experience. The plates remain for several days in the annealing oven, where the temperature is gradually reduced from an intense heat at first, until at the end of the required period it is no hotter than an ordinary room.

[Illustration: PREPARING THE GRINDING TABLE.]

When the plate is taken from the annealing oven it has a rough, opaque, almost undulating appearance on the surfaces. It is only the surface, however, for within it is as clear as crystal. First, it is submitted for careful inspection, so that bubbles or other defects may be marked for cutting out. It then goes to the cutter who takes off the rough edges and squares it into the right dimensions; and thence to the grinding room.

[Illustration: HOW THE GLASS PLATES ARE GROUND

GRINDING THE PLATES]

The grinding table is a large flat revolving platform made of iron, twenty-five feet or more in diameter. The plate must be carried from the annealing oven to the grinding machines, and thence to the racks, by men skilled in the art. Twenty men are required to carry the larger plates of glass, ten on each side, using leather straps and stepping together in perfect time. The lock-step is absolutely essential to prevent accident. The grinding table is prepared by being flooded with plaster of Paris and water; then the glass is carefully lowered, and a number of men mount upon the plate and tramp it into place until it is set. After this, greater security is obtained by pegging with prepared wooden pins; and then the table is set in motion. The grinding is done by revolving runners. Sharp sand is fed upon the table, and a stream of water constantly flows over it. After the first cutting by the sand, emery is used in a similar manner.

The plates are inspected after leaving the grinding room, and if any scratches or defects of any kind are found they are marked. Some of these can be rubbed down by hand. There are also, not infrequently, nicks and fractures found at this stage; and in such case the plate must again be cut and squared. Afterward comes the polishing, which is done on another special table. The polishing material is rouge, or iron peroxide, applied with water, and the rubbing is done by blocks of felt. Reciprocating machinery is so arranged that every part of the plate is brought underneath the rubbing surface.

The grinding and polishing has taken away from the original plate half of its thickness, sometimes more. There is no saving of the material; it has all been washed away. When to this waste is added the fact that fully half of the original weight of lime and soda has been released by the heat of the furnace, escaping into the atmosphere in fumes and acids, one may begin to understand something of the cost of converting the rough materials of sand, limestone and soda into beautiful plate glass.

~HOW MIRRORS ARE MADE~

In preparing plate glass for mirrors great care must be exercised in the selection of the plates. This selection bears reference not only to surface defects, but to the quality in general; defects which cannot ordinarily be seen are magnified many fold after the glass has received a covering of silver.

[Illustration: BEVELING PLATES]

In the process of beveling, the plate passes through the hands of skilled workmen of five different divisions, namely: roughers, emeriers, smoothers, white-wheelers and buffers; and different abrasive materials are used in the order indicated by the titles. These materials are sand, emery, natural sandstone imported from England, pumice and rouge.

The roughing mill is a circular cast-iron disk about 28 inches in diameter, constructed so that the face or top of the mill revolves upon a horizontal plane at a speed of about 250 revolutions per minute. The sand is conveyed to the mill from above through a hopper simultaneously with a stream of water which is played upon the sand to carry it to the mill. The rougher places the edge of the plate upon the rapidly revolving mill, and the cutting of the bevel is done by the passage of the sand between the mill and the plate of glass. A bevel of any desired width may be produced. Pattern plates containing incurves, mitres, etc., require a practiced eye and great skill upon the part of the operator.

When the plate leaves the rougher's hands the surface of the bevel has been ground so deep by the coarse sand that polishing at this stage is impossible. Consequently, in order to produce a surface fine enough to render it susceptible of a high and brilliant polish it must go through the various treatments we have mentioned. The emerier uses a fine grade of emery on a mill similar in construction to a roughing mill, which takes away considerable of the coarse surface given by the first cutting. Then it goes to the smoother, who reduces the roughness slowly by using a fine sandstone from England; then it goes to the white-wheeler who operates an upright poplar-wood wheel using powdered pumice stone as an abrasive; and then, as a last stage it reaches the buffer, whose method of operation is shown in the illustration. The buffer brings a high polish to the bevel by the use of rouge

applied to thick felt which covers his wheel.

[Illustration: SILVERING MIRROR PLATES.]

[Illustration: The two photographs here are of the same building taken under contrasting conditions. The first picture was taken through a window glazed with common window glass. It is an extreme example, to be sure, but of a sort not infrequently seen. The second view shows the same building taken through a window of polished, flawless plate glass. An observing person can see this startling contrast any day as he walks along a residence street. At intervals a front window will be seen which gives a twisted, distorted reflection of the houses or trees on the opposite side: this is window glass. The other kind--the window that gives a sharp brilliant reflection--is _plate glass_. It is practically impossible to obtain superior reflecting quality from window glass. It can only be had from surfaces which have been ground and polished.]

The plate, after leaving the beveling room, is again carefully examined for surface defects. These defects may consist of scratches caused inadvertently by permitting the surface of the plate to come into contact with the abrasive material. These scratches are removed by hand polishing, which must be skillfully done; otherwise the reflection will become distorted through over-polishing in a given area or spot. The plate is then taken to a wash table where the surface to be silvered is thoroughly washed with distilled water; after which it is taken to a table that is covered with blankets, and which is heated to a temperature of from 90° to 110°. The blanketing is to protect the plate from being scratched, and also to catch all of the silver waste. The silvering solution is nitrate of silver liquefied by a certain formula, and is poured over the plate; the fluid having an appearance which to the ordinary observer looks like nothing other than pure distilled water. Within a few minutes the silver, aided by a reactory, added prior to pouring, begins to precipitate upon the glass; the liquids remaining above, and thus preventing air and impurities from coming into contact with the silver. Such contact would produce oxidation. After the silver is precipitated the plate is thoroughly dried, shellacked and painted; after which it is ready for commercial use.

Until about 25 years ago, practically all mirrors were silvered with mercury. There have been two reasons for discouraging the use of mercury for silvering; one being its injuriousness to the health of the workmen. In some European countries stringent laws were enacted, stipulating that men should work only a certain number of hours.

Other hygienic stipulations, added to the fact that the use of mercury was already very expensive, have tended to replace that process by the use of nitrate of silver.

Why Is the Sky Blue?

This question puzzled every one who thought of it for a long time. Even astronomers, the men who make a business of studying the skies, and other learned men, puzzled their brains about it and searched for the answer long ago, until finally, as always happens when a lot of people study a subject, Professor John Tyndall, a noted scientist of the last century, discovered the answer. The explanation follows: All the light we have is sunlight, which is pure white light. This white light is made up of rays of light of different colors. These rays are red, orange, yellow, green, blue, indigo and violet. It takes all of these different rays of light to make our white sunlight, and when you separate sunlight into its original rays you always produce the rays of light in the above colors and in the same order. This is only true, however, when the sunlight is passed through an object which does not absorb any of its rays. This is the arrangement of the different colors of light found in the rainbow. The rainbow is formed by sunlight passing into raindrops or vapor in such a way as to divide the sunlight into the different colored rays of light. When the rainbow is formed none of the rays are absorbed by raindrops or vapor through which the sunlight passes. Some of these rays of light are known as short rays and others as long rays. But when sunlight meets other things besides those which make a pure rainbow, these other objects have the ability to absorb some of the rays of colored light, and they throw off the remainder. When these rays have been thrown off those which have been absorbed make many different combinations, and thus are produced all of the different colors we know, the various tints and shades of color, according to composition and size.

Now, then, to get back to the color of the sky, which is blue as we know. The sky or air which surrounds the earth is filled with countless tiny specks of what we may call dust--particles of solid things hanging or floating in the air. These specks are of just the size and quality that they catch and absorb part of the rays of light which form our sunlight and throw off the rest of the rays, and the part which has been absorbed forms the combination of color which makes our sky so beautifully blue. Sometimes you notice, of course, that the sky is a lighter or darker blue than at other times. This difference is due to the kind and condition of tiny specks in the air at the time, and to the direction or angle at which the sunlight strikes these tiny particles. This fact brings up a question which

you have not asked, but which would come naturally as the result of your first.

What Makes the Colors of the Sunset?

The direction of the sun's rays when they meet these large and small particles in the air has a great deal to do with the combination of colors that result as these objects absorb part of the rays and throw off others. The sky is the most beautiful blue when the sun is high in the sky. But when the sun is setting the light has a greater distance to travel through the belt of air which surrounds the earth than when it is high up over our heads. You know that if you stick a pin straight down into an orange it won't go in very far before it is clear through the peel, but if you stick the pin into an orange along the edge it will go through a great deal more of the peel than the other way. That is the way it is with the sunset colors. The peel of the orange is a good representation of the belt of air which surrounds the earth. At sunset the light instead of coming straight down through the belt of air, thus meeting the eye through the shortest possible amount of air, strikes the air on a slant, and, therefore, travels through a great deal more air and closer to the earth to reach it, with the results that it meets a great many more of these little specks, besides all the smoke and other things that hang in the air near the ground, and we thus get many more colors, because some of the things in the air absorb some of the rays and others absorb very different rays when the light comes in this slanting way, and that is what makes the different colors in the sunset. For this reason sunsets are often richer and more beautiful in color when the air is not so pure, but has much dirt and other matter floating about in it.

Are There Two Sides to the Rainbow?

No, there is only one side to the rainbow. The rainbow is made by reflection of the rays of sunlight through drops of water in the air, but you can never see a rainbow unless you are between it and the sun. You could never see a rainbow if you were looking at the sun, and so if you are looking at a rainbow you can be certain that anyone on the other side of it could not see it, because they would have to be looking right at the sun. The rainbow is always opposite to the sun and there can never be two sides to it.

Do the Ends of the Rainbow Rest on Land?

The ends of the rainbow do not rest on anything. You see, the rainbow is only the reflection of the sun's rays thrown back to us by the inside of the back of the raindrops, which are still in the sky after the rain. Of course, if any of the drops of water touched the ground they would cease to be raindrops and, therefore, could not reflect the rays of the sunlight. So, what we think of as the ends of the rainbow do not really exist at all. The rainbow is only a reflection of the rays of sunlight from countless drops of water in the air, which the sun's rays must strike at a certain angle in order to reflect back the light so we can see it. Where the sun's rays do not strike the drops of water at the right angle no light is reflected, and there is the end of the rainbow.

What Causes the Different Colors of the Rainbow?

The colors of the rainbow, which are always the same, and are shown in this order--red, orange, yellow, green, blue and violet--are sunlight broken up into its original colors. It takes all of these colors in the proportions in which they are mixed in the rainbow to make the pure sunlight. These are known as the prismatic colors. As shown in another answer to one of your puzzling questions, the rainbow is caused by the rays of the sun passing into drops of water in the air and reflected back to us with one part of the drop of water acting on it in such a way as to break up the pure sunlight into these prismatic colors. When a rainbow appears at a time when there is a great deal of sunlight, you will generally see two rainbows. The inner rainbow is formed by the rays of the sun that enter the upper part of the falling raindrops, and the outer rainbow is formed by the rays that enter the under part of the raindrops. In the inner or primary bow, as it is called, the colors beginning at the outside ring of color are red, orange, yellow, green, blue and violet, and being exactly reversed in the outer or secondary bow. The secondary bow is also fainter. You may sometimes see smaller rainbows, even if it has not been raining, when looking at a fountain or waterfall. These are caused in exactly the same way.

What Makes the Hills Look Blue Sometimes?

This is due to the fact that when the hills look blue you are looking at them at a distance, and there is a long stretch of air between you and the hills. This air is filled with countless particles of dust and other things, and what you see is not really blue hills, but the reflection of the sun's rays from the little particles in the air striking your eye. The color is due to the angle at which the light from the

sun strikes these particles, and is reflected back to your eye and partially due to the character of the particles in the air.

Do the Stars Really Shoot Down?

The answer is "No." We have come to use the expression "shooting stars" commonly, but we should probably be more correct if we said "shooting rocks," for the things we refer to commonly as "shooting stars" are more like rocks than anything else. If any of the real stars were to fall into the air surrounding the earth we should all be burned up by the great heat developed long before it actually hit the earth, which it would undoubtedly destroy.

The things that fall and leave a streak of light are really only pebbles, stones, rocks or pieces of iron and other substances that fall from some place into the earth's air belt. When they strike the air at the speed at which they are falling the friction of the air makes a heat that causes them to become luminous, and by far the greater part of them is burned up before they get very near the earth. We call them meteorites. Sometimes, though rarely, one will manage to strike the earth, coming at such great speed and being so large that the air has not been able to burn it up completely, and it will strike the earth and sink deep down into the soil. In most museums can be seen such meteorites that have been dug up after striking the earth. These are constantly falling into the air surrounding the earth, but in the day-time their light is not strong enough to be seen while the sun is shining.

Will the Sky Ever Fall Down?

No, the sky can never fall down, because it is not made of the kind of things that fall. We have become used to thinking of it as the roof of the earth, a great dome-shaped roof, because in our little way of looking at things we compared the earth and what is above it with the houses in which we live. The sky is just space in which the heavenly bodies revolve in their orbits. We cannot really ever see sky. We see only the sun's light reflected by the air belt which surrounds the earth. In this air belt are the clouds which do come closer to the land at times than at others, and this is apt to aid in giving us an incorrect impression of this.

What Is the Milky Way?

The "Galaxy," or "Milky Way," as it is popularly called, is a luminous circle extending completely around the heavens. It is produced by myriads of stars, as can be seen when you look at it through a telescope. It divides into two great branches at one point, which travel for some distance separately and then reunite. It has also several branches. At one point it spreads out very widely into a fanlike shape.

Why Do They Call It the Milky Way?

The stars in the group are so numerous that they present to the naked eye a whiteness like a stream of milk. To produce this effect there are not hundreds of stars, nor thousands of them, but actually millions of them.

When you stop to think that each one of these stars in the Milky Way is a sun like our own--some of them smaller, of course, but many of them much larger--you begin to realize how impossible it is for man to form any real idea of the magnitude and wonders of the earth. Here in the Milky Way are so many suns like our own sun that they together as we look at them form the particles of a path which makes the circle of the heavens, and yet are so far away that to the naked eye each of them looks to us like only one of countless drops of milk in a very large stream of milk that goes around the whole sky.

Why Don't the Stars Shine in the Day-time?

The stars do shine in the day-time. If you will go down into a deep well or the open shaft of a deep mine and look up at the sky, of which you can see a circular patch at the top of the well, you will be able to see the stars in the day-time. The moon also shines in the day-time, on some part of the earth. At certain times during the month you can notice that the moon rises before the sun sets, and sometimes in the morning you can still see the moon in the sky after the sun is up. Usually you cannot see either the moon or the stars in the day-time, because the light from the sun is so bright and strong that the light of the stars and moon are lost in the brightness of the sun's rays. When the moon is visible before the sun sets or after the sun has risen it is because the light of the sun is not so bright and strong at the beginning or close of daylight. If you are fortunate enough some time to witness a total eclipse of the sun you will be able to see the stars in day-time without having to go down into a deep well or mine shaft.

How Far Does Space Reach?

Space surrounds all earths, planets, suns, and extends for an infinite distance beyond each of them in all directions. It is impossible to measure in terms of human knowledge how far space extends. It is one of the things beyond the comprehension of the human mind, and for that reason man can never know in miles or the number of millions of miles how far it extends. Man has been able to measure the distance from the earth of some of the stars, and some of the nearest of them are millions of miles from the earth. Most of them are hundreds and even thousands of million miles away, and when we stop to think that space extends at least as far on the other sides of the stars as it does on this side, and even beyond that, we can readily understand that it is not only impossible to measure space, but also impossible to give in words any conception of what its limits might be.

There is one word--infinite--which we are forced to use in speaking of the extent of space. Infinite means "without end," unbounded, and so man has come to use the word "infinite" in describing the extent of space, and that is as near as any one can describe it.

What Does Horse Power Mean?

The term "horse power" is used in describing the amount of power produced by an engine or motor. When man made the first engines he needed some term to use in describing the amount of power his engine could develop. Up to that time man had used the horse for turning the wheels of his machinery and the horse to him naturally represented the most powerful animal working for man. When engines came into use they replaced the horses because they were capable of developing many times the power of the horse. In finding an expression which would accurately convey to the mind of another the power of a particular engine, it was natural to say that this engine would do the work of five, ten or more horses, and as this described it accurately and in a way that was entirely clear, it became customary to describe the power of an engine as so many times the power of one horse.

To-day we still cling to the term "horse power" in describing the strength of the engine, although the horse-power unit used to-day is greater than the power of an average horse. To speak of an engine of one horse power to-day means an engine that has the power to lift 30,000 pounds one foot in one minute.

[Illustration: WHERE OUR COAL COMES FROM

A COAL BREAKER.

Coal is brought in mine cars from several mine shafts and slopes, dumped onto a conveyor that runs on the inclined framework shown at the right of the picture. At the top it is broken in rolls, sorted and sized as it slides through the different screens, pickers, etc., and is finally delivered into railroad cars.]

The Story in a Lump of Coal

How Did the Coal Get Into the Coal Mines?

The heavy black mineral called coal, which we burn in our stoves and furnaces, and use to heat the boilers of our engines was formed from trees and plants of various sorts. Most of the coal was formed thousands of years ago at a time when the atmosphere that envelopes the earth contained a much larger proportion of carbonic acid gas than it does now, and the climate of all regions of the earth was much warmer than it now is. This period was known as the carboniferous age, that is, the coal-making age, and its atmospheric conditions, favored the growth of plants, so that the earth was covered with great forests, of trees, giant ferns, and other plants, many of which are no longer found on the earth. In the warm, moist, and carbon-laden atmosphere of that period the growth of all kinds of plants was rapid and luxuriant, and as fast as old trees fell and partially decayed, others grew up in their places. In this way, thick layers of vegetable matter were formed over the soil in which the plants grew. In many places, where these beds were formed, the surface of the earth became depressed and the water of the sea flowed over the beds of vegetable matter.

Sediment of various kinds was deposited over the vegetable matter, and in the course of centuries the sediment was transformed into rock.

After the formation of the covering of sediment, the decay of the vegetable matter was checked, but a slow change of another kind was brought about by the pressure of the sedimentary deposits and the heat to which the plant remains were subjected. The

hydrogen and oxygen which constituted the greater part of the plant substance was driven off and the carbon left behind. This change took place very gradually, through periods so long that we can only guess at their duration, but we know that many beds of coal were formed from layers of vegetable matter that were covered up many thousand years ago.

[Illustration: MINE WORKERS THAT NEVER SEE DAYLIGHT

Underground stable constructed of concrete and iron, with natural rock roof to avoid danger of fire. Mules are only taken to surface when mines are idle.]

The coal first formed and submitted longest to pressure is known as hard coal, or anthracite. It is pure black, or has a bluish metallic luster. Its specific gravity is 1.46; which is about the same as that of hard wood. Anthracite contains from 90 to 94 per cent. of carbon, the remainder being composed of hydrogen, oxygen, and ash.

[Illustration: The Mules and their drivers.--An important part of the haulage system. Mules are kept in stables on surface at this mine and driven in every day through slope or drift.]

Hard coal may be called the ideal fuel and is especially adapted to domestic heating purposes. It burns without smoke and produces great heat. There is no soot deposit upon the walls of chimneys, and in good stoves or furnaces the small amount of gas given off by it is consumed. Anthracite is the least abundant of all the varieties of coal and is much more costly than the other varieties. For this reason it is not much used in manufacturing.

[Illustration: HOW THE SLATE PICKERS WORK

Boy slate pickers. Coal slides down the chutes. Boys pick out the slate and rock and throw into chute alongside.]

[Illustration: Spiral slate pickers do work of many boys. Coal and rock start together at the top in the small inner spiral. The coal being lighter slides faster, and in going around is carried over the edge into the outer spiral, while the rock continues in the bottom.]

The coal formed later is very different in composition and is called bituminous or soft coal. Its name is derived from the fact that it contains a soft substance called bitumen, which oozes out of the coal when heat is applied to it. Soft coal contains from 75 to 85 per cent. of carbon, some traces of sulphur, and a larger percentage of oxygen and hydrogen than anthracite. When soft coal is heated in a closed vessel or retort, the hydrogen and oxygen, in combination with some carbon, are driven off.

[Illustration: HOW A COAL MINE LOOKS INSIDE

Shaft gate. One of the two cages in the shaft has just brought the men to the surface; the other is at the bottom. Safety gate resting on top of cage covers top of shaft when cage is down, as shown at right.]

[Illustration: Section showing Anthracite Seams. Coal is shown black; rock and dirt lighter; shaft tunnels and workings, white. Upper part of “Mammoth” seam is stripped and quarried.]

[Illustration: Lignite mine in Texas. Loaded mine cars ready to go to surface.]

[Illustration: HOW THE MINERS LOOSEN THE COAL

Undercutting with pick. The man lying on his side cuts under the coal. A light charge of powder exploded in a drill hole near the roof breaks the coal down in large pieces.]

Soft coal is black, and upon smooth surfaces it is glossy. It lacks the bluish luster sometimes seen in hard coal and is much softer and more easily broken. When handled it blackens the hands more than hard coal does. In this kind of coal are frequently seen the outlines of leaves and stems of plants that enter into its formation. Occasionally, trunks of trees with roots extending down into the clay below the bed of coal have been found.

[Illustration: Undercutting in seam. A compressed air driven machine undercuts deeper and faster than the man with a pick.]

Soft coal has a specific gravity of 1.27. It burns with a yellow flame which is larger than the flame from hard coal, but it does not emit so high a degree of heat. Combustion, generally imperfect, gives rise to offensive gases and to black smoke that concentrates in the air and falls to the ground as soot, which blackens buildings, and, in winter, noticeably discolors the snow.

The formation of lignite has been observed in the timbers of some old mines in Europe. In some of these mines wooden pillars have been supporting the rocks above for four hundred years or longer, and in that time the pressure of the rocks and other influences acting upon the wood of the pillars have caused it to become transformed into a brown substance resembling lignite. This fact tends to confirm the theory of coal formation stated at the beginning of this article. The proportion of carbon in lignite is never above 70 per cent., and the ash indicates the presence of considerable earthy matter. It is chiefly used in those forms of manufacture where a hot fire is not required. In Europe it is used, to some extent, in heating the houses of the poorer classes.

Peat is regarded as the latest of the coal formations. In it, the change in the vegetable matter has not extended beyond merely covering it, and subjecting it to slight pressure.

Peat is formed in marshy soils where there is a considerable growth of plants that are constantly undergoing partial decay and becoming covered by water. It consists of the roots and stems of the plants matted together and mingled with some earthy material. When freshly dug out of the bog or marsh in which it was formed there is always a quantity of water in it, the amount being greatest in the peat found nearest the surface and least in that at the bottom of the bed, where the peat is not very different in appearance from lignite.

Peat is used for fuel where wood is scarce and coal is high in price. Recent experiments in saturating peat with petroleum, have shown that in this way a form of fuel may be produced for which considerable value is claimed. Its manufacture is confined to Southern Russia, where peat is plentiful and petroleum is cheap.

Why Does Firedamp Explode in a Safety Lamp Without Producing an Explosion of the Gas With Which the Lamp Is Surrounded?

The passing of the flame from the lamp to the outside air is prevented by the gauze. This splits the burning gas into little streamlets (784 to each square inch of gauze), which are cooled below the point of ignition, that is, are extinguished by coming in contact with the metal of the gauze, so that the flame does not pass outside the lamp. In some cases the explosion may be so great as to force the flame through the gauze and thus ignite the gas outside.

Are There Any Conditions Under Which it Would Not Be Safe to Use a Safety Lamp?

~THE DANGERS TO THE MINERS~

The underground conditions affecting the safety of the lamp are exposure in air-currents of high velocity by reason of which the flame may be blown through or against the gauze, or exposure for too great a time to mixtures of air and gas which will burn within the lamp and thus heat the gauze. The dangerous velocity of air-currents begins at about 500 feet a minute, but varies with the type of lamp, some being much less sensitive to air-currents of high velocity than others. Other conditions under which the lamp is not safe concern the lamp itself or the one using it. The lamp is dangerous in the hands of inexperienced persons or when the gauze is dirty or broken. If the gauze is dirty, that portion absorbs the heat and may become hot enough to ignite the outside gas; naturally any holes in the gauze will pass the flame.

The safety lamp when left too long in air containing much explosive gas may cause an explosion, and it is extinguished by certain unbreathable gases. The electric lamp burns safely regardless of the atmosphere, but gives no warning of poisonous or explosive gases. It is often used by rescue men wearing oxygen helmets to enter mines full of poisonous gases after explosions.

[Illustration: THE LAMP WHICH SAVES MANY LIVES

The safety lamp. The sheet iron bonnet or covering of the upper part protects the gauze within from strong currents of air, while the glass permits the light to be diffused. The above is a modern lamp similar to a bonnetted Clanny lamp.]

The safety lamp is dangerous when there is a hole in the gauze that will permit the passage of flame to the outside, or when the gauze is dirty, so that any particular spot may be overheated, or when the velocity of the air is so great that the flame is blown through the gauze, or (generally) when in the hands of an inexperienced person. The unbonneted Davy lamp is not safe where the velocity of the air exceeds 360 feet per minute. The velocity with which the air strikes a lamp carried against it is increased by the amount equal to the rate at which the fireboss travels. If he walks at the rate of, say, 4 miles an hour or 352 feet a minute (on the gangways he will usually have to move faster than this to make his rounds on time) he will create by his own motion (and in still air) a velocity practically the same as that at which the unbonneted Davy is considered unsafe.

[Illustration: Open oil lamp commonly worn on hat. Wick is inverted in spout.]

[Illustration: Acetylene or carbide lamp for cap or hand.]

History of the Safety Lamp.

The safety lamp, the miner's faithful and indispensable companion at his dangerous work, has been, heretofore, considered as the invention of the famous English scientist, Humphrey Davy, though the name of George Stephenson, of locomotive fame, has also been mentioned in this connection. Both came out with their inventions about the same time, but neither of them is the real inventor of the safety lamp; for there was, as proven by Wilhelm Nieman, a safety lamp in existence two years before Davy's invention became known. It was not inferior to the latter, but rather surpassed it in illuminating power. Previous to this, all the precaution employed for the prevention of the threatening dangers of firedamp had been quite incomplete. One tried to thoroughly ventilate the mines by fastening a burning torch to a large pole, which was pushed ahead and exploded the gases. This was extremely dangerous work which, in the Middle Ages, was generally done by a criminal, in order that he might atone for his crimes, or by a penitent for the benefit of mankind. The attempt to substitute for the open light phosphorescent substances, encased in glass, was not much of a success. An improvement was the so-called steel mill, invented about 1750 by Carlyle Spedding, manager of a mine. This steel mill consisted of a steel wheel which was put into rapid motion by means of a crank. By pressing a firestone against the fast revolving wheel, an incessant shower of sparks was produced giving a fairly good and absolutely safe illumination. However, the running expenses of his apparatus, which necessitated the continual services of one man, were very high; for instance, the expenditure for light in a coal mine near Newcastle in the year 1816 amounted to about $200 per week. Nevertheless, the steel mill was very much appreciated and in use for a long time, only to be slowly supplanted by the safety lamp.

[Illustration: ELECTRIC CAP LAMP AND BATTERY.

The safety lamp when left too long in air containing much explosive gas may cause an explosion, and it is extinguished by certain unbreathable gases. The electric lamp burns safely regardless of the atmosphere, but gives no warning of poisonous or explosive gases. It is often used by rescue men wearing oxygen helmets to enter mines full of poisonous gases after explosions.]

~THE MAN WHO INVENTED THE SAFETY LAMP~

At the beginning of the nineteenth century the existing coal mines were worked to the limit and the catastrophies, caused by firedamp, increased in an alarming manner. In fact the distress was so great that in 1812 a society for the prevention of mine disasters was formed at Sutherland, and the origin of the safety lamp can be traced back to the efforts and labors of this organization. Dr. William Reid Clanny, a retired ship's surgeon, was probably the first to undertake the task (in the year 1808), which he successfully finished with energy and skill. He concentrated his efforts at first on the separation of the flames from the surrounding atmosphere, but he did not succeed till the latter part of 1812, when he constructed a lamp that seemed to meet all requirements. The report of this invention was submitted to the Royal Society of London, May 20, 1813, and was printed in the minutes of that academy. The casing of this original safety lamp was closed at the top and bottom by two open water tanks; the air was pumped in by means of bellows and, passing in and out, had to go through both these reservoirs which acted as valves, so to speak. The lamp proved to be absolutely safe and was successfully introduced by the management of Herrington Mill pit mine. The clumsy parts of this apparatus were eliminated by its inventor by various improvements. The so-called steam safety lamp was completed in December, 1815, and installed in several mines. In the meanwhile, two competitors made their appearance. George Stephenson had finished his lamp October 21, 1815, and Davy published his first experiments November 9, 1815, in the Transactions of the Royal Society of London. Clanny's lamp, nevertheless, stood the test in the face of this competition, through its much superior illuminating power, and more particularly as it still continued to burn when the Davy and Stephenson lamps had gone out. To Clanny, therefore, belongs the distinction, in the history of invention, of having constructed the first reliable safety lamp.

What Is a Metal?

The oldest known metals in the world are gold and silver, copper, iron, tin and lead. They are to-day still the most useful and widely-used metals. Some of the properties by which we distinguish metals are the following: They are solid and not transparent; they have luster and are heavy. Mercury is an exception to the rule; it is a liquid, though yet a metal, and there is another, sodium, which is solid, though very light.

What Is the Most Valuable Metal?

If you were guessing you would naturally say that gold is, of course, the most valuable of the metals. But you would be wrong. The proper answer to this is iron. We do not mean the pound for pound value, for you could get much more for a pound of gold than for a pound of iron. We mean in useful value--iron is in that sense the most valuable metal known to man. This is true because iron is of such great service to man in so many ways, and it is very fortunate that there is such a great amount of it available for man's purposes. Iron is not generally found in a pure state in the mines. It is generally found compounded with carbon and other substances, and we obtain pure iron by burning these other substances out of the compound.

Iron is put upon the market in three forms, which differ very much in their properties. First, there is cast-iron. Iron in this form is hard, easily fusible and quite brittle, as you will know if you ever broke a lid on the kitchen range. In the form of cast-iron it cannot be forged or welded.

Next comes wrought-iron, which is quite soft, can be hammered out flat or drawn out in the form of a wire and can be welded, but fusible only at a high temperature. Third comes steel, the most wonderful thing we produce with iron. It is also malleable, which means that it is capable of being hammered out flat and can easily be welded, and this is the great property of steel--it acquires when tempered a very high degree of hardness, so that a sharp edge can be put on it, and when in that shape it will easily cut wrought-iron. Ordinarily we make wrought-iron and steel from iron that has been changed from its original state to cast-iron.

The term cast-iron is generally given to iron which has been melted and cast in any form desired for use. Stoves are made in this way. The iron is melted and then poured into a mold; while the product out of which wrought-iron and steel are made is technically cast-iron, the term pig-iron is used in speaking of iron which is cast for this purpose.

The process by which pig-iron is changed into wrought-iron is called _puddling_. The object of puddling, which is done in what is called a reverberatory furnace (which is a furnace that reflects or drives back the flame or heat) is to remove the carbon which is in the pig-iron. This is done partly by the action of the oxygen of the air at high temperature and partly by the action of the cinder formed by the burning furnace. When this has been done the iron is made into balls of a size convenient for handling. These are "shingled" by squeezing or hammering and passed between rolls by which the iron is made to assume any desired form.

Now we come to steel, the most wonderful product or form in which we take advantage of the value of iron. Steel was formerly made from wrought-iron, so that you first had to get cast-iron, from which you made wrought-iron, and eventually got steel by changing the wrought-iron. Now we make steel direct from pig-iron. This is known as the Bessemer process.

The most noticeable feature in the chemical composition of the different grades of iron and steel is found in the percentages of carbon they contain. Pig-iron contains the most carbon; steel the next lowest, and wrought-iron the least.

Iron has been known to men from early historical times. The smelting of iron ores is not any indication of advanced civilization either. Savage tribes in many parts of the world practiced the art of smelting, even before they could have learned it from people who had become civilized.

Why Is Gold Called Precious?

Gold is called one of the precious metals because of its beautiful color, its luster, and the fact that it does not rust or tarnish when exposed to the air. It is the most ductile (can be stretched out into the thinnest wire), and is also the most malleable (can be hammered out into the thinnest sheet). It can be hammered into leaves so thin that light will pass through them. Pure gold is so soft that it cannot be used in that form in making gold coins or in making jewelry. Other substances, generally copper, are added to it to make the gold coins and jewelry hard. Sometimes silver is also added to the gold with copper. The gold coins of the United States are made of nine parts of gold to one of copper. The coins of France are the same, while the coins of England are made of eleven parts of gold to one of copper. The gold used for jewels and watch-cases varies from eight or nine to eighteen carats fine.

Another reason why gold is called a precious metal is that it is very difficult to dissolve it. None of the acids alone will dissolve gold, and only two of them when mixed together will do so. These are nitric acid and hydrochloric acid. When these two acids are mixed and gold put into the mixture the gold will disappear.

What Do We Mean By 18-Carat Fine?

We often hear people in speaking of their watches say, "It is an 18-carat case." Others speak of 14-carat watches or 22-carat or solid-gold rings.

When you see the marks on a watch-case or the inside of a gold ring they read 18 K or 14 K, or whatever number of carats the maker wishes to indicate. A piece of gold jewelry marked 18 K or 18 carats means that it is three-fourths pure gold. In arranging this basis of marking things made of gold, absolutely pure gold is called 24 carats. Then if two, six or ten twenty-fourths of alloy has been added, the amount of the alloy is deducted from twenty-four, and the result is either 22, 18 or 14 carats fine, and so on. On ordinary articles made by jewelers the amount of pure gold used is seldom over 18 carats, or three-fourths. Weddings rings (and these are considered solid gold) are generally made 22 carats fine, that is, there are only two twenty-fourth parts of alloy in them.

Why Does Silver Tarnish?

Silver is a remarkably white metal, which is associated with gold as one of the precious metals. It is harder than gold and will not rust, although it will tarnish, which gold will not, when exposed to certain kinds of air.

The silver tarnishes when it is exposed to any kind of air that has sulphur mixed in it. It ranks below gold as a precious metal for use in making ornaments and is not so costly, because there is a great deal more of it to be found in the world.

While silver is somewhat harder than gold, it is still not sufficiently hard to use pure for making coins, so, as in the case of the gold coins, it is mixed with something else--copper--to harden it. Otherwise our dimes and quarters would wear out too rapidly. Our silver coins are made of nine parts of silver to one of copper. The coins of France are in the same proportion, while the silver coins of England are made of 92½■ parts of silver to 7½■ parts of copper. German silver coins are made of three parts of silver and one of copper.

Why Do We Use Copper Telegraph Wires?

One of the characteristics which distinguishes copper is its color--a peculiar red. It stands next to gold and silver in ductility and malleability, and comes next to iron and steel in tenacity--which means the ability of its tiny particles to hang on to each other. That is why copper wire bends instead of breaking when you twist it. But that is not the only reason, although an important part of the reason, why we use copper for telegraph wires. Copper is an extremely good conductor of electricity when it is pure. So are gold and silver, but we cannot afford to buy gold and silver wires for the telegraph, telephone and other wires, and if we used such wires the cost of the equipment would be so great that we could not afford to have telephones in our homes. But there is a great deal of copper in the world and it is very cheap, and so it makes an ideal element for use in things through which electricity is to pass. When you compound it with other substances it loses some of its conductivity. Copper is used extensively in many ways in the world. This book is printed, for instance, from copper electrotype plates. The whole business of electrotyping is based on the use of copper.

Why Is Lead So Heavy?

Lead is a white metal and is noted for its softness and durability. It has a luster when freshly cut, but becomes dull quite soon after the freshly-cut surface is exposed to the air. Lead is the softest metal in general use. It can be cut with an ordinary knife. It can be rolled out into thin sheets, but cannot be drawn out into wire.

Lead is a very dense metal, that is, its particles are very compact and there is no room for air to circulate in between these particles. A piece of wood is lighter than a piece of lead of exactly equal bulk, because the little particles which make up the piece of wood are not very close together, and there is a lot of air in the ordinary piece of wood, while this is not true of the lead.

A great deal of lead is used in making pipes for plumbing. This is because lead pipe is comparatively cheap, although you might not think so when you think of the general conclusions we have been brought to form about plumbers and everything connected with them. Lead pipe is easily bent in any direction also, and is particularly good for use in plumbing for that reason.

Another wide use of lead is in making paints--white lead being the base used in making oil paints. The process of making white lead for paint is quite interesting and pictures of it are shown in "The Story In a Can of Paint" in another part of "The Book of Wonders."

Why Are Cooking Utensils Made of Tin?

Tin is the least important of the six useful metals. It is also inferior in many ways to the others in this group of elements, but is tougher than lead and will make a better wire, though not a really good one. It has a whiteness and a luster that are not tarnished by ordinary temperature and is cheap. That is why it is used in making cooking utensils, pans, etc., and for roofs. But the pans, roofs, etc., are not pure tin. They are thin sheets of iron coated with tin. Pure tin would not be strong enough for these purposes, so a sheet of iron is first taken to supply the strength and then covered with tin to improve the appearance of the tin pans and keep them from rusting rapidly.

What Is Gravitation?

Gravitation is the result of the attraction which every body, no matter what its size, has for every other body. It is a strange force and difficult to explain in plain words. It is what keeps the heavenly bodies in their paths. Every one of the planets is held in its path by gravitation and every object on each of the planets is kept on the planet by gravitation. We can come nearer understanding gravitation by studying the effect of the attraction of gravitation on our own earth and the objects on it. When you throw a ball or a stone into the air it is the attraction of gravitation that causes it to come back. If this were not so the stone would go on up and up and would keep on going forever. If it were not for this wonderful force you could jump into the air and just keep on going up with nothing to bring you back. The reason you do not pull the earth toward you is because the body or mass with the greater bulk has always the greater pulling power.

This is a wonderful force. It cannot be produced nor can it be destroyed or lessened. It just is. It acts between all pairs of bodies. If other bodies come between any pair of bodies the attraction of gravity between the two outside bodies is neither lessened or increased, and yet each of the outside bodies will have an independent attraction or pull on the body which is in between.

No particle of time is spent by the transmission of the force of gravity from one body to another, no matter how far apart they may be. The only effect that distance has on the attraction of gravitation is to lessen its force. Any body which is being pulled through gravity toward another body would fall toward the center of the attracting body if all the force of attraction from all other bodies were removed.

What Is Specific Gravity?

Specific gravity is the ratio of weight of a given bulk of any substance to that of a standard substance. The substances taken as the standard for solids and liquids is water, and air or hydrogen for gases. Since the weights of different bodies are in proportion to their masses, it follows that the specific gravity of any body is the same as its density, and we now generally use the term “density” instead of specific gravity.

To find, for instance, the specific gravity of a given bulk of silver, we must take an equal bulk of water and weigh it. Then we also weigh the silver. We find that the silver weighs ten and a half times as much as the water, and so the specific gravity of silver is 10.5. If you will bear in mind that water is the standard used for measuring the specific gravity of solids and liquids, and that air or hydrogen are used as standards for the gases, you will always know what the figures after the words specific gravity mean.

Why Do We See Stars When Hit On the Eye?

We do not really see stars, of course, when we are hit on the eye or when we fall in such a way as to bump the front of our heads. What we do see, or think we see, is light.

To understand this we must go back to the explanation of the five senses--sight, hearing, feeling, tasting and touching. Now, each of these senses has a special set of nerves through which the sensations received by each of the senses is communicated to the brain and, as a rule, these special nerves receive no sensations excepting those which occur in their own particular field of usefulness. The eye then has nerves of vision; the nose, nerves of smell; the ear, nerves of hearing; the mouth, nerves of taste, and the entire body nerves of touch. As we have seen then, these special nerves are susceptible of receiving impressions or sensations only in their particular field. But, if you should be able to rouse the nerves of smell in an entirely artificial way and give them a sensation, they might easily act very much as though they smelled something. We find this often in the nerves of touch when we think we feel something when we do not.

Now, when some one hits you in the eye, the nerves of vision are disturbed in such a way as to produce upon the brain the sensation of seeing light. In other words, you cannot affect the eye nerves without causing the sensation of light, and that is just what happens when some one hits you in the eye.

[Illustration: "ARGONAUT, JUNIOR."

Experimental Boat, 1894.]

[Illustration: "ARGONAUT THE FIRST."

Built 1896-1897.]

The Story in a Submarine Boat

How Can a Ship Sail Under Water?

Up to a few years ago the stories we could tell about the ships that sail beneath the water were the creations of the minds of writers of fiction, like the author of "Twenty Thousand Leagues Under the Sea," but to-day we can read of many actual trips beneath the water by the brave men who man our submarines. We never dreamed that the great story of Jules Verne would be realized in the little but very destructive ships of war which can be seen to-day in the naval ports of the nations of the world.

We might have had these submarines long ago but for the fact that the men who were trying to invent them would not give up the secrets which they had discovered. Many men in different parts of the world worked on this problem and each discovered one or more things which were valuable in working out a solution, and if they had all gotten together and compared notes between them they could have produced a submarine boat almost as good as those we have to-day.

How Does the Submarine Get Down Under the Surface?

The first essential in a vessel to enable it to navigate below the surface of the water is that it be made sufficiently strong to withstand the surrounding pressure of water, which increases at the rate of .43 of a pound for each foot of submergence.

A boat navigating at a depth of 100 feet would therefore have 43 pounds pressure per square inch of surface, or 6192 pounds for every square foot of surface. It will readily be seen, therefore, that the first essential is great strength. Therefore, the submarine boats are usually built circular in cross section with steel plating riveted to heavy framing, as that is the best form to resist external pressure. These boats are built for surface navigation as well, therefore they have a certain amount of buoyancy when navigating on the surface, the same as an ordinary surface vessel. When it is desired to submerge the vessel this buoyancy must be destroyed, so that the vessel will sink under the surface.

Now, the submerged displacement of a submarine vessel is its total volume, and, theoretically, a vessel may be put in equilibrium with the water which it displaces by admitting water ballast into compartments contained within the hull of the vessel, therefore, if a vessel whose total displacement submerged was 100 tons, the vessel and contents must weigh also 100 tons. If it weighed one ounce more than 100 tons it would sink to the bottom. If it weighed one ounce less than 100 tons it would float on the surface with a buoyancy of one ounce. If it weighed exactly 100 tons it would be in what submarine designers specify as being "in perfect equilibrium."

It is possible to give a vessel a slight negative buoyancy to cause her to sink to, say, a depth of 50 feet and then pump out sufficient water to give her a perfect equilibrium, and thus cause her to remain at a fixed depth while at rest. In practice, however, this is seldom done. Most submarine boats navigate under the water with a positive buoyancy of from 200 to 1000 pounds and are either steered at the depth desired by a horizontal rudder placed in the stern of the vessel, or are held to the depth by hydroplanes, which hydroplanes correspond to the fins of a fish. They are flat, plane surfaces, extending out from either side of the vessel, and when the vessel has headway, if the forward ends of these planes are inclined downward, the resistance of the water acting upon the planes is sufficient to overcome the reserve of buoyancy and holds the vessel to the desired depth. If the vessel's propeller is stopped, the boat, having positive buoyancy, will come to the surface.

By manipulating either the stern rudders or the hydroplanes, the vessel may be readily caused to either come nearer to the surface or go to a greater depth, as the change of angle will give a greater or less downpull to overcome the reserve of buoyancy.

The above description applies to navigating a vessel when between the surface of the water and the bottom.

Another type of vessel which is used for searching the bottom in locating wrecks, obtaining pearls, sponges, or shellfish, is provided with wheels. In this type of vessel the boat is given a slight negative buoyancy, sufficient to keep it on the bottom, and it is then propelled over the water bed on wheels, the same as an automobile is propelled about the streets. This type of vessel is also provided with a diver's compartment, which is a compartment with a door opening outward from the bottom. If the operators in the boat wish to inspect the bottom, they go into this compartment and turn compressed air into the compartment until the air pressure equals the water pressure outside of the boat; i. e., if they were submerged at a depth of 100 feet they would introduce an air pressure of 43 pounds per square inch into the diving compartment. The door could then be opened and no water could come into the compartment, as the diving compartment would be virtually a diving bell. Divers can then readily leave the boat by putting on a diving suit and stepping out upon the bottom.

[Illustration: ONE OF THE FIRST PRACTICAL SUBMARINES

"PROTECTOR." BUILT 1901-1902, BRIDGEPORT, CONN.

This was the pioneer Submarine Torpedo Boat of the level-keel type, and was built in Bridgeport in 1901-1902. It was shipped to St. Petersburg, Russia, during the Russian-Japanese war. From St. Petersburg it was shipped to Vladivostok, 6000 miles across Siberia, special cars being built for its transport.]

[Illustration: This picture illustrates the same vessel, also at full speed under engines, with the conning-tower entirely awash and with the sighting-hood and the Omniscope alone above water. Notwithstanding the limited areas exposed above the surface, still observation could be had well-nigh continuously either through the dead-lights in the sighting-hood or by means of the Omniscope.

In neither condition is it necessary to have recourse to electrical propulsion--the boats can still be safely and speedily driven as here shown under their engines.]

[Illustration: THE INSIDE OF A SUBMARINE

THE "G-1" RECENTLY DELIVERED TO THE UNITED STATES GOVERNMENT.

The largest, fastest submarine in the United States and the most powerfully armed submarine torpedo boat in the world.

In addition to the usual fixed torpedo tubes arranged in the bow of the vessel, which requires the vessel herself to be trained, the (seal) "G-1" carries four torpedo tubes on her deck which may be trained while the vessel is submerged, in the same manner as a deck gun on a surface vessel is trained, and thus fired to either broadside, which gives many technical advantages.]

[Illustration: The above view gives a general idea of the interior of a submarine torpedo boat and the method of operation when running entirely submerged with periscope only above the surface.

The commanding officer is at the periscope in the conning tower directing the course of the submarine through the periscope, which is a tube arranged with lenses and prisms which gives a view of the horizon and everything above the surface of the water, the same as if the observer in the submarine was himself above water. The steersman is shown just forward of the commanding officer and steers the vessel by compass under the direction of the commanding officer, the same as when navigating above the surface. In the larger type boats the steersman also has a periscope which enables him to see what is going on above the surface. Below decks two of the crew are shown loading a torpedo into the torpedo tube; each torpedo is charged with gun-cotton and will run under its own power over a mile and will explode on striking the enemy. The crew live in the compartment aft of the torpedo room. Aft of this is the engine room, in which are located powerful internal combustion engines for running on the surface and electric motors for running submerged. The electric motors are driven by storage batteries located under the living quarters. Wheels are shown housed in the keel, which may be lowered for navigating on the bottom in shallow water. A diving compartment in the bow permits divers to leave the vessel when on the bottom, to search for and cut or repair cables or to plant mines.]

[Illustration: A SUBMARINE SAILING CLOSE TO THE SURFACE

A submarine running partly submerged with the conning tower hatch open, showing the remarkable steadiness of this type of boat in a semi-submerged condition, a thing no other craft could safely accomplish.]

[Illustration: Another submarine running entirely submerged, periscope only showing. The flag is attached to top of periscope to show her position in maneuvers when periscope goes entirely under water.]

[Illustration: A PHOTOGRAPH TAKEN WITH THE PERISCOPE UNIVERSAL LENS.]

AN ALL-SEEING EYE FOR THE SUBMARINE

Vision under water is limited to but a few yards at best, and hence a submarine boat, when submerged, would be as blind as a ship in a dense fog and would have to grope its way along guided only by chart and compass, were it not for a device known as a periscope, that reaches upward and projects out of the water, enabling the steersman to view his surroundings from the surface. Of course the height of the periscope limits the depth at which the craft may be safely sailed. Nor can the periscope tube be extended indefinitely, because the submarine must be capable of diving under a vessel when occasion demands. But when operating just under the surface, where it can see without being seen, the craft is in far greater danger of collision than vessels on the surface, because it must depend upon its own alertness and agility to keep out of the way of other boats. The latter can hardly be expected to notice the inconspicuous periscope tube projecting from the water in time to turn their great bulks out of the danger course.

The foregoing article describes the type of periscope now in common use on submarines and one of the engravings on this page clearly illustrates the principles of the instrument. A serious defect of this type of instrument is that the field of vision is too limited. The man at the wheel is able to see under normal conditions only that which lies immediately before the boat. It is true that he can turn the periscope about so as to look in other directions, but this, of course, involves considerable inconvenience. On at least two occasions has a submarine boat been run down by a vessel coming up behind it.

[Illustration]

~SEEING IN ALL DIRECTIONS AT ONCE~

As long as the submarine has but a single eye it would seem quite essential to make this eye all-seeing; and since the two lamentable accidents just referred to, an inventor in England has devised a periscope which provides a view in all directions at the same time. This has been attempted before, but it has been found very difficult to obtain an annular lens mirror which would project the image down the periscope tube without distortion. The accompanying illustrations show how this difficulty has now been overcome. While we will not attempt to enter into a mathematical explanation of the precise form of the mirror lens, it will suffice to state that it is an annular prism. The prism is a zonal section of a sphere with a conoidal central opening and a slightly concave base. All the surfaces, however, are generated by arcs of circles owing to the mechanical inconvenience of producing truly hyperboloidal surfaces. The lens mirror is shown in section at _A_ in Fig. 1. The arrows indicate roughly the course of the rays into the lens and their reflection from the surface _B_, which is preferably silvered. The tube is provided with two objectives _C_ and _D_ (Fig. 3) between which a condenser _E_ is interposed at the image plane of the lens _C_. At the bottom of the periscope tube the rays are reflected by means of a prism _F_ into the eyepiece. Two eyepieces are employed. One of lower power, _G_, is a Kelner eyepiece, the purpose of which is to permit inspection of the whole image, while a high-powered eccentrically placed Huyghenian eyepiece, _H_, enables one to inspect portions of the image. The two eyepieces are mounted in a rectilinear chamber, _I_, which may be rotated about the prism at the end of the periscope, thus bringing one or other of the eyepieces into active position. The plan view, Fig. 4, shows in full lines the high-powered eyepiece in operative position, while the dotted lines indicate the parts moved about to bring the low-powered eyepiece into use. A small catch, _J_, shown in Fig. 2, serves to hold the chamber in either of these two positions. The high-powered eyepiece is mounted on a plate, _K_, which may be rotated to bring the eyepiece into position for inspecting any desired portions of the annular image. The parts are so arranged that when the eyepiece is in its uppermost position, as indicated by full lines in Fig. 2, the observer can see that which is directly in front of the submarine, and when the eyepiece is in its low position, as indicated by dotted lines, he sees objects to the rear of the submarine. With the eyepiece at the right or at the left he sees objects at the right or left, respectively, of the submarine. The high-powered eyepiece is slightly inclined, so that the image may be viewed normally and to equal advantage in all parts. Mounted above a plain unsilvered portion of the mirror is a scale of degrees which appears just outside of the annular image. A scale is also engraved on the plate _K_ with a fixed pointer on the chamber, making it possible to locate the position of any object and rotate the plate _K_ so as to bring the eyepiece _H_ on it. The scale also makes it possible to locate the object with respect to the boat.

[Illustration: HOW WE LOOK THROUGH A PERISCOPE

THE PERISCOPE TOP.]

[Illustration: PERISCOPE IN GENERAL USE.]

[Illustration: THE UNIVERSAL OBSERVATION LENS.]

This improved periscope is applicable not only to submarine boats but for other purposes as well, such as photographic land surface work, in which the entire surroundings may be recorded in a single photograph. The accompanying photograph, taken through a periscope of this type, shows the advantages of this arrangement and gives an idea of its value to the submarine observer when using the low-powered eyepiece. Of course, by using the other eyepiece any particular part of the view may be enlarged and examined in detail.

[Illustration: INSIDE OF A MINE-PLANTING SUBMARINE

MINE-PLANTING SUBMERSIBLE.

A Lake type vessel designed for planting contact mines. In naval warfare it is sometimes of advantage to plant mines, either to defend harbors, or in some cases the mines are planted in the course of the approaching enemy. This is a vessel designed for that purpose. The enemy is seen approaching, and the mine-planting submarine runs in ahead of them in a submerged condition and drops a number of contact mines on their course; the enemy strikes the mine and is blown up. A number of vessels were blown up by contact mines of this type in the Russian-Japanese war.]

Accidents and Their Causes.

The accidents which submarine vessels must guard against are as follows: collision, foundering, explosions and asphyxiation. The first danger is, however, no greater than those to which vessels that run entirely on the surface of the water are exposed. The eye of the submarine places the commander on a practical level with the commander of other vessels, so that if a collision occurs it is due to the same lack of watchfulness which causes collisions on the surface of the water.

The submarine boat is less liable to founder than an ordinary vessel, because she is built to withstand a greater pressure of water than other kinds of vessels. Of course, if a submarine springs a leak, she is in grave danger of sinking to the bottom, and there is less chance of the crew being rescued from a submarine, because no one but those on board know of the danger if the boat is under the water.

How Explosions May Occur.

In submarine vessels explosions may occur either through a collection of gases from the batteries or by reason of leaks in the pipes or tanks of the fuel supply system, or through the bursting of the air flasks belonging to the boat, or the air reservoirs in the automobile torpedoes. The greatest danger is from explosive gases and have been the cause of all explosions in modern submarine craft, and the greatest danger in this connection is the liability of a leak in the gasolene pipes or tanks. This gas is a heavy gas and so goes to the bottom of the vessel, where it is not so easily detected as a gas which rises. There is no certain way of guarding against leaks of gasolene. A leak may occur at any time in a pipe or tank of gasolene through some cause or other no matter how carefully inspected, and the gas from this is so active that it will go through the tiniest hole imaginable--even through a hole which water will not penetrate. The crew of a submarine is always subject to this danger unless the tanks are built outside the hull of the ship.

How the Air May Become Poisoned.

There is a constant danger of asphyxiation to the men in the submarine. A very small leakage of gas or the exhaust from an internal combustion engine may make the air so impure that those aboard will be overcome. A great deal of care must be taken to keep the air pure and to warn the crew at the first sign of danger from this.

When submarines first came into practical use, it was found a good idea to take a number of little white mice down with the vessel to warn all if the air began to become impure. As soon as this occurred, the mice became distressed and squealed as loudly as they could, thus warning those aboard the ship of danger. The mice felt the impurity of the air quicker than the men, not because they had any special gift to discover when the air was bad, but because they breathe much more quickly than man--take shorter and many more breaths.

Now, however, a chemical device has been invented which is affected in such a way as to ring a loud bell, if the air in the vessel becomes impure to such an extent that there is any danger.

Breathing the same air over and over may fill the vessel with carbonic acid gas. There should be no great danger from this, however, as submarines are now built sufficiently large to provide enough actually pure air for each man aboard for forty-eight hours, and it is hardly conceivable that a submarine need be submerged more than half that length of time under any conditions.

Of course, then, too, there is the danger of accident due to carelessness or ignorance. In other words, it is just as difficult to make a fool-proof submarine as a fool-proof anything else. Wherever anything is constantly dependent upon the continuous careful attention of human beings, there is constant danger of accident, whether it be on board a submarine, a railroad train, steamship or in connection with anything else.

[Illustration: A SUBMARINE UNDER THE ICE

UNDER-ICE SUBMARINE TORPEDO BOAT.

Submarine designed to navigate submerged under the ice, in ice-bound countries. Vessels of this type could enter harbors and destroy the enemy's shipping at will. A vessel of this type would also be of value in transporting mails, passengers and cargoes between ice-bound ports where navigation by surface vessels is closed for several months in the year.]

Story of How the Submarine Has Been Developed.

It is only within the past twenty years that man has been able to successfully navigate under the surface of the water.

~WHO MADE THE FIRST SUBMARINE BOAT?~

It has been a dream of inventors and engineers for the past three hundred years.

During the reign of King James I. a crude submarine vessel was built of wood, and was designed to be propelled by oars extending out through holes in the side of the vessel, the water being prevented from coming in through the openings by goat skins tied about the oars and nailed to the sides of the boat, which made a water-tight joint, but at the same time gave flexibility to the oars, so that by feathering them on the return stroke they could be manipulated to give head motion. Very little, if any, success could have attended this effort.

Nearly a hundred years later a man by the name of Day built a submarine and made a wager that he could descend to 100 yards and remain there 24 hours. He built a boat and submerged it in a place where there was a depth of 100 yards. He succeeded in remaining the 24 hours, and according to latest advices is still there, as he never returned to the surface.

There is very little information as to the construction of these early craft. The first really serious attempt at submarine navigation was made by a Connecticut man, a Dr. David Bushnell, who lived at Saybrook during the Revolutionary War. He built a small submarine vessel which he called the "American Turtle," and with it he expected to destroy the British fleet, anchored off New York during its occupation by General Washington and the Continental Army.

Thatcher's Military Journal gives a description of this vessel and describes an attempt to sink the British frigate "Eagle" of 64 guns by attaching a torpedo to the bottom of the ship by means of a screw manipulated from the interior of this submarine vessel.

A sergeant who operated the "Turtle" succeeded in getting under the British vessel, but the screw which was to hold the torpedo in place came in contact with an iron scrap, refused to enter, and the implement of destruction floated down stream, where its clockwork mechanism finally caused it to explode, throwing a column of water high in the air and creating consternation among the shipping in the harbor. Skippers were so badly frightened that they slipped their cables and went down to Sandy Hook. General Washington complimented Dr. Bushnell on having so nearly accomplished the destruction of the frigate.

If the performance of Bushnell's "Turtle" was such as described, it seems strange that our new government did not immediately take up his ideas and make an appropriation for further experiments in the same line. When the attack was made on the "Eagle," Dr. Bushnell's brother, who was to have manned the craft, was sick, and a sergeant who undertook the task was not sufficiently acquainted with the operation to succeed in attaching the torpedo to the bottom of the frigate. Had he succeeded the "Eagle" would undoubtedly have been destroyed and the event would have added the name of another "hero" to history and might then have changed the entire art of naval warfare. Instead of Bushnell being encouraged in his plans, however, they were bitterly opposed by

the naval authorities. His treatment was such as finally to compel him to leave the country, but he returned after some years of wandering, and under an assumed name, settled in Georgia, where he spent his remaining days practicing his profession.

Robert Fulton, the man whose genius made steam navigation a success, was the next to turn his attention to submarine boats, and submarine warfare by submerged mines. A large part of his life was devoted to the solution of this problem. He went to France with his project and interested Napoleon Bonaparte, who became his patron and who was the means of securing sufficient funds to build a boat which was called the "Nautilus." With this vessel Fulton made numerous descents, and it is reported that he covered 500 yards in a submerged run of seven minutes.

~HOW SUBMARINES WERE DEVELOPED~

In the spring of 1801 he took the "Nautilus" to Brest, and experimented with her for some time. He and three companions descended in the harbor to a depth of 25 feet and remained one hour, but he found the hull would not stand the pressure of a greater depth. They were in total darkness during the whole time, but afterward he fitted his craft with a glass window 1½ inches in diameter, through which he could see to count the minutes on his watch. He also discovered during his trials that the mariner's compass pointed equally as true under water as above it. His experiments led him to believe that he could build a submarine vessel with which he could swim under the surface and destroy any man-of-war afloat. When he came before the French Admiralty, however, he was met with blunt refusal, one bluff old French admiral saying: "Thank God, France still fights her battles on the surface, not beneath it," a sentiment which apparently has changed since those days, as France now has a large fleet of submarines. After several years of unsuccessful efforts in France to get his plans adopted, Fulton finally went over to England and interested William Pitt, then chancellor, in his schemes. He built a boat there, and succeeded in attaching a torpedo beneath a condemned brig provided for the purpose, blowing her up in the presence of an immense throng. Pitt induced Fulton to sell his boat to the English government and not bring it to the attention of any other nation, thus recognizing the fact that if this type of vessel should be made entirely successful, England would lose her supremacy as the "Mistress of the Seas."

Fulton consented to do so, but would not pledge himself regarding his own country, stating that if his country should become engaged in war, no pledge could be given that would prevent him from offering his services in any way which would be for its benefit.

The English Government paid him $75,000 for this concession. Fulton then returned to New York and built the "Clermont" and other steamboats, but did not entirely give up his ideas of submarine navigation, and at the time of his death was at work on plans for a much larger boat.

Fulton had a true conception of the result of submarine warfare, and in a letter he says: "Gunpowder has within the last three hundred years totally changed the art of war, and all my reflections have led me to believe that this application of it will, in a few years, put a stop to maritime wars, give that liberty on the seas which has been long and anxiously desired by every good man, and secure to Americans that liberty of commerce, tranquillity, and independence which will enable citizens to apply their mental and corporeal facilities to useful and humane pursuits, to the improvement of our country and the happiness of the whole people."

After Fulton's death spasmodic attempts were made by various inventors looking to the solving of the difficult problem, but no very serious efforts were put forth until the period of the Civil War, and then a number of submarine boats were built by the Confederates. These boats were commonly called "Davids," and it was one of them that sank the United States steamship "Housatonic" in Charleston Harbor on the night of the 17th of February, 1864. This submarine vessel drowned four different crews, a total of thirty men, during her brief career. At the time she sank the "Housatonic" her attack was anticipated, and sharp lookout was kept at all times; but, notwithstanding their vigilance, she succeeded in getting sufficiently close to plant a torpedo on the end of a spar, and sink this fine, new ship of 1400 tons displacement.

It will be seen from the above description that these vessels, while able to go under water, were not controllable.

After the Civil War several other inventors took up the problem of trying to design a submarine vessel that could be controlled as to maintenance of depth and direction under water.

In Europe, Gustave Zede, Goubet and Drzwiezki, and in this country Mr. Baker and Mr. John P. Holland, built experimental vessels.

In 1877 Mr. Holland built a small boat which was called the "Fenian Ram." It is stated that this vessel was built with capital furnished by the "Clan-na-Gael," with the idea of using it against the British fleet in an attempt to free Ireland.

While some slight success was met with by these inventors, it was not until about 1897 that any real progress was made.

~THE FIRST SUCCESSFUL SUBMARINE WITH HYDROPLANES~

In 1893, Simon Lake, an American inventor, submitted plans to the United States Naval authorities at Washington for a submarine boat that would navigate between the surface and the bottom by the use of what he called "hydroplanes," which were designed to cause the vessel to submerge on an even keel. Mr. Lake's design of vessel was also provided with wheels to enable it to navigate on the water bed. It was also provided with a diving compartment to enable the crew to don diving suits and leave the vessel, in working on wrecks, cutting cables, planting mines, etc.

In 1904 and 1905 he built a small vessel to demonstrate his principles and succeeded in successfully navigating the vessel on the bottom of New York Bay. He then built a larger vessel of about 50 tons displacement for further experimental purposes. This vessel was called the "Argonaut," and was built in Baltimore in 1906 and 1907. This boat was successful from the start and covered thousands of miles in the Chesapeake Bay and along the Atlantic Coast, New York Bay and Long Island Sound, and was the first successful submarine boat to navigate in the open sea and on the water bed of the ocean.

Mr. Holland had, in 1894, received a contract for a submarine vessel for the United States Navy, and her construction was started in 1895. This vessel was called the "Plunger." This was the first official recognition given to a submarine boat in the United States.

The Government of France had also given an order for a submarine boat which was under construction at this period.

The "Plunger" was never submerged, her construction covering a period of several years, and she was finally abandoned. Mr. Holland had, however, in the meantime prepared the designs of another vessel which he called "The Holland." This vessel was accepted by the United States Government in 1900, and a number of other vessels of this type were built. These vessels were known as submarines of the diving type. They were controlled by means of a horizontal and vertical rudder placed at the stern of the vessel and the boat was, by means of these rudders, inclined down by the bow, and driven under the water by the force of their screw propeller.

England also built a number of submarines of the diving type.

In 1901 Mr. Lake brought out a larger vessel of his type, which was controlled by hydroplanes, which vessel was sold to the Russian Government, was shipped across the Atlantic to Kronstadt, and from there by rail to Vladivostok, and was in commission off Vladivostok just before the close of the Russian-Japanese War.

Mr. Lake then received orders from the Russian and other Governments for a number of additional boats of the even keel type, to be controlled by hydroplanes.

Mr. Lake's principles of control have been now generally adopted by all Governments, as providing the safest and most reliable means of control of the vessel when navigating under the surface.

The United States Government has recently adopted this type to be built in their Navy Yards, and most other builders have adopted the hydroplanes as the means of maintaining depth when running beneath the surface.

[Illustration: CLEARING A CHANNEL OF BUOYANT MINES

This is one of the services to which submarine boats of this type lend themselves with peculiar fitness. It is possible for them to carry on this work with deliberation and to success, under the very guns and searchlights of a vigilant foe, without the slightest danger of being detected.

This would be accomplished preferably by the co-operation of two boats. They would take opposite sides in the channel, with a connecting rope extending out through the diving compartment. It is obvious that as they move along the rope will sweep the whole mine-field and gather in the connecting cables. This would be indicated at once to the operators in the diving compartment by the load upon the sweeping line. A grapple may then be attached to the rope and sent out of one boat and hauled into the other, and thus drag the mine so near that a diver could go out and destroy its electrical connections or cut it adrift. Should the latter operation be the aim, the grapple may be so fashioned as to accomplish this without the diver leaving the compartment. This latter method is one strongly recommended by some of the most prominent military authorities on submarine defense.]

[Illustration: This picture indicates the manner in which the boats have traveled many miles over all kinds of bottom. In the present instance the boat is shown systematically searching the bottom with her diving door open and strong lights being used to facilitate a more perfect examination.

There is no trim or equilibrium to maintain. When the propelling machinery stops the boat comes to rest. A cyclometer attached to these wheels gives a fairly reliable reading of the distance traveled under normal circumstances. As the currents do not carry her out of her course, and as her gauges give an absolute record of changing depths, it is possible to so navigate upon the bottom with remarkable precision. In shallow waters this method has many advantages.]

[Illustration: A MACHINE WHICH MAKES THE DIVER'S TASK EASY

SHOWING TUBE HANDLING CARGO IN SUNKEN SHIP.]

Recovering Cargo or Submerged Objects Without the Aid of Divers.

The operating tube is here shown within the body of a hulk and co-operating with the lifting derrick on the surface craft in the removal of the submerged cargo. A grab-dredge bucket of well-known construction is used, the jaws of which, when being lowered by one rope, open, and when strain is brought on the lifting rope, the jaws close. The working end of the tube is placed in the immediate neighborhood of the cargo to be lifted and, as the grab is being lowered from the boat above, the operator in the compartment controls the grab by means of the guide line shown attached to the small derrick boom, and leads it directly over the cargo to be lifted. The grab is then dropped and the signal sent to the vessel above to hoist. The moment the lifting line tautens the bucket grasps a load and fills itself with material in the manner common to this type of dredge. This method of directing intelligently and deliberately the dredge bucket may be applied as well to the removal of rock or any other obstruction or to any of those various services of kindred character familiar to submarine engineers. The great and prime advantage of the system is the fact that no divers are required, and the work is under the perfect control of an operator subject only to atmospheric pressure. In consequence, therefore, the only limit to the effective operating of this apparatus is the length of the tube, and, as has been said, this can be made long enough to reach depths denied to the diver simply by interposing additional sections.

[Illustration: LIFE ABOARD A SUBMARINE

LIVING QUARTERS ABOARD A SUBMARINE.]

Where Do Sponges Come From?

Until within comparatively recent years, the sponge was regarded as a plant; it is now known to belong to the animal kingdom, and to the order spongida of the class of rhizopoda. Sponge is an elastic, porous substance, formed of interlaced horny fibers, which produce by their numerous inosculations, a rude sort of network, with meshes or pores of unequal sizes, and usually of a square or angulated shape. Besides these pores there are some circular holes of large size scattered over the surface of most sponges, which lead into sinuous canals that permeate their interior in every direction. The oscula, canals, and pores, communicate freely together. The characteristic property of the sponge is the facility with which it absorbs a large quantity of any fluid, more especially of water, which is retained amid the meshes until forced out again by a sufficient degree of compression, when the sponge returns to its former bulk. From this peculiarity, combined with its pleasant softness, arises the value of the sponge for the purposes to which it is applied. In domestic economy and in surgical practice, there is no other product that can be satisfactorily substituted for it.

Sponge is an aquatic production, indigenous to almost every sea and shore. It is abundant and varied between the tropics, but becomes less so in temperate latitudes and continues to diminish in quantity, variety, and size, as it is traced into European and colder seas, until it almost disappears in the vicinity of the polar circles. Some sponges are known to be hermaphrodite, but that the individual at one period produces chiefly male elements, and later, chiefly female elements. Fertilization takes place in the body of the mother, and the egg here undergoes its early development. The embryo eventually bursts the maternal tissue and, passing into one of the canals, is caught by the current sweeping through the canal system and is discharged into the surrounding water through one of the large apertures on the surface of the sponge. In the Bahama Islands and along the coast of Florida, the breeding time of many sponges covers the period from mid-summer on through early Autumn.

There is propagation sometimes by ciliated gemmules, yellowish and oval, arising from the sarcode mass, and carried out by the currents. These are mostly formed in the spring, and after swimming freely about for a time, become fixed and grow. In its natural state, the sponge is a very different looking object from the article of commerce. The entire surface is covered with a thin, slimy skin, usually of a dark color, and perforated to correspond with the apertures of the canals. The sponge of commerce is in reality only the home or the skeleton of the sponge.

There are a few sponges that inhabit ponds and sluggish rivers; the others are marine. Of these, many of the calcareous and siliceous kinds inhabit the shores between tide-marks, preferring a site near the low ebb, where, nevertheless, they are daily alternately submerged, and left exposed to the atmosphere. The figured sponges with a fibrous texture, to whatever genus they belong, are denizens of deeper water, and are never left uncovered. They grow usually in groups, on rock shells, shellfish, corallines, and seaweeds, and either have no power of selection, or the quality of the site is indifferent to them.

How Do Sponges Grow?

In their growth, some sponges assume a determinate figure or at least one whose variations are confined within certain limits. The greater number are irregular and variable, their shape depending in a great measure upon the peculiarities of their state, to which they easily accommodate themselves. They will incrust a shell, or a crab, a rock, or seaweed, following every projection and sinuosity. The offshoots will spring up with a more luxuriant growth in the deeper sheltered places until the original shape of the foundation they grow upon is lost to sight.

Sponges are unmoving and inirritable. They never remain rooted to the places of the germination, and are incapable either of contracting or dilating themselves or even of moving any fiber or portion of their mass. The functions which distinguish them as living beings are few, and faintly imaged.

How Do Sponges Eat?

Although sponges lack the power of motion possessed by most animals, being nearly always attached, in one position or another, to some object, the study of their habits in captivity brings out many of their animal characteristics in a striking manner. Small specimens taken from the sea and placed in dishes of salt water may be kept alive for several hours if well cared for; and by using finely powdered coloring matter, such as carmine or indigo, the manner of their feeding may be readily observed. Sponges are more active in fresh sea water than in stale; they cannot be kept alive out of water and soon die if exposed to the air. Being unable to go in search of food, as a natural result, they can grow only in places where there is always an abundance of food suited to their wants. The great sponging grounds of the world are wholly confined within waters having a relatively high temperature during the entire year. The Old World sponges grow principally in the Mediterranean and the Red seas; the New World sponges are found about the Bahamas, southern and western Florida, and parts of the West Indies. The finest sponges come from the East, but one of the American species, the so-called “sheep’s wool,” stands high in favor.

The commercial sponges are separated into six species, three of which are European and three American. They are all referred to a single genus called spongia, and though having much in common as regards structure, their texture varies to such an extent as to make them of very unequal value for domestic purposes.

The Old World species may be arranged as follows, in order of their grade of excellence, beginning with the best quality: The Turkey cup sponge, Levant toilet sponge, the horse, honey comb, or bath sponge, and the Zimoca sponge. The American species include the sheep’s wool sponge, the yellow glove, violet, and grass, sponges. A very close relationship exists between the species of the two continents.

All known regions in which useful specimens abound contribute to the world’s supply. The trade is extensive. The demands upon the fisheries are great. In the Mediterranean, the fishing is carried on in some places at a depth of forty fathoms. Divers, naked, or in armor, go down to the bottom and tear off the sponges from their places of growth. In some places drag dredges are employed.

How Are Sponges Caught?

In the past quarter-century the sponge-fishery of the Florida coast has grown remarkably. Its headquarters is at Key West and several hundred sailing vessels are engaged in the industry. The fishing appliances consist of a small boat, a long hook, and a

waterglass. The hook is in reality a three-pronged spear attached to a pole thirty-five feet long. In searching for sponge the fishers row about in the small boat. By holding the glass on the surface of the water the bottom is plainly seen and small objects are readily discerned. When a sponge is sighted the pole with the hook attached is shot down and the product deftly gathered. The boat-load is brought to the deck of the schooner, allowed to remain there a few hours, and then is carried down into the hold. On Friday nights, the fishing generally ends for the week, and the vessel sails for some spot on the neighboring coast where there are established crawls, or places for curing the catch. These crawls are about 8 x 10 feet square, their purpose being to hold the sponges while maceration and decomposition take place. The resulting refuse is carried off by the tide.

The fishermen go away for another catch and the sponges are left in the crawls until the end of the following week when a new cargo is brought in. The returning fishermen beat the decomposed sponges with clubs, removing the impurities. The water is squeezed out, then the sponges are allowed to dry on the ground.

After drying, the hold of the large vessel is loaded to the utmost with the product and the voyage to Key West is made. Buyers from New York look over the sponges, and make offers for entire cargoes. The fishermen dispose of their goods rapidly and sail away for more. The buyers store the sponges in some dry building, and cause them to be bleached by lime. A popular manner of bleaching is to wash the sponges thoroughly in water, and then to immerse them in diluted hydrochloric acid to dissolve any of the calcareous substance. Having again been washed they are placed in another bath of dilute hydrochloric acid to which six per cent. of hyposulphite of soda, dissolved in a little warm water, has been added. In this bath the sponges remain for twenty-four hours, or until the bleaching process is completed. After bleaching, the sponges are pressed until their bulk is greatly reduced; they are then baled, and shipped to New York, which is the distributing point for the entire Florida product.

Sponges are by far the most important fishery products of Florida, representing about one-third of the annual value of the fishing industry. In 1899, the yield was over 350,000 pounds of sponges of which the first value was nearly $400,000.

Why Does Yeast Make Bread Rise?

There is a lot of sugar in the dough from which bread is made. Sugar contains three things--carbon, hydrogen and oxygen. When sugar is fermented it amounts practically to burning it. To make good bread from the dough it is necessary to ferment the sugar which is in the ingredients from which it is made. Yeast, which is a simple living plant, has the power to ferment sugar. When sugar ferments, two things are produced. One thing is the formation of carbonic acid gas. A great deal of this carbonic acid gas is caught in the dough in the form of large or small bubbles and some of it escapes into the air. The other part tries to escape into the air also but cannot, and causes the dough to rise, which makes the bread light, as we say. The holes you see in the bread after it is baked are the little pockets where the carbonic acid gas was retained in the dough. These bubbles of gas all through the dough act like a lot of little balloons and lift the dough up with themselves as they try to get to the top and escape into the air.

What Is Yeast?

Yeast is a living plant that is used for the purpose of causing fermentation. The yeast we use in baking bread is an artificial yeast--really a dough made of flour and a little common yeast and made into small cakes and dried. If kept free from moisture it retains the power of causing fermentation for some time. The flour and other matter in a cake of yeast are only used to keep the yeast in a form where it can be preserved. It is necessary to add water to start fermentation and that is why we add hot water when we stir in the yeast for a baking.

Is a Moth Attracted By a Light?

It seems to be a strange contradiction of the nature of living things that a moth should fly deliberately into a light or dash itself to death against the glass surrounding a strong light. This is contrary to the usual law of nature which gives the living thing an instinct to protect itself against enemies.

For a long time we thought that moths did not deliberately burn themselves up by flying right into a light, but our naturalists have proven that not only moths but certain birds, bees, flies and butterflies, burn themselves up by flying into the flame of a light or fire.

[Illustration: HOW MAN LEARNED TO MAKE A FIRE

SAWING

This was probably man's first method of producing fire. By rubbing two sticks together in this way sufficient heat was produced to set fire to easily burnable material such as dried grass, etc.]

[Illustration: DRILLING

An improvement came when man learned that by twirling a dry stick in a hole in another piece of dry wood the fire could be started more quickly.]

How Man Discovered Fire

Fire was probably one of man's first, if not the first, great discoveries, and has been one of his greatest servants as well as one of his greatest dangers. We do not know who discovered fire, or what nation first used it. It is, however, one of the signs that distinguishes man from the other animals. Not any of the lower animals was acquainted with the use of fire, while probably the earliest races of mankind seem to have been acquainted with it.

Mythology tells us wonderful stories of the origin of fire: according to these tales it was stolen from the sun, or the gods, and given to man; and Pandora, the first woman, was sent down to earth to punish man for his theft.

The most popular of these stories is the legend of Prometheus. According to this legend, fire, in the early days, was under the exclusive control of the gods. Prometheus, brother of Atlas, the god who supported the world on his shoulders, determined that the use of fire should be given to the people. He decided by some means to send a spark of fire to the earth, believing that one spark caught by man would start a burning flame that would never go out.

With this idea in mind, Prometheus visited Zeus, the great ruler, to carry out his purpose, for Zeus controlled fire. While Zeus was not looking, Prometheus "stole some brands of fire from the hearth, which he hid in the stalk of a fennel and sent it down to the earth." Through this Prometheus gave to man his first knowledge of fire.

But while this story of fire may or may not be true, the use of fire rests entirely with man and his ingenuity. Through his ingenuity man was able to subject fire to his will; making it perform certain of his labors; and to a certain extent making it his servant; although it always did and always will get beyond his control at times.

Our ancestors were not satisfied with preserving the fire which the gods gave them; they tried and succeeded in producing it. One day one of them discovered that by rubbing two sticks together rapidly, the friction would create a fire. It was a most useful discovery. Before long the whole of mankind had learned this trick; others improved on this crude method until step by step men learned that by striking two pieces of flint or other hard mineral together, quicker action was obtained.

[Illustration: DRILLING WITH BOW STRING

Man's ingenuity soon taught him that if he tied one end of a string to something and wrapped it around his drilling stick, one end of which was in a hole as in the first drilling picture, he could increase the rapidity of making fire.]

[Illustration: DRILLING WITH HELP

With some other to hold the drilling stick while he operated the string he was able to produce fire more quickly than he had ever done before.]

All kinds of methods were devised to increase knowledge of producing fire. The early Greeks found out how to catch the rays of the sun on a burning-glass and produce fire; the Romans achieved the same results through the use of mirrors.

[Illustration: PLOWING

This is another method man used for rubbing two pieces of wood together. In following this plan he usually used one stick of bamboo and rubbed it back and forth in a slot he had made in another piece of bamboo.]

[Illustration: FLINT AND PYRITES

In some places it was discovered that if you struck a piece of hard stone, like flint, against another, a spark was produced which could be caught on a bunch of dry grass or moss and so start a fire.]

In about A.D. 900, an Arab, named Bechel, discovered phosphorus, but it took almost 800 years more for Haukwitz to learn that when phosphorus was brought into friction with sulphur, fire would result. In another hundred years the world was benefited by the invention of the friction match--and since that time about one-half the people have been carrying matches about with them, able thus to start a fire easily any time.

~FIRE A MARK OF CIVILIZATION~

Fire and man's knowledge of it have had much to do with man's progress in civilization. Before man had fire, his life and movements were much like those of other animals. When man had learned to make a fire he was free to move and live anywhere and, therefore, people began to cover more territory.

[Illustration: THE FLINT AND STEEL METHOD OF MAKING FIRE

THE INTRODUCTION OF THE FLINT AND STEEL METHOD

Because fire was so important to him, man kept on trying to make this task easier. He finally contrived a tinder box when iron and steel became known. The tinder box is where he kept his flint and the piece of steel which he struck upon the flint. He also kept in the box pieces of cloth or paper on which he caught the sparks so produced.]

[Illustration: PISTOL TINDER BOX

This is a picture of a tinder box in the form of a pistol. It enabled man to produce sparks in greater numbers and more rapidly.]

[Illustration: PRODUCING SPARK WITH FLINT AND STEEL

This shows the method for striking the piece of steel against the flint to make the sparks fall on the cloth or paper in the box.]

[Illustration: A COMPLETE TINDER BOX SET

This picture shows a very complete tinder box set used by the wealthy people in the old days. A man carried this outfit with him just as today he carries matches.]

[Illustration: This tinder box set is very neat and compact. It is said still to be used among the Himalayan tribes where it was discovered.]

[Illustration: THE FIRST MATCHES

THE OXYMURIATE MATCH

This match, the first, was introduced in 1505. It was a slip of wood tipped with a chemical mixture. To light it it was necessary to stick its head into a bottle containing acid.]

[Illustration: PROMETHEAN MATCH

This was a paper cigarette dipped in a mixture of sugar and potash. Rolled within the paper was a tiny glass bulb filled with sulphuric acid. To light the match you pressed the bulb with pincers hard enough to break the bulb. This released the acid which set fire to the paper.]

What Would We Do Without Matches?

If one were to ask the man in the street what invention of the nineteenth century is his most constant and invaluable ally he might be mystified for the moment, but the undoubted answer would surely come in the single word "Matches." These familiar objects, apart from their luxurious use by smokers, are the indispensable servants of mankind from the moment of rising in the morning till the household is wrapped in sleep, and it is to them we turn when disturbed in the hours of darkness.

[Illustration: FIRST LUCIFER MATCH

Invented by John Walker in 1827. It consisted of a stick of wood tipped with sulphur and then with a chlorate mixture. To ignite it the match was drawn rapidly through a folded piece of sandpaper.]

[Illustration: MODERN SAFETY MATCH

The first practical match was made less than a century ago.]

No doubt "familiarity breeds contempt," and it is difficult to imagine how man would fare, bereft of his box of matches. It might help the world to realize how much it owes to the inventors of the Lucifer Match, were it possible to cut off the supply of these magic fire producers for only one brief day. It requires no very vivid imagination to picture the consternation and confusion that such a step would produce, and there is a grim humor in wondering how the primitive methods of obtaining a light would serve the public convenience in these days of strenuous hustle.

Seeing that fire has been employed by man since prehistoric days, one would expect that easy means of obtaining it would have been devised in the early ages. We find, however, that until the beginning of the nineteenth century nothing in the nature of a match was available, and the crudest methods were still in use. We know from Virgil that in the reign of the Emperor Titus fire was obtained by rubbing decayed wood with a roll of sulphur between two stones, but it is not till Saxon times that we have evidence of the use of the tinder box with its flint and steel. That this latter was still regarded as something remarkable, as late as the fifteenth century, is proved by its representation in the collar of the Order of the Golden Fleece, which was founded in 1429. Burning glasses had, of course, been employed from the most primitive times, but one can imagine the despair of an early Briton who had to wait for a sunny day before he could boil his kettle.

Incredible as it may seem, it was not a time well within the memory of many people living to-day that matches in anything approaching the form now familiar were offered to the public. The way for their manufacture had been prepared by two discoveries; one by a German who isolated phosphorus in 1669; the other by a Frenchman who produced chlorate of potash in 1786. From this latter date the production of fire was much facilitated, and a few years before Queen Victoria came to the throne, John Walker--a chemist of Stockton-on-Tees--produced the first friction matches of which there is any certain record. These, called "Congreves," were sold in boxes of fifty for 2/6, and their success soon led others to experiment in match manufacture, so that improvements were rapidly invented and factories sprang up in all parts of the country.

It would be a difficult task to compute accurately the value to the human race of the introduction to general use of this little article. At the present writing, in America the consumption of matches amounts to over a billion of matches a day.

How Matches Are Made.

To-day matches are in such demand that the ingenuity of man has devised a machine which makes complete matches without the help of the human hand.

At the very start of operations a man feeds blocks of wood into the jaws of the machine, and thenceforth the mechanical monster does its own work. Seizing the block from the man's hand, the machine grips it between rollers and forces it against rows of keen-edged cutters, which are so arranged that there is little or no waste. Each of these cutters (and there are usually forty-eight in a machine) severs a piece of wood of exact size and shape. At the same moment a plate rises from beneath, which thrusts these little pieces of wood into a moving flexible cast-iron band, or rather into small holes in this band, from which the embryo matches project like bristles. This traveling band is about 700 feet in length, and follows a serpentine course in its journey, which occupies about an hour from start to finish, the speed being regulated according to temperature so that the matches may be quite dry when they reach the boxes.

When the band arrives at the finishing point, a steel bar punches out the matches stuck in its surface and they fall into the inside boxes placed ready to catch them. These boxes are kept continually shaking, to that no spaces are left and the matches fill them completely. As the inside boxes fill, a steel arm presses them forward into their covers, and they are passed along a trough in dozens, quickly wrapped in paper and sealed by a machine. Quick-fingered girls then wrap twelve of these dozen packages and we have the gross packages of boxes so familiar in the stores. It will be seen, that in spite of the marvellous machines which do so much, there is still plenty of work for human hands.

How Match Boxes Are Made.

The machines for making the wooden box which contain the matches are in themselves wonderful. First, a section of the trunk of an aspen tree, about 30 inches in length, is made to revolve in what is known as a peeling machine. After a few revolutions the rough outer surface is removed, and thin rolls of smooth-surfaced wood are peeled off or veneered. The machine at the same time scores the wood ready for folding by the boxmaking machine. Cut into skillets, i. e., into pieces of the size required for box covers or

insides, the ends are next dipped in pink dye to cover the edge of the wood which is not covered by the label. The skillets then go to the box machines, which fold and label them, and after half an hour in a cleverly devised drying chamber they are ready for use. In one room alone sixty machines are labelling and folding the skillets to the number of several thousand gross a day. To see these machines take a strip of wood, push it forward to receive the pasted label, fold it, fasten the joint, wipe off the superfluous paste, and, finally, toss the finished "outside" into a receiving basket, is as fascinating an example of mechanical ingenuity as the industrial world can afford.

Are Matches Poisonous?

A non-poisonous "strike anywhere" safety match, made from selected, clear, strong cork pine is now made in this country, and is the first satisfactory non-poisonous match. It is also the first match to be endorsed by the country's recognized leaders and authorities in fire prevention and the conservation of human life and property.

The Hughes-Esch Anti-White Phosphorus Match Bill, which became a law during the administration of President Taft, was drafted by the attorneys of the American Association of Labor Legislation, and is the most drastic that our National Constitution will permit. It would be unconstitutional to absolutely prohibit the manufacture of white phosphorus matches, but the Hughes-Esch bill obtains the same result, viz.: absolute prohibition by means of excessive taxation. No match manufacturer in these days of keen competition can afford to pay a tax of ten cents on each box of white phosphorus matches made, and place his factory under government surveillance, for this tax of ten cents is over three times as much as his present selling price to the wholesale trade.

As soon as man learned to make fire and light, he began to appreciate how much more comfortable he could be if he could keep his lights burning and to have his light independent of his fire, because it was at times very uncomfortable to sit by a fire on a hot night simply because he wished to use the light which it made. The first schemes devised for lighting purposes merely were the camp-fire torch and the rushlight. With these as a basis, man was enabled to fashion more convenient forms of lighting. He invented the candle and the lamp, and grown "enlightened," boxed his light in iron and in other metals.

Did Candles Come Before Lamps?

The candle is in appearance a primitive affair, yet there is little doubt that its predecessor was the lamp. Those old Egyptian tombs, which have unlocked many mysteries, held lamps, and through them evidence of ancient burial customs. Lamps played a part in the solemn feasts of the Egyptians, who on such occasions placed them before their houses, burning them throughout the night. Herodotus, in one of his numerous references to Xerxes, alludes to the hour of lamp-lighting, and evidences abound regarding the use of lamps among the ancient Greeks. Lamps, indeed, are pictured upon some of their oldest vases, indicating the symbolic significance which attached to them.

[Illustration: A French watch tower of the fifteenth century in time of siege. The tower is lighted by means of beacons and is protected by dogs. Ruins of such a tower can still be seen at Godesberger on the Rhine.]

What Were the Earliest Lamps?

It is probable that the earliest lamps were nothing more than convenient vessels, filled with oil and fired by means of rushes. Among the Romans pine splinters, the torch and the flambeau, supplied light until the fifth century before Christ, and even when the Roman began to use the lamp, it was by no means common, finding a place only in the homes of the rich, or on special festival days.

The custom of burning funeral lights beside the dead before interment is a very old one. Gregory, interpreting its significance for the Christian, says that departed souls, having walked here as the children of light, now walk with God in the light of the living. The Roman, Pliny, refers to the use of the pith of brittle rushes in making funeral lights and watch-candles, which were probably the ancient prototype of the old rushlight of England. Again, in speaking of flax, Pliny states that the part of the reed that is nearest to the outer skin is called tow, and is good for nothing but to make lamp-matches or candlewicks.

What Were the Lamps of the Wise and Foolish Maidens Made Of?

When lamps had come into general favor, better attention was given to their form and construction. The first seem to have been made of baked clay, moulded by hand into elongated vessels to contain the oil, and provided at one end with a lip to admit the wick.

These are the lamps which artists have pictured in the hands of the wise and foolish virgins, though in the opinion of some scholars they were merely rods of porcelain and iron, covered with cloth and steeped in oil. Another early type, which was less common, presents a simple disc with an aperture in the centre for the oil, and a hole for the wick, at one or both of the sides.

Under the Empire, when the light of the lamp had become general, the better ones were made of bronze, ornamented with heads, animals, and other decorations, attached to the handles, while as life in Rome partook more of luxury and extravagance, gold, silver, or Corinthian brass were the materials, the designs being more elaborate and complicated. Many and beautiful examples of these ancient lamps have been unearthed from the ruins of Herculaneum and Pompeii.

When Were Street Lamps First Used?

Dark must have been the lives of those people who, until comparatively recent times, lived, in the absence of sunlight, by the feeble, uncertain light of the primitive illuminants borne by these lamps. And as for street lighting--that was a luxury but seldom indulged in, and then, not for public benefit, but to enhance the glory of a potentate, or grace the obsequies of some great man. Even Rome, at the height of her luxury and beauty, rarely exhibited more than one or two lanterns in her streets. These were suspended over the baths and places of public resort. Occasionally, however, the streets were illuminated during festivals and other public occasions, while the Forum was sometimes lighted for a midnight exhibition. With these glittering exceptions, and that memorable one when, to satisfy the homicidal impulses of a bad emperor, the bodies of Christians were made living torches, Rome was a city of darkness.

[Illustration: THE FIRST STREET LIGHT IN AMERICA

The first street light in America. Early in 1795 several large cressets were placed on the corners of Boston's most frequented street. Pine-knots were placed in these fire baskets by the night watchman.]

When Were Candles Introduced?

Historical records indicate the prevalent use of candles in the earliest days of Rome, but these candles were of the simplest sort--mere string or rope which had been smeared with pitch or wax. In the early Christian centuries it was the custom to dip rushes in pitch and coat them with wax, a method of candle-making that was long continued, for it was not until the fourteenth century that dipped tallow candles were introduced. In the Middle Ages wax candles provided the usual means of illumination, and these were made, not by common craftsmen, but by monks, or by the servants of the rich. Until the fifteenth century their use was confined to churches, monasteries and the houses of nobles, but the demand for them had become so great that the chandlers of London obtained an act of incorporation. As late as the eighteenth century the candles were made by dipping the wicks into melted wax or tallow, but about this time an ingenious Frenchman conceived the idea of casting them in metal moulds.

[Illustration: A part of the "Amende Honorable" of Jacques Coeur before Charles VII of France.]

[Illustration: A pagan votive lamp of bronze, now in the museum at Naples.]

It is only within a modern period that the state or city has assumed responsibility in the matter of public lighting, which for the most part had been left to the good will and public spirit of citizens. But in England a proclamation was issued to the effect that every individual should place a candle in each of the lower windows of his house, and keep it burning from nightfall until midnight.

[Illustration: THE FIRST OIL LANTERN

The first "Réverbère"--oil lantern--with a metal reflector, used to light the streets of Paris. It was invented by Bourgeois de Châteaublanc in 1765, and used until the introduction of gas.]

Paris was the first city to improve upon this method of street lighting, and in 1658 huge, vase-like contrivances, filled with resin and pitch, were set up in the principal thoroughfares. The improvement proving, as may readily be seen, both dangerous and expensive, the falct, so-called, were replaced by the lantern. This was at first simply a rude frame, covered with horn or leather, within which a candle burned. For more than one hundred years this was the extent of the illumination which the authorities could provide. But of course it was understood that no honest man would venture abroad without his torch or flambeau, and as London, Berlin, Vienna, and all leading cities of Europe, were in like case, the darkness of Paris could be borne.

[Illustration: Argand got his first suggestion for his burner--invented in 1780--from this style of alcohol lamp, then in general use throughout France.]

But progress had been made, and early in the eighteenth century the Corporation of London entered into contract with a certain individual to set up public lights, giving him permission to exact a sum of six shillings from every householder whose actual rent exceeded ten pounds. In the middle of the same century the Lord Mayor and Common Council applied to Parliament for power to light the streets of London better. From the granting of this permission dates improvement in public lighting.

Where Did the Word "Gas" Originate?

A Belgium chemist, Van Helmont, coined the word "gas" in the first half of the seventeenth century. The Dutch word "geest," signifying "ghost," suggested the term to him, and his superstitious neighbors hounded him into obscurity for talking of ghosts.

[Illustration: Hanging lamp from Nushagak in Southern Alaska. It is suspended from the framework of the tent by cords. Oils and fats from northern animals give a clear and steady light, and Eskimo lamps are frequently praised by travelers.]

[Illustration: WHAT THE BIG TANK NEAR THE GASWORKS IS FOR

SIX MILLION CUBIC FOOT GAS HOLDER.

Almost every boy and girl has seen the big tank near the gas works, and most of them have wondered what was in it and what it is for. This big tank is a "holder" in which the gas is stored after it is manufactured.

The giant holders are reservoirs from which gas is constantly being taken and the quantity on storage constantly replenished, as the ordinary gas plant never ceases manufacturing its product.

There is little or no danger of an interruption of the supply by reason of accident, as gas plants are always equipped with duplicate apparatus for emergencies.]

When Illuminating Gas Was Discovered.

The first practical demonstration of the value of gas made from coal for lighting was made by a Scotchman--Robert Murdock--who in 1797, after some years of experimenting, fitted up an apparatus in the workshop of Boulton and Watt, in Birmingham, England, which successfully lighted a portion of that establishment. The advantages of this kind of lighting were so apparent that its use was rapidly extended, although in many instances the people were afraid of it. For a time this kind of lighting was confined to street lights. One of the first great structures to be lighted by gas was Westminster Bridge in London, and great crowds gathered to watch the burning jets nightly. It was difficult to remove from the minds of the people the belief that the gas-pipes were filled with fire and the jets were only openings through which the flame in the pipes escaped. People sometimes touched the pipes expecting to find them hot, and when the pipes were put in buildings they made sure that they were placed several feet from the walls lest the fire in them set fire to the buildings.

The use of illuminating gas for lighting private houses developed quite slowly because of this fear of the fire in the gas-pipes. This was not entirely unwarranted, however, because at first the plumbers did not know, as they do now, how to prevent leakage of gas from the pipes. The methods of joining the pipes were oftentimes imperfect and, not realizing the dangers which would follow leaks, causing explosions, the workmen were often careless in installing the pipes.

The first American house in which gas was used for lighting was the home of David Mellville at Newport, R. I. Baltimore, Maryland, was the first American city to use gas for lighting. It was introduced there in 1817.

How Does Gas Get Into the Gas Jet?

If you hold a cool drinking glass over a burning gas jet for a moment, a film of moisture will form on the inside of the glass and remain until the tumbler becomes warm, and then disappear. Now, then, you will remember that water is a mixture of oxygen and hydrogen, and that when hydrogen is burned in the air, water is formed. It is also true that whenever water is formed by burning anything, hydrogen is present in it. You see, therefore, that the gas used for lighting purposes must contain hydrogen.

Let us now learn something more about what gas is made of. Wet a piece of glass with a little fresh lime water and hold this over the lighted gas jet. In a few moments a change takes place in the water. The water turns somewhat milky. This indicates the presence of carbonic acid gas, and the formation of carbonic acid gas, when burning is going on, means the presence of carbon.

From these two experiments we gather that the gas in the jet contains hydrogen and carbon. All kinds of illuminating gas contain these two substances. Sometimes there are small quantities of other substances present, but the value of gas for lighting depends on hydrogen and carbon.

We have already learned about hydrogen, but it would be well to re-learn about carbon.

Carbon is an element, and an extremely important one, for a large part of the composition of every living thing is carbon. It is found in more compounds than any other element. Almost pure carbon can easily be obtained by heating a piece of wood, in a covered utensil, until it is turned into charcoal. Charcoal, which is black, is composed almost entirely of carbon. It is a very interesting product in all ways; in connection with gas we are particularly interested in the fact that carbon will burn when heated in the air or in oxygen.

Charcoal is very much like hard coal, both being formed in practically the same way. Ages of years ago many large forests of trees were buried under a layer of soil and rocks, during changes that occurred in the earth's surface, and the hot inside earth slowly heated the wood, until almost nothing was left but the carbon.

[Illustration: WHERE THE GAS IS TAKEN FROM THE COAL

GENERATOR HOUSE AND 175-FT. STACK.

In the process of gas making, coal is placed in the generator and heated to an incandescent state, then from the top or bottom steam is admitted and forced through the heated coal, producing a crude water gas which is passed on to the carbureter. In this shell enriching oil is produced, but as the oil and the water gas do not effectually unite, they are passed on to the superheater, where, as its name implies, they are subjected to a high temperature which thoroughly gasifies them into a permanent gas.]

[Illustration: AN INTERIOR VIEW OF GENERATOR HOUSE.]

* Pictures on Gas Manufacture by courtesy of the Consolidated Gas, Electric Light and Power Co. of Baltimore.

[Illustration: ILLUMINATING GAS MUST BE SCRUBBED

SHAVING SCRUBBERS.

After passing into the scrubbers the gas is cooled, passed into the scrubbers, and by contact with wooden slat trays, made up like screens; a large portion of the tar is removed from the gas, the tar passing off to large receptacles.]

Soft coal was formed in much the same manner, but the process was not so completely finished. Mixed with the carbon in soft coal we find quite a good deal of other substances, of which hydrogen forms the principal part. This is what makes soft coal valuable in the making of illuminating gas.

When soft coal is heated in a closed receptacle a gas is formed which will burn. To show this we have only to take an ordinary clay pipe, put a little piece of coal in the bowl, close the top with wet clay, and put the bowl part of the pipe in the fire. When it is quite hot, a gas will be found coming out of the stem of the pipe, which will, when lighted, burn.

The Story In a Gas Jet.

~HOW ILLUMINATING GAS IS MADE~

Soft coal is heated in large tubes of fire clay called retorts, and the gas that is formed is then collected in a large tank and sent through pipes to our homes after being purified. The part of the coal that is left consists largely of carbon and is what we call coke.

While the gas that comes directly from coal will burn if lighted, it is not a desirable gas to burn in our homes, because it contains a number of substances that should be eliminated before it is used for lighting.

How the Gas Is Purified.

From the clay retorts the gas passes through horizontal pipes containing water. This cools it and takes out of it most of the tar and water vapor that are driven off with the gas when formed. These substances settle in the water. The gas then goes through a series of curved pipes, which are air cooled. These pipes constitute what is known as an atmospheric condenser. From these the gas goes into a series of receptacles containing wooden slat trays, made up like screens. These receptacles are called the scrubbers, and they take out of the gas the last traces of tar and some of the other compounds found present. The removal of the sulphur is very important, for burning sulphur gives off a gas which is not only extremely impure to breathe, but also injurious to the health.

From the scrubbers the gas goes on through pipes to the purifiers--boxes which contain wood shavings coated with iron rust upon which the sulphur is deposited by chemical action. At the same time the lime absorbs a small quantity of carbonic acid gas, which is formed with the other gases. From the purifiers the gas passes into the great iron tanks, in which it is stored until needed.

The gas in the tanks consists chiefly of hydrogen, a number of compounds of hydrogen and carbon, and a small amount of a compound of carbon and oxygen containing less oxygen than carbonic acid gas, known as carbon monoxide. The hydrogen and carbon monoxide burn with a very pale flame, which gives but little light and much heat. The light-giving quality of the gas is found in the compounds of carbon and hydrogen. When these burn, the particles of carbon are heated white hot and glow very brightly, making a luminous flame.

There are, of course, some impurities in the purified gas. These are compounds containing sulphur and ammonia. The quantities of these substances, however, are so small that they are harmless; but the compounds taken out in the process of purifying the gas are saved, as considerable use is made of them. The water used for washing the gas is heavily charged with ammonia and is, in fact, the chief source of the ammonia sold by druggists.

[Illustration: HOW THE IMPURITIES ARE TAKEN FROM THE GAS

PURIFYING BOXES.

The principal impurity to be removed is sulphur, and this is accomplished by passing the gas through large iron rectangular boxes filled with wood shavings coated with iron rust upon which the sulphur is deposited by chemical action.]

[Illustration: STATION METER HOUSE, SHOWING CONSTRUCTION OF TWO NEW 13-FT. METERS.]

[Illustration: HOW THE METER MEASURES THE GAS

Fig 1

Fig 3

Fig. 2.

Fig 4

Gas first enters inlet pipe _A_ (Fig. 3) passing along _A1_ into covered valve chamber _B_ up through orifice _O_. It then passes down through two of the valve ports at the same time, ports _C_ and _D1_ (Fig. 2). Before _C1_ (Fig. 3) has gotten to its extreme opening, the valve on the opposite side has moved to allow gas to pass down port _D_. On every quarter turn of tangent _P_, one port is opening to receive gas which passes down through the valve ports into the chambers below (see arrows on Fig. 2), which shows the gas passing into chamber _F_. The pressure being greater on the outside of the diaphragm, forces the diaphragm inward and expels the gas from the inside of _D2_ through _D_ and passes over the cross-bar into the fork channel (see Fig. 1). On the other side gas is passing down through port _D1_ (Fig. 2) entering diaphragm _D3_, the pressure being greater on the inside of _D3_ therefore forces the diaphragm outward and expels the gas from the outside of diaphragm _D3_; out through port _C1_ into fork channel same as shown in (Fig. 1). All exhaust gas from the chambers below is checked from entering the chamber _B_ by the slide valve _G_ and _G1_ (Fig. 2). Instead of passing into chamber _B_ it passes over the cross-bars between _D1E1_ and _C1E1_ into the fork channels, then to outlet pipe _N_ (Fig. 3) to house pipe.

NOTE: All gas registered must pass through outlet _N_.]

In addition to coal gas made in the way just described, there is another form of illuminating gas, in the manufacture of which coal is indirectly employed. This gas, known as water gas, because it is formed by the decomposition of water, is produced by passing steam over red hot carbon, in the form of hard coal or coke. When this is done, the hydrogen in the steam is set free and the

oxygen combines chemically with the carbon, to form the carbon monoxide, that was mentioned as being present, in small proportions, in ordinary coal gas. This carbon monoxide is poisonous, if much of it is breathed, and as it has no odor it is difficult to detect when escaping. A number of deaths have resulted from water gas for this reason, and in some states the laws forbid its use for lighting purposes.

When water gas is used it must be enriched with some other substances before it will yield much light. You have already learned that neither hydrogen nor carbon monoxide burns with a bright flame, and you will see that water gas must have something added to it to fit it for lighting purposes. The substance usually added is the vapor of some light, volatile oil, like gasoline. This vapor is composed of compounds of carbon and hydrogen, and when it is mixed with the water gas it forms a gas that yields a very satisfactory light; and that may be produced more cheaply than common coal gas.

There remains one more form of illuminating gas which has been the subject of much discussion in recent years, namely, acetylene. This is a compound of carbon and hydrogen, in which there is twelve times as much carbon as hydrogen. It has not been discovered recently, for it was known early in the nineteenth century, but its possible use for lighting purposes was not considered then.

Attention was directed to it a few years ago by the discovery of a substance called calcium carbide. This is a compound of carbon and the metal calcium, formed by heating to a very high temperature a mixture of coal and lime. It has the peculiar property of decomposing, when treated with water. The calcium present combines with the oxygen and half the hydrogen of the water, to form common slacked lime or calcium hydrate, while the carbon and the remainder of the hydrogen combine to form acetylene gas.

The gas formed in this way needs no purifications before burning; it can be produced in small generators, and the production can be checked at any time. When burned in the proper form of burner it yields the brightest of all gas flames. For these reasons it is adapted for use in small villages and for lighting single houses. It is also frequently used in magic lanterns, where a strong and steady light is necessary. But the cost of producing acetylene in large quantities is greater than that of coal gas, and it seems extremely unlikely that it will ever be much used for lighting large cities and towns.

How the Light Gets Into the Electric Light Bulb.

The incandescent lamp was invented in 1879 and the patents were granted to Thomas A. Edison. There were, however, a number of electrical men who were working on the idea at this time who deserve a great deal of credit for developing the lamp.

The incandescent lamp, which is used chiefly for house lighting, consists of a glass bulb from which the air has been exhausted by pumps and chemical processes--in which there is a thin filament of tungsten metal wound on what is called an arbor (as shown in Fig. 4). This filament opposes high resistance to the passage of the current of electricity, and, consequently, is heated to incandescence when a current passes through it. The removal of the air from the bulb prevents the tungsten metal from burning up, as it would do if oxygen were present.

The filaments of the first lamps were made of vegetable fibre. The next development was the cellulose process, which is still used in carbon and metallized lamps, although a number of processes are used now which improve the filament considerably.

The discovery that tungsten metal could be used in incandescent lamps was made in 1906. The first tungsten lamp manufactured in America was made in 1907.

[Illustration: THE DEVELOPMENT OF INCANDESCENT LAMPS

Edison's first lamp with a filament of bamboo fibre.]

[Illustration: The carbon lamp--the oldest form of incandescent lamp.]

[Illustration: Standard Mazda lamp--the highest development of the incandescent lamp.]

[Illustration: The Tantalum lamp developed just before the Mazda lamp.]

[Illustration: Improved Mazda lamp for lighting large areas--the most efficient lamp ever made.]

The filaments of the first tungsten lamps were composed of two or three short pieces of wire. In 1910, however, a lamp with a continuous tungsten filament was invented which increased the strength of the lamp wonderfully.

Mazda is a trade name given to all metal filament lamps made by the prominent American lamp manufacturers.

The reason that the Mazda lamp is so much more efficient than the carbon filament lamp is because the tungsten filament can be burned at a much higher temperature than the present carbon filament, without seriously blackening the bulb.

How Does an Arc Light Burn?

In the arc light a current of electricity is made to leap across from the tip of one rod of carbon to the tip of another that is held a short distance from the first. In passing across the current does not follow a straight path, but makes a curve, or arc, whence comes the name “arc light.”

In this form of light the carbons are not enclosed in a space from which air is excluded, consequently there is some destruction of the carbon. The light is due to the fact that the air between the tips of the carbon rods opposes a high degree of resistance to the current, so that the rods become intensely hot at their tips. The high degree of heat causes a slow burning of the carbon at the tips, and the small particles that burn are heated white hot before they are consumed, thus producing light.

In order to keep the light from an arc light uniform in strength, it is necessary to keep the tips of the carbon rods always the same distance apart. This is practically impossible, and, as a result, the arc light does not produce light that is well adapted for reading or for other purposes that require constant use of the eyes. The light produced by the arc light is very powerful, however, and for that reason it is much used for street lighting.

What Are X-Rays?

It was discovered by Professor Conrad Roentgen in 1895, that if a current of electricity be passed through a certain form of glass bulb, from which most of the air has been exhausted, a disturbance is produced in the ether that bears some resemblance to light waves. For want of a better name to give to a disturbance which was not well understood, Roentgen called his discovery the X-Ray, but it is now frequently called in his honor the Roentgen ray. The nature of this disturbance is not yet known, but as it does not affect the eye it is not light. These rays are produced with a glass vacuum tube and a battery from which a current of electricity is sent through the tube. The wires of the battery are connected with two electrodes, one of which consists of a concave disk of aluminum, and the latter of a flat disk of platinum. The X-rays are discharged in straight lines as shown in the figure. The most striking properties of the X-ray is its power to penetrate many substances that are impermeable to light. All vegetable substances, and the flesh of animals, are penetrated by it very readily. Glass, metals, bones, and mineral substances generally are opaque to it. Consequently, when a limb, or even the body of an animal, is exposed to X-rays they pass through the fleshy parts, but are stopped by the bones. Certain substances have the property of glowing, or becoming fluorescent, when exposed to the X-ray, and when screens of paper are coated with these substances they form a convenient means of detecting the presence of X-rays. By holding the hand between a tube that is giving off X-rays and a screen of this kind, the bones of the hand will be outlined in shadow on the screen, and the rest of the surface will glow with a greenish light. If a bullet or other piece of metal has become imbedded in the body, it may easily be located, if it is not in a bone, and the extent of an injury to a bone or a joint may be plainly shown. For this reason the X-ray is now widely used by surgeons.

How Man Learned to Fight Fire.

When you see the modern fire engine racing through the streets, gongs ringing, with the firemen hanging on and the police clearing the track, you should remember that it has taken man a long time to learn as much as he has about fighting fire.

No sooner did man learn to make fire than he found it necessary to learn how to put it out.

The first fire apparatus of record is found in Rome. The Gauls burned the city in 390 B. C., each citizen was ordered to keep in his house a “machine for extinguishing fire.” This consisted of a syringe.

The first record of an actual machine for putting out fire is by Hero of Alexandria. This contrivance, a “siphon used in conflagrations,” was used in Egypt about a hundred and fifty years before Christ.

The first record of what we would call a fire department is also found in Rome. A disastrous fire, occurring in the reign of Augustus called his attention to the benefit of a regular fire brigade would bring. So he organized a fire department. It consisted of seven

companies of a thousand men each.

The first real fire engines were used in 1633 at a big fire on London Bridge. The first fire hose was invented by the two Van der Heydes in 1672. One of the earliest engines used consisted of a tank drawn by two horses, which threw a stream an inch in diameter to a height of eighty feet. An improved engine was invented in 1721 by Newsham, of London, and the first engine used in the United States was made by Newsham. The first steam fire engine was invented by John Braithwaite, of London, in 1829.

Fire alarms came into use in medieval times. It was the custom, in many of the towns to have a watchman stationed on a high building whose duty it was to look for fires. As soon as he saw one, he gave warning by blowing a horn, firing a gun, or ringing a bell.

The first London fire department consisted of ten men of each ward.

The first municipal American fire department was created in Boston in 1678. The fire engine was a hand pump bought in England.

The first leather fire hose was made in America in 1808 in Philadelphia. Rubber hose was first made in England at about 1820.

How Did Man Learn to Cook His Food?

The primitive man lived on raw food--raw flesh, roots, fruits and nuts. There must have been a time when he lived thus because there was a time when he had no fires and no knowledge of how to make a fire. There are no records, however, to show when man learned that cooked food was best.

It must have come about almost simultaneously with his knowledge of fire, for the art of cooking goes back to the first knowledge of fire. We do not know either how man learned to make a fire. The earliest nations of which we have any record seem to have been acquainted with fire and certain methods for producing it. Not only one but all early nations seem to have been possessed of this knowledge. Occasionally travellers have reported that people have been found who were unacquainted with either fire or cooking, but investigation has always proven these reports unauthentic. Cookery has always been found in practice where people knew about fire.

It is strange how man has lost track of the beginning of his knowledge of fire and cookery, because fire represents the beginning of man's culture and cookery goes hand in hand with it.

There are many legendary accounts of how man learned the value of cooked food, all of which are based upon the accidental burning or roasting of animals or birds. Perhaps, therefore, Charles Lamb's "Roast Pig" story, which we read with much laughter in our school readers, was quite accurate from a historical standpoint. According to the story a man's house burned and he cried more over the fate of his pet pig than about the loss of his house. He kept his pig in the house you will remember and as soon as the fire died away he rushed into the debris to look for his pet pig, hoping still to rescue him. He found him in a corner and made haste to pick him up and carry him into the open air. But the poor pig had been roasted to a turn and was still hot. The man's fingers went right into the well done roast pig and were burned. With a cry he withdrew his fingers and put them into his mouth to blow on them and thus he secured his first taste of roast pig, which he found so much to his taste that he repeated the operation of licking his fingers.

While this is but a story, it is quite likely historically correct as to this discovery of the value of cooked food to some of the early nations. No doubt Fire and Cookery were developed together.

When man had learned to make fire, he found that it often got beyond his control. Here and there he would set the woods on fire quite without intention perhaps, but with damaging results. He would watch the conflagration and, when it was passed, he would find the baked bodies of deer or other animals which had been overcome by the fire and learned that baked meats were good to the taste and more easily digestible than raw meats.

Why Does a Sponge Hold Water?

A sponge will hold water because it has, on account of the plan on which it is grown the power of capillary attraction. The sponge is made up of little hair like tubes. If you take a glass tube, open at both ends and immerse one end in a vessel of water, you will find that the water will rise in the tube to a level higher than the surface of the water in the vessel. The smaller the hole through the glass

tube, the higher the water will rise. This is caused by the cohesion of the water against the inside surface of the hole in the tube and causes a pull upward. The water is pulled up into the tube because the surface of the tube has a greater cohesive attraction for the water than for the air which was in it and the air is forced out partly. Some liquids, such as mercury will not rise in the same way, but is depressed in a glass tube, since it cannot adhere to glass. Mercury however will run or rise in a tin tube, just as water in a glass tube, because it adheres to the tin.

Now a sponge is merely a lot of capillary tubes which have the same power of pulling up the water as the glass tube. The tubes in a sponge are so fine that the water will rise to the entire length of the tubes. In addition, this adhesive quality of water to the inside of the tubes in the sponge is so strong, that the sponge can be taken entirely out of the water and the water will remain in it.

Why Is the Right Hand Stronger Than the Left?

The right hand is stronger than the left only in case you are right-handed. If you have the habit of being left-handed, your left hand becomes stronger. If you are truly ambidextrous, your strength will be the same in both hands.

We get our strength by moving the various parts of the body, i. e., by using them. When a little baby stretches his arms and legs and kicks, he is only exercising naturally, making the blood circulate.

You can prove that the fact that your right hand is stronger than your left because of the greater use or exercise you give it, by tying your right arm close to your side and keeping it in that condition without using it for several weeks. When you remove the bands which held it tight, you will find your arm has lost its strength and that now your left hand is stronger. If, however, you are left-handed and tie that hand down for the same length of time, your right hand would be the stronger. This shows that the strength we have in our arms and legs, and other parts of the body, is developed by using them and giving them rational exercise. Of course, it is possible to over-use a part of the body, but you will notice that nature always gives us a warning by making us tired before we come to the point where further use of that particular part of the body would cause injury.

Why Do My Muscles Get Sore When I Play Ball In the Spring?

They do this because you have probably not been exercising the particular muscles which you employ in throwing a ball enough in the winter to keep you in good condition. Muscles which have been developed through use or work need more work to keep them in condition. In a sense certain of the muscles which you employ in playing ball have been treated during the winter very much as if you had tied them down, as we suggested you might do with your arm. You have not been using them--they have not been doing enough work, and they begin to lose their strength when for any period they have not been used enough. The soreness that you feel is the natural condition that arises when you begin to use a muscle that has been idle for some time.

Why Does a Barber's Pole Have Stripes?

In early years the barber not only cut hair and shaved people, but he was also a surgeon. He was a surgeon to the extent that he bled people. In early times our knowledge of surgery was practically limited to blood letting. A great many of the ailments were attributed to too much blood in the body, and when anything got wrong with a man or woman, the first thing they thought of was to reduce the amount of blood in the body by taking some of it out.

The town barber was the man who did this for people and his pole represented the sign of his business.

The round ball at the top which was generally gilded represents the barbering end of the business. It stood for the brass basin which the barber used to prepare lather for shaving customers.

The pole itself represents the staff which people who were having blood taken out of their bodies held during the operation. The two spiral ribbons, one red and one white, which are painted spirally on the pole, represented the bandages. The white one stood for the bandage which was put on before the blood was taken out and the red one the bandage which was used for binding up the wound when the operation was completed.

How Was the Flag Made?

The design of our flag was outlined in a congressional resolution passed on June 14, 1777, which stated "that the flag of the thirteen United States be thirteen alternate stripes red and white; that the union be thirteen stars, white in a blue field, representing the new constellation." After Vermont and Kentucky had been admitted to the Union, Congress made a decree in 1794 that after May 1, 1795, "the flag of the United States be fifteen stripes alternate red and white and that the Union be fifteen stars white on a blue field." This made the stars and stripes again equal and it was the plan to add a new stripe and a new star for each new state admitted to the Union. Very soon, however, it was realized that the flag would be too large if we kept on adding one stripe for each new state admitted to the Union, so on April 4, 1818, Congress passed a resolution reducing the number of stripes to thirteen once more to represent the original colonies, and to add only a new star to the field when a new state was admitted to the Union. At this time there were twenty states in the Union. Since that time none of the flags of the United States have more than thirteen stripes while a new star has been added for each state until now we have forty-eight stars, representing the forty-eight states.

Why Are Some Guns Called Gatling Guns?

A gatling gun is a kind of gun invented by Richard Jordan Gatling in 1861 and 1862 and so it receives its name from its inventor. The original gatling gun had ten parallel barrels and was capable of firing 1,000 shots per minute when operated by hand power. It was discharged by turning a crank and would shoot in proportion to the rapidity with which the crank was turned. It was at first not a huge success but has from time to time been improved so that the crank is now turned by electric power and about fifteen hundred shots per minute can be fired with it.

How Did Hobson's Choice Originate?

As used today, this expression means a choice with only one thing to choose. Tobias Hobson was a livery stable keeper at Cambridge, England, during the reign of King Charles I. He kept a stable of forty horses which he hired out by the hour or day, and was famous in his day so far as a livery stable keeper could be.

When you went to Hobson to hire a horse, you had the privilege of looking over all the horses in the stable to decide which one you would like to drive, but he always made you take the one in the stall nearest the door. In this way all the horses in the stable were worked in turn and while you might pretend to choose your own horse, you really had no choice--you had to take the one nearest the door or none. As soon as a horse was hired, the other horses in the stable were moved up, each one to the stall next towards the door so there was always a horse in the stall nearest the door.

Why Do They Call It a Honeymoon?

The word Honeymoon which is commonly used to describe the first few weeks after marriage, has always meant the first month or moon after marriage, but does not have any reference to the month or moon excepting as that describes a certain period of time.

The word originated in an old custom quite common among newly married couples among the ancient Teutons of drinking a kind of wine made from honey during the first thirty days after being married.

In these days newly married couples generally take a trip away from home for a short or longer period after their wedding day and this is called the honeymoon whether it is but a few days or three months or more. The custom of drinking wine made from honey has been abandoned so that the word is now used in an entirely different sense than formerly.

Why Is a Horseshoe Said to Bring Good Luck?

The luck of the horseshoe comes from three lucky things always connected with horseshoes. These consist of the following facts: It is the shape of a crescent; it is a portion of a horse; it is made of iron.

Each of these has from time immemorial been considered lucky. Anything in the shape of a crescent was always considered a thing to bring luck. From the earliest times, too, at least since the world knew something of the qualities of iron, iron has been regarded as a thing to give protection and incidentally that would involve good luck. And lastly the horse, since the days of English mythology, has been regarded as a luck animal. When, then, we had a combination of the three--the crescent, the iron and the horse in one object, it became a true lucky sign in the eyes of the people.

Some Wonders of the Human Body.

There are said to be more than two million little openings in the skins of our bodies to serve as outlets for an equal number of sweat glands. The body contains more than two hundred bones. It is said that as much blood as is in the entire body passes through the heart every minute, i.e., all the blood in the body goes in and out of the heart once every minute. The lung capacity of the average person is about 325 cubic inches.

With every breath you inhale about two-thirds of a pint of fresh air and exhale an equal amount if you breathe normally.

The stomach of the average adult person has a capacity of about five pints and manufactures about nine pounds of gastric juice daily.

There are over five hundred muscles in the body all of which should be exercised daily to keep you in the best condition. The average adult human heart weighs from eight to twelve ounces and it beats about 100,000 times every twenty-four hours. The perspiration system in the body has only very small ducts or pipes, but there are about nine miles of them. The average person takes about one ton of food and drink each year. We breathe about eighteen times a minute, which amounts to about 3,000 cubic feet an hour.

Where Did the Expression "Kick the Bucket" Originate?

The expression originally came from the method used in stringing a hog after killing it. The pig after being slaughtered was hung by the hind legs. A piece of bent wood was passed in behind the tendons of each of the hind legs and the pig hung up by this stick of wood much like we hang up clothes with a clothes hanger today. The piece of wood was called a bucket. The "bucket" part of the expression does not, therefore, refer to a bucket at all but to this bent piece of wood. All are not agreed on this explanation, however, as it does not explain where the "kick" comes in. Many investigators hold to the belief that a man named Bolsover was the first to "kick the bucket" literally and that the expression came from the manner of his death. He stood on a pail or bucket while arranging to hang himself by tying a rope around his neck and to a beam which he could not reach without standing on the bucket. When ready he kicked the bucket out from under his feet and so succeeded in carrying out his own wishes and in so doing coined a famous expression which still means "to die."

How Did the Word "News" Originate?

The word "News" which was created to describe what newspapers are supposed to print, came from the four letters which have for ages been used as abbreviations of the directions of the compass. In this N stands for North, E for East, S for South and W for West, and in illustrating the points of the compass the following diagram has long been used:

N | W--+--E | S

The earliest newspapers always printed this sign on the front pages of their papers in every issue. This was done to indicate that the paper printed all the happenings from four quarters of the globe.

Later on some enterprising newspaper man who may have forgotten the original significance of the letter in the diagram, arranged the letters N. E. W. S. in a straight line at the head of the paper and that is how what we read in the papers came to be known as news.

Almost one-half the whole number of newspapers published in the world are published in the United States and Canada.

Who Made the First Umbrella?

No one knows who made the first umbrella but we know that Jonas Hanway of London was the first man to carry one over his head to keep off the rain.

Umbrellas seem to have been known as far back as the days of Ninevah and Persepolis, for representations of them appear frequently in the sculptures of those early days. The women of ancient Rome and Greece carried them but the men never did.

Mr. Hanway is said to be the first man who walked in the streets of London with an open umbrella over his head to keep off the rain. He is said to have used it for thirty years before they came into general use for this purpose.

[Illustration: HOW MAN LEARNED TO TELL TIME

The first picture shows what was probably man's first method of telling time. The principle was the same as that of the sun-dial. It provides to-day an accurate method of telling time.

Of course, man in the early days needed to find some other means of noting the passing of time at night, for then the sun cast no shadow for him. His ingenuity taught him to make a candle which was light and dark in alternate rings, and as each section burned he made a mark to record the passing of a certain length of time. Before candles were invented he used a rope in which he tied knots at equal spaces apart and which he burned as shown in the third picture.]

The Story in a Time Piece

What Is Time?

Time, as a separate entity, has not yet been defined in language. Definitions will be found to be merely explanations of the sense in which we use the word in matters of practical life. No human being can tell how long a minute is; only that it is longer than a second and shorter than an hour. In some sense we can think of a longer or shorter period of time, but this is merely comparative. The difference between 50 and 75 steps a minute in marching is clear to us, but note that we introduce motion and space before we can get a conception of time as a succession of events, but time, in itself, remains elusive.

In time measures we strive for a uniform motion of something and this implies equal spaces in equal times; so we here assume just what we cannot explain, for space is as difficult to define as time. Time cannot be "squared" or used as a multiplier or divisor. Only numbers can be so used; so when we speak of "the square of the time" we mean some number which we have arbitrarily assumed to represent it. This becomes plain when we state that in calculations relating to pendulums, for example, we may use seconds and inches--minutes and feet--or seconds and meters--and the answer will come out right in the units which we have assumed. Still more, numbers themselves have no meaning till they are applied to something, and here we are applying them to time, space and motion; so we are trying to explain three abstractions by a fourth! But, happily, the results of these assumptions and calculations are borne out in practical human life, and we are not compelled to settle the deep question as to whether fundamental knowledge is possible to the human mind.

What Was Man's First Division of Time?

Evidently, man began by considering the day as a unit and did not include the night in his time-keeping for a long period. "And the evening and the morning were the first day," Gen. i, 5; "Evening and morning and at noonday," Ps. lv, 17, divides the day ("sun up") in two parts. "Fourth part of a day," Neh. ix, 3, shows another advance. Then comes, "are there not twelve hours in a day," John xi, 9. The "eleventh hour," Matt. xx, 1 to 12, shows clearly that sunset was 12 o'clock. A most remarkable feature of this 12-hour day, in the New Testament, is that the writers generally speak of the third, sixth and ninth hours, Acts ii, 15; iii, 1; x, 9. This is extremely interesting, as it shows that the writers still thought in quarter days (Neh. ix, 3) and had not yet acquired the 12-hour conception given to them by the Romans. They thought in quarter days even when using the 12-hour numerals! Note, further, that references are to "hours"; so it is evident that in New Testament times they did not need smaller subdivisions. "About the third hour" shows the mental attitude. That they had no conception of our minutes, seconds and fifth-seconds becomes quite plain when we notice that they jumped down from the hour to nowhere, in such expressions as "in an instant--in the twinkling of an eye."

Before this the night had been divided into three watches (Judges vii, 19). Poetry to this day uses the "hours" and the "watches" as symbols.

This twelve hours of daylight gave very variable hours in latitudes some distance from the equator, being long in summer and short in winter. The amount of human ingenuity expended on time measures so as to divide the time from sunrise to sunset into twelve equal parts is almost beyond belief. In Constantinople, to-day, this is used, but in a rather imperfect manner, for the clocks are modern and run twenty-four hours uniformly; so the best they can do is to set them to mark twelve at sunset. This necessitates setting to the varying length of the days, so that the clocks appear to be sometimes more and sometimes less than six hours ahead of ours. A clock on the tower at the Sultan's private mosque gives the impression of being out of order and about six hours ahead,

but it is running correctly to their system. Hotels in Constantinople often show two clocks, one of them to our twelve o'clock noon system. Evidently the Jewish method of ending a day at sunset is the same and explains the command, "let not the sun go down upon thy wrath," which we might read, "do not carry your anger over to another day."

This simple line of steps in dividing the day and night is taken principally from the Bible because every one can easily look up the passages quoted and many more, while quotations from books not in general use would not be so clear.

How Did Man Begin to Measure Time?

Now, as to the methods of measuring time, we must use circumstantial evidence for the prehistoric period. The rising and the going down of the sun--the lengthening shadows, etc., must come first, and we are on safe ground here, for savages still use primitive methods like setting up a stick and marking its shadow so that a party trailing behind can estimate the distance the leaders are ahead by the changed position of the shadow. Men notice their shortening and lengthening shadows to this day. When the shadow of a man shortens more and more slowly till it appears to be fixed, the observer knows it is noon, and when it shows the least observable lengthening then it is just past noon. Now, it is a remarkable fact that this crude method of determining noon is just the same as "taking the sun" to determine noon at sea. Noon is the time at which the sun reaches his highest point on any given day.

[Illustration: The Sun-dial is only an improvement on the stick which cast a shadow which enabled man to tell the time of day at any hour. The shadow moves around the dial, falling on the numbers on the circle.]

How Is the Time Calculated at Sea?

At sea this is determined generally by a sextant, which simply measures the angle between the horizon and the sun. The instrument is applied a little before noon and the observer sees the sun creeping upward slower and slower till a little tremor or hesitation appears, indicating that the sun has reached his height--noon. Oh! you wish to know if the observer is likely to make a mistake? Yes, and when accurate local time is important, several officers on a large ship will take the meridian passage at the same time and average their readings, so as to reduce the "personal error." All of which is merely a greater degree of accuracy than that of the man who observes his shadow.

The gradual development of the primitive shadow methods culminated in the modern sun-dial. The "dial of Ahas" (Isa. xxxviii, 8), on which the sun went back ten "degrees," is often referred to, but in one of the revised editions of the Bible the sun went back ten "steps." This becomes extremely interesting when we find that in India there still remains an immense dial built with steps instead of hour lines.

In a restored flower garden, within one of the large houses in the ruins of Pompeii, may be seen a sun-dial of the Armillary type, presumably in its original position. It looks as if the plane of the equator and the position of the earth's axis must have been known to the maker.

Both these dials were in use before the beginning of our era and were covered by the great eruption of Vesuvius in 79 A.D., which destroyed Pompeii and Herculaneum.

~THREE GREAT STEPS IN MEASURING TIME~

Modern sun-dials differ only in being more accurately made and a few "curiosity" dials added. The necessity for time during the night, as man's life became a little more complicated, necessitated the invention of time machines. The "clepsydra," or water-clock, was probably the first. A French writer has dug up some old records putting it back to Hoang-ti 2679 B.C., but it appears to have been certainly in use in China in 1100 B.C., so we will be satisfied with that date. In presenting a subject to the young student it is sometimes advisable to use round numbers to give a simple comprehension and then leave him to find the overlapping of dates and methods as he advances. Keeping this in mind, the following table may be used to give an elementary hint of the three great steps in time measuring.

Shadow time, 2000 to 1000 B.C.

Dials and water-clocks, 1000 B.C. to 1000 A.D.

Clocks and watches, 1000 to 2000 A.D.

Gear-wheel clocks and watches have here been pushed forward to 2000 A.D., as they may last to that time, but no doubt we will supersede them. At the present time science is just about ready to say that a time measurer consisting of wheels and pinions--a driving power and a regulator in the form of a pendulum or balance, is a clumsy contrivance and that we ought to do better very soon.

It is remarkable how few are aware that the simplest form of sun-dial is the best, and that, as a regulator of our present clocks, it is good within one or two minutes. No one need be without a "noon-mark" sun-dial; that is, every one may have the best of all dials. Take a post or any straight object standing "plumb," or best of all the corner of a building. In the case of the post, or tree trunk, a stone (shown in solid black) may be set in the ground; but for the building a line may often be cut across a flagstone of the footpath. Many methods may be employed to get this noon mark, which is simply a north and south line: Viewing the pole star, using a compass (if the local variation is known) or the old method of finding the time at which the shadow of a pole is shortest. But the best practical way in this day is to use a watch set to local time and make the mark at 12 o'clock.

[Illustration:

Drawing by James Arthur.

A form of Sun-dial that is as good to-day as any dial for determining noon.]

On four days of the year the sun is right and your mark may be set at 12 on these days, but you may use an almanac and look in the column marked "mean time at noon" or "sun on meridian." For example, suppose on the bright day when you are ready to place your noon mark you read in this column 11.50, then when your watch shows 11.50 make your noon mark to the shadow and it will be right for all time to come. Owing to the fact that there are not an even number of days in a year, it follows that on any given yearly date at noon the earth is not at the same place in its elliptical orbit, and the correction of this by the leap years causes the equation table to vary in periods of four years. The centennial leap years cause another variation of 400 years, etc., but these variations are less than the error in reading a dial.

How Did Men Tell Time When the Sun Cast No Shadows?

[Illustration:

Photo by James Arthur.

WATER CLOCKS FOR TELLING TIME

This picture shows the hour-glass or sand-glass. It is really a type of water-clock, being based on the same principle. The upper glass bulb was filled with sand and this sand fell through a little hole between the two bulbs. When the sand had all gone through, the glass was turned upside down and the operation repeated.

TIME-BOY OF INDIA.--WATER-CLOCK.

The Water-clock consisted of a large vessel filled with water, on the surface of which was placed a smaller vessel, really a gong, with a hole in the bottom. The water gradually filled the smaller vessel, and it sank. The Time-boy sat beside the Water-clock and as soon as the vessel sank he fished it out, emptied it, struck the gong one or more times and set it on the water again.]

During the night and also in cloudy weather the sun-dial was useless, and we read that the priests of the temples and monks of more modern times "went out to observe the stars" to make a guess at the time of night. The most prominent type after the shadow devices was the "water-clock" or "clepsydra," but many other methods were used, such as candles, oil lamps, and in comparatively late times, the sand-glass. The fundamental principle of all water-clocks is the escape of water from a vessel through a small hole. It is evident that such a vessel would empty itself each time it is filled in very nearly the same time. The reverse of this has been used, as shown in the picture of the Time-boy of India. He sat in front of a large vessel of water and floated a bronze cup having a small hole in its bottom in this large vessel, and as the water ran in through the hole the cup sank. The boy then fished it up and struck one or more blows on it as a gong. This he continued and a rude division of time was obtained--while the boy kept awake!

[Illustration: Drawing from description by James Arthur.

The "Hon-woo-et-low," Canton, China. Copper jars dropping water.]

The most interesting of all water-clocks was undoubtedly the "copper jars dropping water," in Canton, China, where it can still be seen. Referring to the picture herewith and reading the four Chinese characters downwards the translation is "Canton City." To the left and still downwards, "Hon-woo-et-low," which is, "Copper jars dropping water." Educated Chinamen inform me that it is over 3000 years old. The little open building or tower in which it stands is higher than surrounding buildings. It is, therefore, reasonably safe to state that the Chinese had a weather and time station over 1000 years before our era.

[Illustration:

Photo by James Arthur.

TOWER OF THE WINDS.

This tower is located at Athens, Greece. It was built about 50 B.C. It is octagonal in shape and had at one time sun-dials on each of its eight sides. On top was a bronze weather vane from which it derived its name.]

~A PRIMITIVE TWELVE-HOUR CLOCK~

It is a 12-hour clock, consisting of four copper jars partially built in masonry forming a stair-like structure. Commencing at the top jar each one drops into the next downward until the water reaches the solid bottom jar. In this lowest one a float, "the bamboo stick," is placed and indicates the height of the water, and thus in a rude way gives the time. It is said to be set morning and evening by dipping the water from jar 4 to jar 1, so it runs 12 hours of our time. What are the uses of jars 2 and 3, since the water simply enters them and drips out again? No information could be obtained, but I venture an explanation and hope the reader can do better, as we are all of a family and there is no jealousy. When the top jar is filled for a 12-hour run it would drip out too fast during the first six hours and too slow during the second six hours, on account of the varying "head" of water. Now, the spigot of jar 2 could be set so that it would gain water during the first six hours, and lose during the second six hours, and thus equalize a little by splitting the error of jar 1 in two parts. Similarly, these two errors of jar 2 could be again split by jar 3 making four small variations in lowest jar, instead of one large error in the flow of jar 1. This could be extended to a greater number of jars, another jar making eight smaller errors.

The best thing the young student could do at this point would be to grasp the remarkable fact that the clock is not an old machine, since is covers only the comparatively short period from 1364 to the present day. Compared with the period of man's history and inventions it is of yesterday. Strictly speaking, as we use the word clock, its age from De Vick to the modern astronomical is only about 540 years. If we take the year 1660, we find that it represents the center of modern improvements in clocks, a few years before and after that date includes the pendulum, the anchor and dead beat escapements, the minute and second hands, the circular balance and the hair spring, along with minor improvements. Since the end of that period, which we may make 1700, no fundamental invention has been added to clocks and watches. This becomes impressive when we remember that the last 200 years have produced more inventions than all previous known history--but only minor improvements in clocks! The application of electricity for winding, driving, or regulating clocks is not fundamental, for the time-keeping is done by the master clock with its pendulum and wheels, just as by any grandfather's clock 200 years old. This broad survey of time measuring does not permit us to go into minute mechanical details.

[Illustration: THE FIRST MODERN CLOCK

Drawing by James Arthur.

Modern clocks commence with De Vick's of 1364, which is the first unquestioned clock consisting of toothed wheels and containing the fundamental features of our present clocks. References are often quoted back to about 1000 A.D., but the words translated "clocks" were used for bells and dials at that date; so we are forced to consider the De Vick clock as the first till more evidence is obtained. It has been pointed out, however, that this clock could hardly have been invented all at once; and therefore it is probable that many inventions leading up to it have been lost to history. That part of a clock which does the ticking is called the "escapement," and the oldest form known is the "Verge."]

~EARLIEST CLOCKS HAD NO DIALS OR HANDS~

Scattered references in old writings make it reasonably certain that from about 1000 A.D. to 1300 A.D. bells were struck by machines regulated with this verge escapement, thus showing that the striking part of a clock is older than the clock itself. It seems strange to us to say that many of the earlier clocks were strikers only, and had no dials or hands, just as if you turned the face of

your clock to the wall and depended on the striking for the time.

[Illustration:

Photo by James Arthur.

ENGLISH BLACKSMITH'S CLOCK.]

A good idea of the old church clocks may be obtained from the picture herewith. Tradition has followed it down as the "English Blacksmith's Clock." It has the very earliest application of the pendulum. The pendulum is less than 3 inches long and is hung on the verge, or pallet axle, and beats 222 per minute. This clock may be safely put at 250 years old, and contains nothing invented since that date. Wheels are cast brass and all teeth laboriously filed out by hand. Pinions are solid with the axles, or "staffs," and also filed out by hand. It is put together, generally by mortise, tenon and cotter, but it has four original screws all made by hand with the file. How did he thread the holes for these screws? Probably made a tap by hand as he made the screws. But the most remarkable feature is the fact that no lathe was used in forming any part--all staffs, pinions and pivots being filed by hand. This is simply extraordinary when it is pointed out that a little dead center lathe is the simplest machine in the world, and he could have made one in less than a day and saved himself weeks of hard labor. It is probable that he had great skill in hand work and that learning to use a lathe would have been a great and tedious effort for him. So we have a complete striking clock made by a man so poor that he had only his anvil, hammer and file. The weights are hung on cords as thick as an ordinary lead-pencil and pass over pulleys having spikes set around them to prevent the cords from slipping. The weights descend 7 feet in 12 hours, so they must be pulled up--not wound up--twice a day. The single hour hand is a work of art and is cut through like lace. Public clocks may still be seen in Europe with only one hand. Many have been puzzled by finding that old, rudely made clocks often have fine dials, but this is not remarkable when we state that art and engraving had reached a high level before the days of clocks.

[Illustration: THE LARGEST CLOCK IN THE WORLD

Courtesy of Colgate and Company.

THE HANDS OF THE LARGEST CLOCK IN THE WORLD--ON THE ROOF OF THE COLGATE FACTORY.

This big clock faces the giant office buildings of down-town New York. Its dial is 38 feet in diameter and can be read easily at a distance of three miles, so that passengers on the incoming liners pick out the clock as one of their first sights of New York.

The next largest clock (on the Metropolitan Tower) is 26½■ feet in diameter; the Westminster clock of London, 22½■ feet.

The great clock weighs approximately 6 tons. The minute hand, 20 feet long, travels at its point 23 inches every minute; more than one-half mile each day.

The bed of this clock is 4 feet in length, the wheels and gears being made of bronze and pinions of hardened steel. The time train occupies about one-third of the bedplate, and has a main time wheel measuring 18½■ inches in diameter. This train is equipped with Dennison's double three-legged gravity escapement, which was invented by Sir Edmund Becket, chiefly for use on the famous Westminster clock, installed in the Parliament Buildings, in London, England. The use of this escapement is most advantageous for a gigantic clock of this kind as it allows the impulse given the pendulum rod to be always constant, and therefore does not permit any change of power or driving force of the clock to affect its time-keeping qualities.

It requires about 600 pounds of cast-iron to propel this time train, and the clock is arranged to run eight days without winding. The gravity arms of the escapement are fastened at a point very near the suspension spring, and the arms are fitted with bronze roller beat pins.

The dial contains 1134 square feet, or about one thirty-fifth of an acre. The numerals consist of heavy black strokes, 5 feet 6 inches long and 30 inches wide at the outer end, tapering to a point at the inner end. The circumference of the dial is approximately 120 feet. The distance from center to center of numerals is 10 feet, and the minute spaces are 2 feet.

The background on dial is painted white, and in the daytime the black numerals show up distinctly. At night the numerals, or hour marks, are designated by a row of incandescent bulbs placed in a trough 5 inches wide and 5 inches deep. The hands at night are outlined with incandescent electric lights, there being 27 lamps on the hour hand and 42 lamps on the minute hand.]

[Illustration: THE MACHINERY WHICH RUNS A BIG CLOCK]

This picture shows the machinery necessary to operate a large modern tower clock.

The mechanism is held in place and confined entirely within a cast-iron structure which is firmly bolted to the floor. The wheels are composed of bronze, the pinions of steel (hardened) and the gears are machine cut. At the front of the clock is a small dial which enables one to tell exactly the position of the hands on the outside dials, and there is also a second hand to permit of very close regulation and adjustment.

Three ways are provided for the regulation. First by a knurled screw at the top of bed frame. Second by a revolving disc at the bottom of the pendulum ball. Very often by either of these two methods it is impossible to bring the clock to fractional seconds, and in order to permit of a nicety of adjustment there is a cup fitted at the top of the ball so that by inserting or taking out lead pellets, the rating can be brought to absolute time.

[Illustration: THE CLOCK IN INDEPENDENCE HALL

INDEPENDENCE HALL, PHILADELPHIA]

[Illustration: NEW YORK CITY HALL]

Where Does the Day Begin?

To understand this subject we must first appreciate that a day as we think of it is a division of time made by man for the purpose of his own reckoning. So far as the beginning of day is concerned, it begins at a different place in the world every hour; yes, every minute and every second in the day. As, however, the distance in feet where the day begins from one minute to another is so short that we can hardly notice it in such short measurements of time, we will look at the answer to the question from hour to hour. When you understand the subject from that point you can yourself see that the day actually begins at a different point of the earth every minute and every second of time.

How Much of the Earth Does the Sun Shine on at One Time?

The sun is shining on some part of the earth all the time and the shining of the sun makes the difference between day and night. Wherever the sun is shining it is day-time, and where the sun is not shining it is night-time.

To illustrate we will make use of an ordinary orange and a lighted gas jet. Let us take a long hat-pin and stick it through the orange from stem to stem. Now hold the orange by the ends of the hat-pin up before the lighted gas jet. You will notice that one-half of the orange is lighted, while the other half is dark. Of course, it is the half of the orange away from the light that is dark. Now, revolve the orange slowly on the hat-pin axis toward the light. When you have turned the orange half way round the part that was formerly dark is now lighted up and the other part is now dark.

Now examine closely and you will see that just one-half of the orange is lighted at one time and the other half is dark. You revolve the orange in front of the light slowly and a portion of the surface of the orange is always coming into the light, while a corresponding portion of it on the opposite side is constantly going into the dark. In other words, whatever the speed at which you revolve the orange toward the light, one-half of it is always light and the other half is always dark.

This is exactly what happens in the relation of the earth to the sun every day. One-half of the earth, which is continually revolving on its axis, is facing the sun, and is, therefore, in the daylight, while the other half of the earth's surface is in darkness, because the light from the sun does not strike any portion of it. If the earth did not revolve one-half of it would always be in day-time, while the other half would be continually having night-time. As the earth is always moving or revolving the half where it is day-time is constantly changing, so that the day is beginning on one-half of the earth's surface every second of the day. Actually, of course, then, if you live on the east side of town day begins with you a little sooner than with your chum who lives on the west side of town. We have come to measure the beginning of day as sunrise and the beginning of night as sunset, wherever we happen to be.

For convenience in setting clocks and in measuring time we do not take into consideration these very slight differences in the rising and setting of the sun, but set our clocks all alike in different parts of the same town or city to avoid confusion. In fact, in order to overcome the difficulties and confusions arising in reckoning the time of the clock in different localities, and still keep the beginning of what we call day-time constant with the hands of the clock, we have agreed upon what we call standard time. We agreed upon this system of fixing standard time because the actual sun time by which people set their clocks up to a few years ago led to so

many mistakes in catching trains, keeping engagements and other misunderstandings where the question of time was involved. Then when this system of standard time was adopted the confusion became even worse, and the mistakes and misses more numerous, because some people insisted on setting their clocks to standard time and others insisted on sticking to the old sun time schedule. So you could never tell by looking at the clock what time it really was unless they put a sign on the clock saying what kind of time they were going by. Finally, however, most of the people came to appreciate that it would be a good idea to use one uniform system of setting the clocks and of having them in harmony in a sense with the other clocks in the world, and the adoption of the standard time plan became universal. To make this system practical and effective, certain points about equally distant from each other were selected, at which point

Where Is the Hour Changed?

the hour would change for all points within that zone. Under this system all timepieces in any one zone point to the same hour. So the clock time changes only as you go east or west. All points on a north and south line have the same time as the zone in which it is located.

For convenience in adjusting the time in America the country was divided into four east and west zones. The first zone takes in everything on a straight north and south line east of Pittsburg, and is called Eastern time. The second zone extends from Pittsburg to Chicago, and is called Central time; the third zone extends from Chicago to Denver, and is called Mountain time; while the fourth zone extends from Denver to the Pacific Ocean. These selections were made because the sun actually rises about one hour later in Pittsburg than in New York; one hour later in Chicago than in Pittsburg; one hour later in Denver than in Chicago, and one hour later on the Pacific Coast than in Denver. Under this plan when it is nine o'clock in New York it is only eight o'clock at Pittsburg and all points in the Central zone; seven o'clock in all points in the Mountain zone; six o'clock in Denver and five o'clock in San Francisco. As you keep travelling westward you drop one hour of the clock time in every zone, and as under this system the earth's east to west distance is divided into twenty-four such zones, if you went west entirely around the world you would lose a whole day of clock time.

If, however, you went around the world from west to east in the same manner you would gain a whole day.

Where Does the Day Change?

This system of agreeing on fixed places where the hour changes made it necessary to also fix a point where for the purposes of the calendar the day also changes. This imaginary north and south line is fixed upon at 180 degrees west longitude, which would cut the Pacific Ocean in two. This line makes it possible for a person to travel all day before approaching this line and then find himself after crossing it travelling all the next day with the same name for the day of the week. Thus he could spend all of Sunday travelling toward the International Day Line, as this is called, and after crossing it spend another Sunday, which would be the next day, going away from it. This would give him the novel experience of having two Sundays on successive days. The same thing would happen if he were travelling to the Day Line on Monday, Tuesday, Wednesday, Thursday, Friday or Saturday. He would live through two succeeding days of the same name in the same week, one right after the other. This would be in going westward.

If you were traveling eastward and crossed the International Day Line on Sunday at midnight you would lose a day completely out of the week, for when you woke up the next morning it would be Tuesday.

Why Do We Cook the Things We Eat?

We have several reasons for doing this. The first and most important reason to us is that the application of heat to food makes it more easy to digest. Other reasons are that when cooked our food is more palatable; the process of cooking kills all microbes, which, if taken into our bodies alive, would give us diseases, and also it is easier for us to chew food that has been cooked.

[Illustration: WONDERS PERFORMED BY ELECTRIC LIFT MAGNET

This picture shows the construction of a successful electric lift magnet. This device, by means of magnetic attraction, fastens itself to practically all kinds of iron and steel without the aid of slings, cables or chains.]

The Story in a Magnet

What Makes an Electro Magnet Lift Things?

The working parts of an electric lift magnet are as follows:

A Shell.--This is a steel casting heavily ribbed on the top for strength, and also to assist in radiating the heating effect from the coil.

It is usually made circular in shape, the outside rim forming one pole, while the lug in the center forms the other. The coil fits in between these poles, thus making a magnet similar to the ordinary horseshoe type.

A Bottom Plate.--The under side of the magnet is closed by a very tough and hard non-magnetic steel plate, in order to protect the coil.

As well as being non-magnetic, this plate also has sufficient strength to resist the severe wear to which a magnet is necessarily subjected.

A Terminal Box.--A one-piece heavily-constructed steel casting bolted to the top of the shell, containing and protecting the brass sockets into which the wires from the coil terminate, forms the Terminal Box.

The sockets are made to receive plugs placed on the end of the conductor wire, by which the magnet is connected with the generator.

A Coil.--This consists of a round insulated wire which is passed, while being wound, through a cement-like substance, heavily coating each individual strand.

A low voltage of current is then passed through the coil, a sufficient length of time, to thoroughly dry out and bake the coating. This renders the magnet absolutely fireproof, eliminating all danger of short circuiting of the coil.

When finished it is well taped to protect the outside wire from becoming chafed.

The coil is made slightly smaller than the inside dimensions of the shell and the remaining space is filled with an impregnating compound, which hardens to the consistency of pitch.

This renders the coil thoroughly waterproof; also forms a cushion to prevent injury from the severe jars and shocks, received when dropping a magnet on its load.

A Controller.--The rapidity with which it is necessary to turn current on and off while operating a magnet, creates what is called a "back kick." Unless this is dissipated quickly it is very destructive to the coil.

A special controller dissipates this back kick through a set of resistance coils placed in the controller. By means of an automatic arrangement, connection with these coils is made instantly upon breaking the current between the magnet and generator.

A system of control used prevents undue heating of the coil. This enables the magnet to lift as large a load after a long steady run as at the start.

What Is a Lodestone?

A lodestone is a variety of the mineral named magnetite which is a natural magnet. The name magnet comes from the name of the mineral magnetite and this in turn derived its name from the fact that it was first discovered in Magnesia. The word magnet really means the "Stone of Magnesia."

A lodestone is one of the mysteries of nature. Its properties can more nearly be understood if we examine an artificial magnet, which is generally made in the form of either a straight bar or a shoe. An artificial magnet is made of iron. If you drop a bar magnet into a box of iron filings, the filings attach themselves to the bar. If you examine it closely you observe that most of the filings attach themselves to the ends of the bar. Therefore we call the ends of the bar the poles of the magnet.

If you suspend a magnetic needle at its center of gravity so that it is absolutely free to turn, you will soon find one end of the needle pointing north and the other south of course. The end which is pointed toward the north is called the north pole and the other the south pole. If you have a horse-shoe magnet, you can demonstrate this for yourself. Rub the end of your magnet over a sewing

needle and oil the needle so that when you lay it on the surface of a glass of water it will float. Then look at it closely. You will see the needle slowly turn until finally it becomes quite still. If you have a compass at hand so that you know surely which is north and which is south, you will find one end of the needle pointing north and the other south. You can then place the end of your magnet against the outside of the glass and draw the needle toward your magnet. Your horse-shoe magnet has its north and south poles close together.

If you have a bar magnet and the end of the needle with the eye in it is pointing north, you can drive the needle on the surface of the water away from you by touching the outside of the glass opposite that end of the needle with the north pole of your magnet. On the other hand, if you reverse the experiment and place the south pole of your magnet to the side of the glass, the needle will come toward the magnet. In other words then the like poles of a magnet repel each other and the unlike poles attract each other.

Another interesting way to show this is to take two lodestones or two magnets and let a lot of iron filings attach themselves to the ends of them. Then when you have done this, point the two north poles of the magnets or lodestones at each other close together. You will be intensely interested in seeing how quickly the mysterious something that is in the magnets makes the filings on the two ends of the magnet try to get away from each other. On the other hand when you put a north and south pole together, they form a union of the iron filings.

Another strange thing about a magnet is that if you break it in two, each half will be a complete magnet in itself with a north and south pole also, and this is true no matter how many times you break it into pieces. From this we learn that each tiny particle or molecule throughout the bar is a magnet by itself.

[Illustration: WHAT A LODESTONE IS

This is a picture of a complete electro magnet. The magnet is attached to the arm of a crane by the loop in the center and when the magnet then comes in contact with any kind of iron or steel it lifts it as soon as the current is turned on. By making the electric current stronger, greater weight can be lifted. Many tons of material can be lifted at one time. An electro magnet will do the work of many men at much less cost.]

[Illustration: In this picture we see the magnet lifting a great weight of miscellaneous pieces of scrap iron. As many as twenty tons can be lifted and transferred from one place to another at one time.]

Some things can be magnetized while others cannot. Many substances have not the property of magnetizing other substances when they have once been attracted by a magnet. These are called magnetic substances. They remain magnetized only as long as they are in touch with the magnet; other substances when once magnetized become permanent magnets. Steel and lodestone have this faculty. A compass needle is an artificial magnet which becomes a permanent magnet when rubbed with a magnet.

What Is Electricity?

If you pass a hard rubber comb through your hair, in frosty weather, a crackling sound is produced, and the individual hairs show a tendency to stick to the comb. After being drawn through your hair a few times, you may notice that the comb has become charged with electricity. This electricity is produced by friction. Not only rubber but many other substances become electrified by friction, such as a bar of sealing wax rubbed with flannel, or a glass rod rubbed with silk, will show the same qualities, and these simple experiments teach us many of the fundamental facts about electricity.

Some simple experiments will be found instructive and interesting. Rub with flannel a stick of sealing wax until it is electrified and then bring it close to a pith ball which should be hung by a silk thread. The pith ball will at once be attracted to the sealing wax, and, if brought quite close, the ball will adhere to the wax for a few moments, and then fly away from it. The ball will now be repelled by the sealing wax instead of being drawn toward it. Now take a glass rod, rub it with a silk cloth after drying it thoroughly. When the pith ball is brought close to the glass rod it also will at first be attracted toward the glass and, if brought in contact with the glass, the pith ball will adhere as before. It will also then fly away in the same way it did from the sealing wax. Repeat these experiments with the sealing wax now and you will find the ball will be attached, as it was at first, but if it touches the wax it will again adhere for a moment and then fly away. By using the sealing wax and glass rod alternately and bringing them into contact with the pith ball, you discover that when it is attracted by one, it is repelled by the other, and that, after it has been in contact with either for a few moments it is no longer attracted by it.

We learn thus that the electricity in the glass and the sealing wax are not the same. To distinguish the two kinds of attraction, we say the glass is charged with positive, or vitreous electricity, while the charge on the sealing wax is called negative, or resinous electricity.

When the pith ball was touched with the sealing wax, it became filled with negative electricity, and was then no longer attracted by the wax, but was repelled by it and attracted by the glass rod; but when the ball had been filled with positive electricity, it was repelled by the glass and attracted by the wax. We conclude from these facts that bodies filled with the same kind of electricity repel each other, while bodies filled with opposite kinds of electricity attract each other.

When two substances are charged, as we say, with electricity of opposite kinds and are brought into contact, and left so for some time, the two charges disappear, one appearing to neutralize the other. From this, we conclude, and rightly, that any substance not electrified, contains equal amounts both positive and negative electricity. When, therefore, we rub a piece of glass with silk, we are not creating electricity, but only separating the different kinds. The positive electricity adheres to the glass, and the negative remains behind, on the silk. In the same manner, when we electrify sealing wax with flannel the negative kind remains in the sealing wax and the flannel becomes charged with the positive. Whenever a body is electrified by friction, both kinds of electricity are produced; it is impossible to produce one kind without the other.

[Illustration: WHAT ELECTRICITY IS

Magnets are particularly valuable in lifting raw material in a steel mill. The red-hot pig-iron, from which steel is made, can be handled easily in this way, whereas it would be impossible to handle same by hand. Sometimes great quantities of iron are broken up by the magnet. A weight of many tons is lifted by the magnet and allowed to fall on the material to be broken up. The weight falls as soon as the current is turned off.]

[Illustration:

Weight of wheel, 8160 lbs.

Pieces of machinery which cannot be lifted by men on account of their great weight and shape are handled easily.]

You must rub the entire glass rod or bar of sealing wax to electrify the whole of it. If only a part of the glass rod or sealing wax is rubbed, only that part becomes electrified, as may be shown by trying to attract a pith ball with the part that has not been rubbed.

~WHAT GOOD AND BAD CONDUCTORS OF ELECTRICITY ARE~

If, however, the charged part of the sealing wax is brought into contact with a metal rod resting on, say, a drinking glass, the rod becomes charged, not only where it is brought into contact, but all over its surface. Substances over which electricity flows readily are called conductors of electricity. All metals are of this kind. Things like glass and sealing wax over which electricity does not flow readily, are called non-conductors, or insulators. Water, the human body, and the earth are good conductors and rubber, porcelain, most resins, and dry air are non-conductors.

You have already learned that substances charged with opposite kinds of electricity attract each other, and substances charged with the same kind repel each other. We will try to discover why substances charged with either kind of electricity attract small light objects, such as pith balls, when these latter are not charged with electricity. As we have discovered, all substances which have remained undisturbed have both kinds of electricity present in them, in equal amounts. Now, when an uncharged body is brought near a charged body, the two kinds of electricity in the uncharged body have a tendency to separate. The kind opposite in character, to that on the charged body, is attracted toward the charged body, and the other kind is repelled. Thus, if our bar of sealing wax, charged with, let us say, negative electricity, is brought near a pith ball, the positive electricity in the ball is attracted to the side nearest the scaling wax, and the negative electricity is repelled to the farther side. As the positive electricity on the pith is nearer to the scaling wax than the negative, its attraction for the negative charge, on the sealing wax, is stronger than the repulsion between the negative electricities of the two objects, and consequently, the ball is attracted to the sealing wax. If the charged sealing wax i

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The decay and the restoration of civilization

Albert Schweitzer

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The Dale Memorial Lectures, 1922.

THE DECAY AND THE RESTORATION OF CIVILIZATION

THE PHILOSOPHY OF CIVILIZATION

PART I

BY

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To ANNIE FISCHER IN DEEPEST GRATITUDE

AUTHOR'S PREFACE

"The Decay and the Restoration of Civilization" is the first part of a complete philosophy of civilization with which I have been occupied since the year 1900.

The second part, entitled "Civilization and Ethics", will appear immediately. The third is called "The World-View_(_*_)_ of Reverence for Life". The fourth has to do with the civilized State.

That over which I have toiled since 1900 has been finally ripened in the stillness of the primeval forest of Equatorial Africa. There, during the years 1914-17, the clear and definite lines of this philosophy of civilization have been developed.

The first part, "The Decay and the Restoration of Civilization", is a kind of introduction to the philosophy of civilization. It states the problem of civilization.

Entering on the question as to what is the real essential nature of civilization, I come to the pronouncement that this is ultimately ethical. I know that in thus stating the problem as a moral one I [pg viii] shall surprise and even disgust the spirit of our times, which is accustomed to move amidst æsthetic, historical and material considerations. I imagine, however, that I am myself enough of an artist and also of an historian to be able to comprehend the æsthetic and historical elements in civilization, and that, as a modern physician and surgeon, I am sufficiently modern to appreciate the glamour of the technical and material attainments of our age.

Notwithstanding this, I have come to the conviction that the æsthetic and the historical elements, and the magnificent extension of our material knowledge and power, do not themselves form the essence of civilization, but that this depends on the mental disposition of the individuals and nations who exist in the world. All other things are merely accompanying circumstances of civilization, which have nothing to do with its real essence.

Creative, artistic, intellectual, and material attainments can only show their full and true effects when the continued existence and development of civilization have been secured by founding civilization itself on a mental disposition which is truly ethical. It is only in his struggle to become ethical that man comes to possess real value as a personality; it is only under the influence of ethical

convictions that the various relations of human society are formed in such a way that individuals and peoples can [pg ix] develop in an ideal manner. If the ethical foundation is lacking, then civilization collapses, even when in other directions creative and intellectual forces of the strongest nature are at work.

This moral conception of civilization, which makes me almost a stranger amidst the intellectual life of my time, I express clearly and unhesitatingly, in order to arouse amongst my contemporaries reflection as to what civilization really is. We shall not succeed in re-establishing our civilization on an enduring basis until we rid ourselves completely of the superficial concept of civilization which now holds us in thrall, and give ourselves up again to the ethical view which obtained in the eighteenth century.

The second point which I desire should obtain currency is that of the connection between civilization and our theory of the universe. At the present time no regard is paid to this connection. In fact, the period in which we are living altogether misses the significance of having a theory of the universe. It is the common conviction nowadays, of educated and uneducated alike, that humanity will progress quite satisfactorily without any theory of the universe at all.

The real fact is that all human progress depends on progress in its theory of the universe, whilst, conversely, decadence is conditioned by a similar [pg x] decadence in this theory. Our loss of real civilization is due to our lack of a theory of the universe.

Only as we again succeed in attaining a strong and worthy theory of the universe, and find in it strong and worthy convictions, shall we again become capable of producing a new civilization. It is this apparently abstract and paradoxical truth of which I proclaim myself the champion.

Civilization, put quite simply, consists in our giving ourselves, as human beings, to the effort to attain the perfecting of the human race and the actualization of progress of every sort in the circumstances of humanity and of the objective world. This mental attitude, however, involves a double predisposition: firstly, we must be prepared to act affirmatively toward the world and life; secondly, we must become ethical.

Only when we are able to attribute a real meaning to the world and to life shall we be able also to give ourselves to such action as will produce results of real value. As long as we look on our existence in the world as meaningless, there is no point whatever in desiring to effect anything in the world. We become workers for that universal spiritual and material progress which we call civilization only in so far as we affirm that the world and life possess some sort of meaning, or, which is the same thing, only in so far as we think optimistically.

[pg xi]

Civilization originates when men become inspired by a strong and clear determination to attain progress, and consecrate themselves, as a result of this determination, to the service of life and of the world. It is only in ethics that we can find the driving force for such action, transcending, as it does, the limits of our own existence.

Nothing of real value in the world is ever accomplished without enthusiasm and self-sacrifice.

But it is impossible to convince men of the truth of world- and life-affirmation and of the real value of ethics by mere declamation. The affirmative and ethical mentality which characterizes these beliefs must originate in man himself as the result of an inner spiritual relation to the world. Only then will they accompany him as strong, clear, and constant convictions, and condition his every thought and action.

To put it in another way: world- and life-affirmation must be the products of thought about the world and life. Only as the majority of individuals attain to this result of thought and continue under its influence will a true and enduring civilization make progress in the world. Should the mental disposition towards world- and life-affirmation and towards ethics begin to wane, or become dim and obscured, we shall be incapable of working for true civilization, nay, more, we shall be unable even to [pg xii] form a correct concept of what such civilization ought to be.

And this is the fate which has befallen us. We are bereft of any theory of the universe. Therefore, instead of being inspired by a profound and powerful spirit of affirmation of the world and of life, we allow ourselves, both as individuals and as nations, to be driven hither and thither by a type of such affirmation which is both confused and superficial. Instead of adopting a determined ethical attitude, we exist in an atmosphere of mere ethical phrases or declare ourselves ethical sceptics.

How is it that we have got into this state of lacking a theory of the universe? It is because hitherto the world- and life-affirming and ethical theory of the universe had no convincing and permanent foundation in thought. We thought again and again that we had found such a basis for it; but it lost power again and again without our being aware that it was doing so, until, finally, we have been obliged, for more than a generation past, to resign ourselves more and more to a complete lack of any world-theory at all.

Thus, in this introductory part of my work, I proclaim two truths and conclude with a great note of interrogation. The truths are the following: The basic ethical character of civilization, and the connection between civilization and our theories of [pg xiii] the universe. The question with which I conclude is this: Is it at all possible to find a real and permanent foundation in thought for a theory of the universe which shall be both ethical and affirmative of the world and of life?

The future of civilization depends on our overcoming the meaninglessness and hopelessness which characterize the thoughts and convictions of men to-day, and reaching a state of fresh hope and fresh determination. We shall be capable of this, however, only when the majority of individuals discover for themselves both an ethic and a profound and steadfast attitude of world- and life-affirmation, in a theory of the universe at once convincing and based on reflection.

Without such a general spiritual experience there is no possibility of holding our world back from the ruin and disintegration towards which it is being hastened. It is our duty then to rouse ourselves to fresh reflection about the world and life.

In "Civilization and Ethics", the second part of this philosophy of civilization, I describe the road along which thought has led me to world- and life-affirmation and to ethics. The root-idea of my theory of the universe is that my relation to my own being and to the objective world is determined by reverence for life. This reverence for life is given as an element of my will-to-live, and becomes clearly [pg xiv] conscious of itself as I reflect about my life and about the world. In the mental attitude of reverence for life which should characterize my contact with all forms of life, both ethics and world- and life-affirmation are involved. It is not any kind of insight into the essential nature of the world which determines my relation to my own existence and to the existence which I encounter in the world, but rather only and solely my own will-to-live which has developed the power of reflection about itself and the world.

The theory of the universe characterized by reverence for life is a type of mysticism arrived at by self-consistent thought when persisted in to its ultimate conclusion. Surrendering himself to the guidance of this mysticism, man finds a meaning for his life in that he strives to accomplish his own spiritual and ethical self-fulfilment, and, simultaneously and in the same act, helps forward all the processes of spiritual and material progress which have to be actualized in the world.

I do not know how many, or how few, will allow themselves to be persuaded to travel with me on the road indicated above. What I desire above all things—and this is the crux of the whole affair—is that we should all recognize fully that our present entire lack of any theory of the universe is the ultimate source of all the catastrophes and misery of [pg xv] our times, and that we should toil in concert for a theory of the universe and of life, in order that thus we may arrive at a mental disposition which shall make us really and truly civilized men.

It was a great joy to me to be afforded the opportunity of putting forward, in the _Dale Lectures_, delivered in Oxford, the views on which this philosophy of civilization is based.

I would tender my deepest thanks to my friends, Mr. C. T. Campion, M.A., now of Grahamstown, South Africa, and Dr. J. P. Naish, of Oxford. Mr. Campion is the translator of this first part of the "Philosophy of Civilization". Dr. Naish has seen the book through the press and translated this preface.

ALBERT SCHWEITZER.

Strasbourg, Alsace.

February, 1923.

[pg xvi]

CONTENTS

CHAPTER I How Philosophy is Responsible for the Collapse of Civilization [1]

CHAPTER II Hindrances to Civilization in our Economic and Spiritual Life [15]

CHAPTER III Civilization essentially Ethical in Character [35]

CHAPTER IV The Way to the Restoration of Civilization [62]

CHAPTER V Civilization and Theories of the Universe [80]

[pg xvii]

THE DECAY AND THE RESTORATION OF CIVILIZATION

CHAPTER I

HOW PHILOSOPHY IS RESPONSIBLE FOR THE COLLAPSE OF CIVILIZATION

Our self-deception as to the real conditions of our civilization. The collapse of the theory of the universe on which our ideals were based. The superficial character of modern philosophizing.

We are living to-day under the sign of the collapse of civilization. The situation has not been produced by the war; the latter is only a manifestation of it. The spiritual atmosphere has solidified into actual facts, which again react on it with disastrous results in every respect. This interaction of material and spiritual has assumed a most unhealthy character. Just below a mighty cataract we are driving along in a current full of formidable eddies, and it will need the most gigantic efforts to rescue the vessel of our fate from the dangerous side channel into which we have [pg 002] allowed it to drift, and bring it back into the main stream, if, indeed, we can hope to do so at all.

We have drifted out of the stream of civilization because there was amongst us no real reflection upon what civilization is. It is true that at the end of the last century and the beginning of this there appeared a number of works on civilization with the most varied titles; but, as though in obedience to some secret order, they made no attempt to settle and make clear the conditions of our intellectual life, but devoted themselves exclusively to its origin and history. They gave us a relief map of civilization marked with roads which men had observed or invented, and which led us over hill and dale through the fields of history from the Renaissance to the twentieth century. It was a triumph for the historical sense of the authors. The crowds whom these works instructed were filled with satisfied contentment when they understood that their civilization was the organic product of so many centuries of the working of spiritual and social forces, but no one worked out and described the content of our spiritual life. No one tested its value from the point of view of the nobility of its ideas, and its ability to produce real progress.

Thus we crossed the threshold of the twentieth century with an unshakable conceit of ourselves, [pg 003] and whatever was written at that time about our civilization only confirmed us in our ingenuous belief in its high value. Anyone who expressed doubt was regarded with astonishment. Many, indeed, who were on the road to error, stopped and returned to the main road again because they were afraid of the path which led off to the side. Others continued along the main road, but in silence; the understanding and insight which were at work in them only condemned them to isolation.

It is clear now to everyone that the suicide of civilization is in progress. What yet remains of it is no longer safe. It is still standing, indeed, because it was not exposed to the destructive pressure which overwhelmed the rest, but, like the rest, is built upon rubble, and the next landslide will very likely carry it away.

But what was it that preceded and led up to this loss of power in the innate forces of civilization?

The age of the Illuminati and of rationalism had put forward ethical ideals, based on reason, concerning the development of the individual to true manhood, his position in society, the material and spiritual problems which arose out of society, the relations of the different nations to each other, and their issue in a humanity which should be united in [pg 004] the pursuit of the highest moral and spiritual objects. These ideals had begun, both in philosophy and in general thought, to get into contact with reality and to alter the general environment. In the course of three or four generations there had been such progress made, both in the ideas underlying civilization and in their material embodiment, that the age of true civilization seemed to have dawned upon the world and to be assured of an uninterrupted development.

But about the middle of the nineteenth century this mutual understanding and co-operation between ethical ideals and reality began to break down, and in the course of the next few decades it disappeared more and more completely. Without resistance, without complaint, civilization abdicated. Its ideas lagged behind, as though they were too exhausted to keep pace with it. How did this come about?

* * * * *

The decisive element in the production of this result was philosophy's renunciation of her duty.

In the eighteenth century and the early part of the nineteenth it was philosophy which led and guided thought in general. She had busied herself with the questions which presented themselves to mankind at each successive period, and had kept the [pg 005] thought of civilized man actively reflecting upon them. Philosophy at that time included within herself an elementary philosophizing about man, society, race, humanity and civilization, which produced in a perfectly natural way a living popular philosophy that controlled the general thought, and maintained the enthusiasm for civilization.

But that ethical, and at the same time optimistic, view of things in which the Illuminati and rationalism had laid the foundations of this healthy popular philosophy, was unable in the long run to meet the criticism levelled at it by pure thought. Its naïve dogmatism raised more and more prejudice against it. Kant tried to provide the tottering building with new foundations, undertaking to alter the rationalistic view of things in accordance with the demands of a deeper theory of knowledge, without, however, making any change in its essential spiritual elements. Goethe, Schiller and other intellectual giants of the age, showed, by means of criticism both kindly and malicious, that rationalism was rather popular philosophy than real philosophy, but they were not in a position to put into the place of what they destroyed anything new which could give the same effective support to the ideas about civilization which were current in the general thought of the time.

[pg 006]

Fichte, Hegel, and other philosophers, who, for all their criticism of rationalism, paid homage to its ethical ideals, attempted to establish a similar ethical and optimistic view of things by speculative methods, that is by logical and metaphysical discussion of pure being and its development into a universe. For three or four decades they succeeded in deceiving themselves and others with this supposedly creative and inspiring illusion, and in doing violence to reality in the interests of their theory of the universe. But at last the natural sciences, which all this time had been growing stronger and stronger, rose up against them, and, with a plebeian enthusiasm for the truth of reality, reduced to ruins the magnificent creations of their imagination.

Since that time the ethical ideas on which civilization rests have been wandering about the world, poverty-stricken and homeless. No theory of the universe has been advanced which can give them a solid foundation; in fact, not one has made its appearance which can claim for itself solidity and inner consistency. The age of philosophic dogmatism had come definitely to an end, and after that nothing was recognized as truth except the science which described reality. General theories of the universe no longer appeared as fixed stars; they [pg 007] were regarded as resting on hypothesis, and ranked no higher than comets.

The same weapon which struck down the dogmatism of knowledge about the universe struck down also the dogmatic enunciation of spiritual ideas. The early simple rationalism, the critical rationalism of Kant, and the speculative rationalism of the great philosophers of the nineteenth century had all alike done violence to reality in two ways. They had given a position above that of the facts of science to the views which they had arrived at by pure thought, and they had also preached a series of ethical ideals which were meant to replace by new ones the various existing relations in the ideas and the material environment of mankind. When the first of these two forms of violence was proved to be a mistaken one, it became questionable whether the second could still be allowed the justification which it had hitherto enjoyed. The doctrinaire methods of thought which made the existing world nothing but material for the production of a purely theoretical sketch of a better future were replaced by sympathetic attempts to understand the historical origin of existing things for which Hegel's philosophy had prepared the way.

With a general mentality of this description, a real combination of ethical ideals with reality was no [pg 008] longer possible; there was not the freedom from prejudice which that required, and so there came a weakening of the convictions which were the driving power of civilization. So, too, an end was put to that justifiable violence to human convictions and circumstances without which the reforming work of civilization can make no advance, because it was bound up with that other unjustifiable violence to reality. That is the tragic element in the psychological development of our spiritual life during the latter half of the nineteenth century.

Rationalism, then, had been dismissed; but with it went also the optimistic convictions as to the moral meaning of the universe and of humanity, of society and of man, to which it had given birth, though the conviction still exerted so much influence that no attention was paid to the catastrophe which had really begun.

* * * * *

Philosophy did not realize that the power of the ideas about civilization which had been entrusted to it was becoming a doubtful quantity. At the end of one of the most brilliant works on the history of philosophy which appeared at the close of the nineteenth century philosophy is defined as the process "by which there comes to completion, step by step, [pg 009] and with ever clearer and surer consciousness, that conviction about the value of civilization the universal validity of which it is the object of philosophy itself to affirm." But the author has forgotten the essential point, viz., that there was a time when philosophy did not merely convince itself of the value of civilization, but also let its convictions go forth as fruitful ideas destined to influence the general thought, while from the middle of the nineteenth century onwards these convictions had become more and more of the nature of hoarded and unproductive capital.

Once philosophy had been an active worker producing universal convictions about civilization. Now, after the collapse in the middle of the nineteenth century, this same philosophy had become a mere drawer of dividends, concentrating her activities far from the world on what she had managed to save. She had become a mere science, which sifted the results of the historical and natural sciences, and collected from them material for a future theory of the universe, carrying on with this object in view a learned activity in all branches of knowledge. At the same time she became more and more absorbed in the study of her own past. Philosophy came to mean practically the history of philosophy, but the creative spirit had left her. She became more and [pg 010] more a philosophy which contained no real thought. She reflected, indeed, on the results achieved by the individual sciences, but she lost the power of thought about fundamental problems.

She looked back with condescending pity on the rationalism which she had outstripped. She prided herself on being able to trace her descent through Kant, on having been shown by Hegel the inner meaning of history, and on being at work to-day in close sympathy with the natural sciences. But for all that she was poorer than the poorest rationalism, because she now carried on in imagination only, and not in reality, the recognized work of philosophy, which the latter had practised so zealously. Rationalism, for all its simplicity, had been a working philosophy, but philosophy herself had now become, for all her insight, merely a pedantic philosophy of degenerates. She still played, indeed, some sort of _rôle_ in schools and universities, but she had no longer any message for the great world.

In spite of all her learning, she had become a stranger to the world, and the problems of life which occupied men and the whole thought of the age had no part in her activities. Her way lay apart from the general spiritual life, and just as she derived no stimulus from the latter, so she gave none back. Refusing to concern herself with fundamental [pg 011] problems, she contained no fundamental philosophy which could become a philosophy of the people.

From this impotence came the aversion to all generally intelligible philosophizing which is so characteristic of her. Popular philosophy was for her merely a review, prepared for the use of the crowd, simplified, and therefore rendered inferior, of the results given by the individual sciences which she had herself sifted and put together in view of a future theory of the universe. She was wholly unconscious of several things, viz., that there is a popular philosophy which arises out of such a review; that it is just the province of philosophy to deal with the primary, deeper questions about which individuals and the crowd are thinking, or ought to be thinking, to apply to them more comprehensive and more thorough methods of thought, and then restore them to general currency; and, finally, that the value of any philosophy is in the last resort to be measured by its capacity, or incapacity, to transform itself into a living philosophy of the people.

Whatever is deep is also simple, and can be reproduced as such, if only its relation to the whole of reality is preserved. It is then something abstract, which secures for itself a many-sided life as soon as it comes into contact with facts.

[pg 012]

Whatever of inquiring thought there was among the general public was therefore compelled to languish, because our philosophy refused either to acknowledge or to help it. It found in front of it a deep chasm which it could not cross.

Of gold coinage, minted in the past, philosophy had abundance; hypotheses about a soon to be developed theological theory of the universe filled her vaults like unminted bullion; but food with which to appease the spiritual hunger of the present she did not

possess. Deceived by her own riches, she had neglected to plant any ground with nourishing crops, and therefore, ignoring the hunger of the age, she left the latter to its fate.

That pure thought never managed to construct a theory of the universe of an optimistic, ethical character, and to build up on that for a foundation the ideals which go to produce civilization, was not the fault of philosophy; it was a fact which became evident as thought developed. But philosophy was guilty of a wrong to our age in that it did not admit the fact, but remained wrapped up in its illusion, as though this were really a help to the progress of civilization.

The ultimate vocation of philosophy is to be the guide and guardian of the general reason, and it was her duty, in the circumstances of the time, to confess [pg 013] to our world that ethical ideals were no longer supported by any general theory of the universe, but were, till further notice, left to themselves, and must make their way in the world by their own innate power. She ought to have shown us that we have to fight on behalf of the ideals on which our civilization rests. She ought to have tried to give these ideals an independent existence by virtue of their own inner value and inner truth, and so to keep them alive and active without any extraneous help from a corresponding theory of the universe. No effort should have been spared to direct the attention of the cultured and the uncultured alike to the problem of the ideals of civilization.

But philosophy philosophized about everything except civilization. She went on working undeviatingly at the establishment of a theoretical view of the universe, as though by means of it everything could be restored, and did not reflect that this theory, even if it were completed, would be constructed only out of history and science, and would accordingly be unoptimistic and unethical, and would remain for ever an "impotent theory of the universe," which could never call forth the energies needed for the establishment and maintenance of the ideals of civilization.

So little did philosophy philosophize about [pg 014] civilization that she did not even notice that she herself and the age along with her were losing more and more of it. In the hour of peril the watchman who ought to have kept us awake was himself asleep, and the result was that we put up no fight at all on behalf of our civilization.

[pg 015]

CHAPTER II

HINDRANCES TO CIVILIZATION IN OUR ECONOMIC AND SPIRITUAL LIFE

The unfree economic position of the modern man. The undeveloped condition of the modern man. The modern man's want of humanity. The lack of spiritual independence in the man of to-day.

Even if the abdication of thought has been, as we have seen, the decisive factor in the collapse of our civilization, there are yet a number of other causes which combine with it to hinder our progress in this regard. They are to be found in the field of spiritual as well as in that of economic activity, and depend, above all, on the interaction between the two, an interaction which is unsatisfactory and continually becoming more so.

The capacity of the modern man for progress in civilization is diminished because the circumstances in which he finds himself placed injure him psychically and stunt his personality.

The development of civilization comes about—to put it quite generally—by individual men thinking out ideals which aim at the progress of the whole, and then so fitting them to the realities of life that [pg 016] they assume the shape in which they can influence most effectively the circumstances of the time. A man's ability to be a pioneer of progress, that is, to understand what civilization is and to work for it, depends, therefore, on his being a thinker and on his being free. He must be the former if he is to be capable of comprehending his ideals and putting them into shape. He must be free in order to be in a position to launch his ideals out into the general life. The more completely his activities are taken up in any way by the struggle for existence, the more strongly will the impulse to improve his own condition find expression in the ideals of his thought. Ideals of self-interest then get mixed up with and spoil his ideals of civilization.

Material and spiritual freedom are closely bound up with one another. Civilization presupposes free men, for only by free men can it be thought out and brought to realization.

But among mankind to-day both freedom and the capacity for thought have been sadly diminished.

If society had so developed that a continually widening circle of the population could enjoy a modest, but well-assured, condition of comfort, civilization would have been much more helped than it has been by all the material conquests which are lauded in its name. These do, indeed, make [pg 017] mankind as a whole less dependent upon nature, but at the same time they diminish the number of free and independent lives. The artisan who was his own master becomes the factory hand through the compulsion of machinery. Because in the complicated business world of to-day only undertakings with abundant capital behind them can maintain their existence, the place of the small, independent dealer is being taken more and more completely by the employee. Even the classes which still possess a larger or smaller amount of property or maintain a more or less independent activity get drawn more and more completely into the struggle for existence because of the insecurity of present conditions under the economic system of to-day.

The lack of freedom which results is made worse still because the factory system creates continually growing agglomerations of people who are thereby compulsorily separated from the soil which feeds them, from their own homes and from nature. Hence comes serious psychical injury. There is only too much truth in the paradoxical saying that abnormal life begins with the loss of one's own field and dwelling-place.

Civilization is, it is true, furthered to a certain extent by the self-regarding ideals produced by the [pg 018] groups of people who unite and co-operate in defence of their similarly threatened interests in so far as they seek to obtain an improvement in their material, and thereby also in their spiritual, environment. But these ideals are a danger to the idea of civilization as such, because the form which they assume is either not at all, or very imperfectly, determined by the really universal interests of the community. The consideration of civilization as such is held back by the competition between the various self-regarding ideals which go under its name.

To the want of freedom we have to add the evil of overwork. For two or three generations numbers of individuals have been living as workers merely, not as human beings. Whatever can be said in a general way about the moral and spiritual significance of labour has no bearing on what they have to do. An excessive amount of labour is the rule to-day in every department of industry, with the result that the labourer's spiritual element cannot possibly thrive. This overwork hits him indirectly even in his childhood, for his parents, caught in the inexorable toils of work, cannot devote themselves to his up-bringing as they should. Thus his development is robbed of something which can never be made good, and later in life, when he himself is the slave of over-long hours, he feels more and [pg 019] more the need of external distractions. To spend the time left to him for leisure in self-cultivation, or in serious intercourse with his fellows or with books, requires a mental collectedness and a self-control which he finds very difficult. Complete idleness, forgetfulness, and diversion from his usual activities are a physical necessity. He does not want to think, and seeks not self-improvement, but entertainment, that kind of entertainment, moreover, which makes least demand upon his spiritual faculties.

The mentality of this mass of individuals, spiritually relaxed and incapable of self-collectedness, reacts upon all those institutions which ought to serve the cause of culture, and therewith of civilization. The theatre takes a second place behind the pleasure resort or the picture show, and the instructive book behind the diverting one. An ever increasing proportion of periodicals and newspapers have to accommodate themselves to the necessity of putting their matter before their readers in the shape which lets it be assimilated most easily. A comparison of the average newspapers of to-day with those of fifty or sixty years ago shows how thoroughly such publications have had to change their methods in this respect.

When once the spirit of superficiality has penetrated [pg 020] into the institutions which ought to sustain the spiritual life, these exercise on their part a reflex influence on the society which they have brought to this condition, and force on all alike this state of mental vacuity.

How completely this want of thinking power has become a second nature in men to-day is shown by the kind of sociability which it produces. When two of them meet for a conversation each is careful to see that their talk does not go beyond generalities or develop into a real exchange of ideas. No one has anything of his own to give out, and everyone is haunted by a sort of terror lest anything original should be demanded from him.

The spirit produced in such a society of never-concentrated minds is rising among us as an ever growing force, and it results in a lowered conception of what man should be. In ourselves, as in others we look for nothing but vigour in productive work and resign ourselves to the abandonment of any higher ideal.

When we consider this want of freedom and of mental concentration, we see that the conditions of life for the inhabitants of our big cities are as unfavourable as they could be. Naturally, then, those inhabitants are in most danger on their spiritual side. It is doubtful whether big cities [pg 021] have ever been foci of civilization in the sense that in them there has arisen the ideal of a man well and truly developed as a spiritual personality; to-day, at any rate, the condition of things is such that true civilization needs to be rescued from the spirit that issues from them and their inhabitants.

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But, besides the hindrance caused to civilization by the modern man's lack of freedom and of the power of mental concentration, there is a further hindrance caused by his imperfect development. The enormous increase of human knowledge and power, in specialized thoroughness as well as in extent, necessarily leads to individual activities being limited more and more to well-defined departments. Human labour is organized and co-ordinated so that specialization may enable individuals to make the highest and most effective possible contribution. The results obtained are amazing, but the spiritual significance of the work for the worker suffers. There is no call upon the whole man, only upon some of his faculties, and this has a reflex effect upon his nature as a whole. The faculties which build up personality and are called out by comprehensive and varied tasks are ousted by the less comprehensive ones, which from this point of view are, in the [pg 022] general sense of the word, less spiritual. The artisan of to-day does not understand his trade as a whole in the way in which his predecessor did. He no longer learns, like the latter, to work the wood or the metal through all the stages of manufacture; many of these stages have already been carried out by men and machines before the material comes into his hands. Consequently his reflectiveness, his imagination, and his skill are no longer called out by ever varying difficulties in the work, and his creative and artistic powers are atrophied. In place of the normal self-consciousness which is promoted by work into the doing of which he must put his whole power of thought and his whole personality, there comes a self-satisfaction which is content with a fragmentary ability which, it may be admitted, is perfect, and this self-satisfaction is persuaded by its perfection in mastering details to overlook its imperfection in dealing with the whole.

In all professions, most clearly perhaps in the pursuit of science, we can recognize the spiritual danger with which specialization threatens not only individuals, but the spiritual life of the community. It is already noticeable, too, that education is carried on now by teachers who have not a wide enough outlook to make their scholars understand the interconnection of the individual sciences, and [pg 023] to be able to give them a mental horizon as wide as it should be.

Then, as if specialization and the organization of work, where it is unavoidable, were not already injurious enough to the soul of the modern man, it is pursued and built up where it could be dispensed with. In administration, in education, and in every kind of calling the natural sphere of activity is narrowed as far as possible by rules and superintendence. How much less free in many countries is the elementary school teacher of to-day compared with what he was once! How lifeless and impersonal has his teaching become as a result of all these limitations!

Thus through our methods of work we have suffered loss spiritually and as individuals just in proportion as the material output of our collective activity has increased. Here, too, is an illustration of that tragic law which says that every gain brings with it, somehow or other, a corresponding loss.

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But man to-day is in danger not only through his lack of freedom, of the power of mental concentration, and of the opportunity for all-round development: he is in danger of losing his humanity.

The normal attitude of man to man is made very [pg 024] difficult for us. Owing to the hurry in which we live, to the increased facilities for intercourse, and to the necessity for living and working with many others in an overcrowded locality, we meet each other continually, and in the most varied relations, as strangers. Our circumstances do not allow us to deal with each other as man to man, for the limitations placed upon the activities of the natural man are so general and so unbroken that we get accustomed to them, and no longer feel our mechanical, impersonal intercourse to be something that is unnatural. We no longer feel uncomfortable that in such a number of situations we can no longer be men among men, and at last we give up trying to be so, even when it would be possible and proper.

In this respect, too, the soul of the townsman is influenced most unfavourably by his circumstances, and that influence, in its turn, works most unfavourably on the mentality of society.

Thus we tend to forget our relationship with our fellows, and are on the path towards inhumanity. Wherever there is lost the consciousness that every man is an object of concern for us just because he is man, civilization and morals are shaken, and the advance to fully developed inhumanity is only a question of time.

As a matter of fact, the most utterly inhuman [pg 025] thoughts have been current among us for two generations past in all the ugly clearness of language and with the authority of logical principles. There has been created a social mentality which discourages humanity in individuals. The courtesy produced by natural feeling disappears, and in its place comes a behaviour which shows entire indifference, even though it is decked out more or less thoroughly in a code of manners. The standoffishness and want of sympathy which are shown so clearly in every way to strangers are no longer felt as being really rudeness, but pass for the behaviour of the man of the world. Our society has also ceased to allow to all men, as such, a human value and a human dignity; many sections of the human race have become merely raw material and property in human form. We have talked for decades with ever increasing light-mindedness about war and conquest, as if these were merely operations on a chess-board; how was this possible save as the result of a tone of mind which no longer pictured to itself the fate of individuals, but thought of them only as figures or objects belonging to the material world? When the war broke out the inhumanity within us had a free course. And what an amount of insulting stuff, some decently veiled, some openly coarse, about the coloured races, has made its appearance during the last decades, and passed for truth and [pg 026] reason, in our colonial literature and our parliaments, and so become an element in general public opinion! Twenty years ago there was a discussion in one of our Continental parliaments about some deported negroes who had been allowed to die of hunger and thirst; and there was no protest or comment when, in a statement from the tribune, it was said that they "had been lost" ("_eingegangen_" or "_crêvé_"), as though it were a question of cattle!

In the education and the school books of to-day the duty of humanity is relegated to an obscure corner, as though it were no longer true that it is the first thing necessary in the training of personality, and as if it were not a matter of great importance to maintain it as a strong influence in our human race against the influence of outer circumstances. It has not been so always. There was a time when it was a ruling influence not only in schools, but in literature, even down to the book of adventures. Defoe's hero, Robinson Crusoe, is continually reflecting on the subject of humane conduct, and he feels himself so responsible for loyalty to this duty that when defending himself he is continually thinking how he can sacrifice the smallest number of human lives; he is so faithful, indeed, to this duty of humanity, that the story of his adventures acquires thereby quite a peculiar character. Is [pg 027] there among works of this kind to-day a single one in which we shall find anything like it?

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Another hindrance to civilization to-day is the over-organization of our public life.

While it is certain that a properly ordered environment is the condition and, at the same time, the result of civilization, it is also undeniable that, after a certain point has been reached, external organization is developed at the expense of spiritual life. Personality and ideas are then subordinated to institutions, when it is really these which ought to influence the latter and keep them inwardly alive.

If a comprehensive organization is established in any department of social life, the results are at first magnificent, but after a time they fall off. It is the already existing resources which are realized at the start, but later on the destructive influence of such organization on what is living and original is clearly seen in its natural results, and the more consistently the organization is enlarged, the more strongly its effect is felt in the repression of creative and spiritual activity. There are modern States which cannot recover either economically or spiritually from the paralysing effects of a concentration which dates from a very early period of their history.

[pg 028]

The conversion of a wood into a park and its maintenance as such may be a step towards carrying out several different objects, but it is all over then with the rich vegetation which would assure its future condition in nature's own way.

Political, religious and economic associations aim to-day at forming themselves in such a way as will combine the greatest possible inner cohesion with the highest possible degree of external activity. Constitution, discipline, and everything that belongs to administration are brought to a perfection hitherto unknown. They attain their object, but just in proportion as they do so these centres of activity cease to work as living organizations, and come more and more to resemble perfected machines. Their inner life loses in richness and variety because the personalities of which they are composed must needs decay in character.

Our whole spiritual life nowadays has its course within organizations. From childhood up the man of to-day has his mind so full of the thought of discipline that he loses the sense of his own individuality and can only see himself as thinking in the spirit of some group or other of his fellows. A thorough discussion between one idea and another or between one man and another, such as constituted the greatness of the eighteenth century, is never met [pg 029] with now. But at that time fear of public opinion was a thing unknown. All ideas had then to justify themselves to the individual reason. To-day it is the rule—and no one questions it—always to take into account the views which prevail in organized society. The individual starts by taking it for granted that both for himself and his neighbours there are certain views already established which they cannot hope to alter, views which are determined by nationality, creed, political party, social position, and other elements in one's surroundings. These views are protected by a kind of taboo, and are not only kept sacred from criticism, but are not a legitimate subject of conversation. This kind of intercourse, in which we mutually abjure our natural quality as thinking beings, is euphemistically described as respect for other people's convictions, as if there could be any convictions at all where there is no thought.

The modern man is lost in the mass in a way which is without precedent in history, and this is perhaps the most characteristic trait in him. His diminished concern about his own nature makes him as it is susceptible, to an extent that is almost pathological, to the views which society and its organs of expression have put, ready made, into circulation. Since, over and above this, society, [pg 030] with its well-constructed organization, has become a power of as yet unknown strength in the spiritual life, man's want of independence in the face of it has become so serious that he is almost ceasing to claim a spiritual existence of his own. He is like a rubber ball which has lost its elasticity, and preserves indefinitely every impression that is made upon it. He is under the thumb of the mass, and he draws from it the opinions on which he lives, whether the question at issue is national or political or one of his own belief or unbelief.

Yet this abnormal subjection to external influences does not strike him as being a weakness. He looks upon it as an achievement, and in his unlimited spiritual devotion to the interests of the community he thinks he is preserving the greatness of the modern man. He intentionally exaggerates our natural social instincts into something fantastically great.

It is just because we thus renounce the indefeasible rights of the individual that our race can neither produce new ideas nor make current ones serviceable for new objects; its only experience is that prevailing ideas obtain more and more authority, take on a more and more one-sided development, and live on till they have produced their last and most dangerous consequences.

Thus we have entered on a new mediæval period. [pg 031] The general determination of society has put freedom of thought out of fashion, because the majority renounce the privilege of thinking as free personalities, and let themselves be guided in everything by those who belong to the various groups and cliques.

Spiritual freedom, then, we shall recover only when the majority of individuals become once more spiritually independent and self-reliant, and discover their natural and proper relation to those organizations in which their souls have been entangled. But liberation from the Middle Ages of to-day will be a much more difficult process than that which freed the peoples of Europe from the first Middle Ages. The struggle then was against external authority established in the course of history. To-day the task is to get the mass of individuals to work themselves out of the condition of spiritual weakness and dependence to which they have brought themselves. Could there be a harder task?

Moreover, no one as yet clearly perceives what a condition of spiritual poverty is ours to-day. Every year the spread of opinions which have no thought behind them is carried further by the masses, and the methods of this process have been so perfected, and have met with such a ready welcome, that our [pg 032] confidence in being able to raise to the dignity of public opinion the silliest of statements, wherever it seems necessary to get them currently accepted, has no need to justify itself before acting.

During the war the control of thought was made complete. Propaganda definitely took the place of truth.

With independence of thought thrown overboard, we have, as was inevitable, lost our faith in truth. Our spiritual life is disorganized, for the over-organization of our external environment leads to the organization of our absence of thought.

Not only in the intellectual sphere, but in the moral also, the relation between the individual and the community has been upset. With the surrender of his own personal opinion the modern man surrenders also his personal moral judgment.

In order that he may find good what the mass declares to be such, whether in word or deed, and may condemn what it declares to be bad, he suppresses the scruples which stir in him. He does not allow them to find utterance either with others or with himself. There are no stumbling-blocks which his feeling of unity with the herd does not enable him to surmount, and thus he loses his

judgment in that of the mass, and his own morality in theirs.

Above all, he is thus made capable of excusing [pg 033] everything that is meaningless, cruel, unjust, or bad in the behaviour of his nation. Unconsciously to themselves, the majority of the members of our barbarian civilised States give less and less time to reflection as moral personalities, so that they may not be continually coming into inner conflict with their fellows as a body, and continually having to get over things which they feel to be wrong.

Public opinion helps them by popularizing the idea that the actions of the community are not to be judged so much by the standards of morality as by those of expediency, but they suffer injury to their souls. If we find among men of to-day only too few whose human and moral sensibility is still undamaged, the chief reason is that the majority have offered up their personal morality on the altar of their country, instead of remaining at variance with the mass and acting as a force which impels the latter along the road to perfection.

Not only between the economic and the spiritual, then, but also between the mass of men and individuals, there has developed a condition of unfavourable action and reaction. In the days of rationalism and serious philosophy the individual got help and support from society through the general confidence in the victory of the rational and moral, which society never failed to acknowledge [pg 034] as something which explained and justified itself. Individuals were then carried along by the mass; we are stifled by it. The bankruptcy of the civilized State, which becomes more manifest every decade, is ruining the man of to-day. The demoralization of the individual by the mass is in full swing.

The man of to-day pursues his dark journey in a time of darkness, as one who has no freedom, no mental collectedness, no all-round development, as one who loses himself in an atmosphere of inhumanity, who surrenders his spiritual independence and his moral judgment to the organized society in which he lives, and who finds himself in every direction up against hindrances to the temper of true civilization. Of the dangerous position in which he is placed philosophy has no understanding, and therefore makes no attempt to help him. She does not even urge him to reflection on what is happening to himself.

The terrible truth that with the progress of history and the economic development of the world it is becoming not easier, but harder, to develop true civilization, has never found utterance.

[pg 035]

CHAPTER III

CIVILIZATION ESSENTIALLY ETHICAL IN CHARACTER

What is civilization? Origin of the unethical conception of civilization. Our sense of reality. Our historical sense. Nationalism. National civilization. Our misleading trust in facts and organization. The true sense for reality.

This question ought to have been pressing itself on the attention of all men who consider themselves civilized, but it is remarkable that in the world's literature generally one hardly finds that it has been put at all until to-day, and still more rarely is any answer given. It was supposed that there was no need for a definition of civilization, since we already possessed the thing itself. If the question was ever touched upon, it was considered to be sufficiently settled with references to history and the present day. But now, when events are bringing us inexorably to the consciousness that we live in a dangerous medley of civilization and barbarism, we must, whether we wish to or not, try to determine the nature of true civilization.

For a quite general definition we may say that civilization is progress, material and spiritual progress, on the part of individuals as of the mass.

[pg 036]

In what does it consist? First of all in a lessening of the strain imposed on individuals and on the mass by the struggle for existence. The establishment of as favourable conditions of living as possible for all is a demand which must be made partly for its own sake, partly with a view to the spiritual and moral perfecting of individuals, which is the ultimate object of civilization.

The struggle for existence is a double one: man has to assert himself in nature and against nature, and similarly also among his fellow-men and against them.

A diminution of the struggle is secured by strengthening the supremacy of reason over both external nature and human nature, and making it subserve as accurately as possible the ends proposed.

Civilization is then twofold in its nature: it realizes itself in the supremacy of reason, first, over the forces of nature, and, secondly, over the dispositions of men.

Which of these kinds of progress is most truly progress in civilization? The latter, though it is the least open to observation. Why? For two reasons. First, the supremacy which we secure by reason over external nature represents not unqualified progress, but a progress which brings with its advantages also disadvantages which may work in the direction of barbarism. The reason why the economic circumstances of our time endanger our civilization is to be sought for partly in the fact that we have pressed [pg 037] into our service natural forces which can be embodied in machines. But with that there must be such a supremacy of reason over the dispositions of men that they, and the nations which they form, will not use against one another the power which the control of these forces gives them, and thus plunge one another into a struggle for existence which is far more terrible than that between men in a state of nature.

A normal claim to be civilized can, then, only be reckoned as valid when it recognizes this distinction between what is essential in civilization and what is not.

Both kinds of progress can, indeed, be called spiritual in the sense that they both rest upon a spiritual activity in man, yet we may call the supremacy over natural forces material progress because in it material objects are mastered and turned to man's use. The supremacy of reason over human dispositions, on the other hand, is a spiritual achievement in another sense, in that it means the working of spirit upon spirit, _i.e._, of one section of the power of reflexion upon another section of it.

And what is meant by the supremacy of the reason over human dispositions? It means that both individuals and the mass let their willing be determined by the material and spiritual good of the whole and the individuals that compose it; that [pg 038] is to say, their actions are ethical. Ethical progress is, then, that which is truly of the essence of civilization, and has only one significance; material progress is that which is not of the essential at all, and may have a twofold effect on the development of civilization. This moral conception of civilization will strike some people as rationalistic and old-fashioned. It accords better with the spirit of our times to conceive of civilization as a natural manifestation of life in the course of human evolution, but one with most interesting complications. We are concerned, however, not with what is ingenious, but with what is true. In this case the simple is the true—the inconvenient truth with which it is our laborious task to deal.

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The attempts to distinguish between civilization as what the Germans call "Kultur" and civilization as mere material progress aim at making the world familiar with the idea of an unethical form of civilization side by side with the ethical, and at clothing the former with a word of historical meaning. But nothing in the history of the word "civilization" justifies such attempts. The word, as commonly used hitherto, means the same as the German "Kultur", viz., the development of man to a state of higher organization and a higher [pg 039] moral standard. Some languages prefer one word; others prefer the other. The German usually speaks of "Kultur", the Frenchman usually of "civilisation", but the establishment of a difference between them is justified neither philologically nor historically. We can speak of ethical and unethical "Kultur" or of ethical and unethical "civilisation", but not of "Kultur" and "civilisation".

But how did it come about that we lost the idea that the ethical has a decisive meaning and value as part of civilization?

All attempts at civilization hitherto have been a matter of processes in which the forces of progress were at work in almost every department of life. Great achievements in art, architecture, administration, economics, industry, commerce, and colonization succeeded each other with a spiritual impetus which produced a higher conception of the universe. Any ebb of the tide of civilization made itself felt in the material sphere as well as in the ethical and spiritual, earlier, as a rule, in the former than in the latter. Thus in Greek civilization there set in as early as the time of Aristotle an incomprehensible arrest of science and political achievement, whereas the ethical movement only reached its completion in the following centuries in that great work of education which was undertaken in the ancient [pg 040] world by the Stoic philosophy. In the Chinese, Indian and Jewish civilizations ability in dealing with material things was from the start, and always remained, at a lower level than the spiritual and ethical efforts of these races.

In the movement of civilization which began with the Renaissance, there were both material and spiritual-ethical forces of progress at work side by side, as though in rivalry with each other, and this continued down to the beginning of the nineteenth century. Then, however, something unprecedented happened: man's ethical energy died away, while the conquests achieved by his spirit in the material sphere increased by leaps and bounds. Thus for several decades our civilization enjoyed the great advantages of its material progress while as yet it hardly felt the consequences of the dying down of the ethical movement. People lived on in the conditions produced. By that movement without seeing clearly that their position was no longer a tenable one and preparing to face the storm that was brewing in the relations between the nations and within the nations themselves. In this way our own age, having never taken the trouble to reflect, arrived at the opinion that civilization consists primarily in scientific, technical and artistic achievements, and that it can reach its goal without ethics, or, at any rate, with a minimum of them.

[pg 041]

Public opinion bowed down before this merely external conception of civilization because it was exclusively represented by persons whose position in society and scientific culture seemed to show them to be competent to judge in matters of the spiritual life.

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What was the result of our giving up the ethical conception of civilization, and therewith all attempts to bring reasoned ethical ideals into effective relation with reality? It was that instead of using thought to produce ideals which fitted in with reality, we left reality without any ideals at all. Instead of discussing together the essential elements, such as population, State, Church, society, progress, which decide the character of our social development and that of mankind generally, we contented ourselves with starting from what is given by experience. Only forces and tendencies which were already at work were to be considered. Fundamental truths and convictions which ought to produce logical or ethical compulsion we would no longer acknowledge. We refused to believe that any ideas could be applicable to reality except those derived from experience. Thus ideals which had been knowingly and intentionally lowered dominated our spiritual life and the whole world.

[pg 042]

How we glorified our practical common-sense, which was to give us such power in dealing with the world! Yet we were behaving, really, like boys who give themselves up exultingly to the forces of nature and whizz down a hill on their toboggan without asking themselves whether they will be able to steer their vehicle successfully when they come to the next bend or the next unexpected obstacle.

It is only a conviction which is based upon reasoned ethical ideals that is capable of producing free activity, _i.e._, activity deliberately planned with a view to its object. In proportion as ideals taken from the workaday world are combined with it, reality influences reality. But then the human soul acts merely as an agent of debasing change.

Events which are to produce practical results within us are worked upon and moulded by our mentality. This mentality has a certain character, and on that character depends the nature of those value-judgments which rule our relation to facts.

Normally this character is to be found in the reasoned ideas which our reflection upon reality brings into existence. If these disappear there is not left a void in which "events in themselves" can affect us, but the control of our mentality passes now to the opinions and feelings which hitherto have been ruled and kept under by our reasoned ideas. When the virgin forest is cut down, brushwood [pg 043] springs up where the big trees were formerly. Whenever our great convictions are destroyed their place is taken by smaller ones which carry out in inferior fashion the functions of the former.

With the giving up of ethical ideals which accompanies our passion for reality our practical efficiency is not, therefore, improved, but diminished. It does not make the man of to-day a cool observer and calculator such as he supposes himself to be, for he is under the influence of opinions and emotions which are created in him by facts. All unconsciously he mixes with what is the work of his reason so much of what is emotional that the one spoils the other. Within this circle move the judgments and impulses of our society, whether we deal with the largest questions or the smallest. Individuals and nations alike, we deal indiscriminately with real and imaginary values, and it is just this confused medley of real and unreal, of sober thought and capacity for enthusiasm for the unmeaning, that makes the mentality of the modern man so puzzling and so dangerous.

Our sense of reality, then, means this, that, as a result of emotional and short-sighted calculations of advantage, we let one fact issue immediately in another, and so on indefinitely. As we are not consciously aiming at any definitely planned goal, our activity

may really be described as a kind of natural happening.

[pg 044]

We react to facts in the most irrational way. Without plan or foundations we build our future into the circumstances of the time and leave it exposed to the destructive effects of the chaotic jostling that goes on amongst them. “Firm ground at last”! we cry, and sink helpless in the stream of events.

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The blindness with which we endure this fate is made worse by our belief in our historical sense, which, in this connection, is nothing else than our sense of reality prolonged backwards. We believe ourselves to be a critical generation which, thanks to its thorough knowledge of the past, is in a position to understand the direction which events are destined to take from the present to the future. We add to the ideals which have been taken from existing reality others which we borrow from history.

The achievements of historical science reached by the nineteenth century do, indeed, deserve our admiration, but it is another question whether our generation, for all its possession of an historical science, possesses a true historical sense.

Historical sense, in the full meaning of the term, implies a critical objectivity in the face of far-off and recent events alike. To keep this faculty free from the bias of opinions and interests when we are [pg 045] estimating facts is a power which even our historians do not possess. As long as they are dealing with a period so remote that it has no bearing on the present they are critical so far as the views of the school to which they belong allow it. But if the past stands in any real connection with “to-day”, we can perceive at once in their estimate the influence of their particular standpoint, rational, religious, social or economic.

It is significant that while during the last few decades the learning of our historians has, no doubt, increased, their critical objectivity has not. Previous investigators kept this ideal before their eyes in much greater purity than have those of to-day; we have gone so far that we no longer seriously make the demand that in scientific dealings with the past there shall be a suppression of all prejudices which spring from nationality or creed. It is quite common nowadays to see the greatest learning bound up with the strongest bias. In our historical literature the highest positions are occupied by works written with propagandist aims.

So little educative influence has science had on our historians that they have often espoused as passionately as anyone the opinions of their own people instead of calling the latter to a thoughtful estimate of the facts, as was their duty to their profession; they have remained nothing but men [pg 046] of learning. They have not even started on the task for which they entered the service of civilization, and the hopes of civilization, which in the middle of the nineteenth century rested on the rise of a science of history, have been as little fulfilled as those which were bound up with the demand for national States and democratic forms of government.

The generation that has been brought up by teachers such as these has naturally not much idea of an elevated or active conception of events. Accurately viewed, its characteristic feature is not so much that we understand our past better than earlier generations understood theirs, but rather that we attribute to the past an extraordinarily increased meaning for the present. Now and again we actually substitute it for the latter. It is not enough for us that what has been is present in its results in what now is; we want to have it always with us, and to feel ourselves determined by it.

In this effort to be continually experiencing our historical process of becoming, and to acknowledge it, we replace our normal relation to the past by an artificial one, and wishing to find within the past the whole of our present, we misuse it in order to deduce from it, and to legitimize by an appeal to it, our claims, our opinions, our feelings and our passions. Under the very eyes of our historical learning there springs up a manufactured history for popular use, [pg 047] in which the current national and confessional ideas are unreservedly approved and upheld, and our school history books become regular culture beds of historical lies.

The misuse of history is a necessity for us. The ideas and dispositions which rule us cannot be justified by reason; nothing is left for us but to give them foundations in history.

It is significant that we have no real interest in what is valuable in the past. Its great spiritual achievements are mechanically registered, but we do not let ourselves be touched by them. Still less do we accept them as a heritage; nothing has any value for us except what can be squared with our plans, passions, feelings, and æsthetic moods of to-day. With these we live ourselves by lies into the past, and then assert with unshaken assurance that we have our roots in it.

This is the character of the reverence we pay to history. Blinded by what we consider or declare to be past and done with, we lose all sense for what is to happen, so that of nothing can we say: "It is finished," nothing now gets accomplished. Again and again we let what is past rise up artificially in what is present, and endow bygone facts with a persistence of being which makes wholly impossible the normal development of our peoples. Just as our sense of reality makes us lose ourselves in [pg 048] present-day events, so does our historical compel us to do the same in those of the past.

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From these two things, our sense of reality and our historical sense, is born the nationalism to which we must refer the external catastrophe in which the decadence of our civilization finds its completion.

What is nationalism? It is an ignoble patriotism, exaggerated till it has lost all meaning, which bears the same relation to the noble and healthy kind as the fixed idea of an imbecile does to normal conviction.

How does it develop among us?

About the beginning of the nineteenth century the course of thought gave the national State its rightful position, starting for this from the axiom that it, as a natural and homogeneous organism, was better calculated than any other to make the ideal of the civilized State a working reality. In Fichte's addresses to the German nation the nation-State is summoned to the bar of the moral reason and learns that it has to submit in all things to the latter. It gives the necessary promise and straightway receives a commission to bring the civilized State into existence. It is given emphatically to understand that it must recognize as its highest task the [pg 049] continuous and steady development of the purely human element in the nation's life. It is to seek greatness by representing the ideas which can bring healing to the nations. Its citizens are urged to show their membership of it not through the lower, but through the higher, patriotism, that is, not to overvalue its external greatness and power, but to be careful to take for their aim "the unfolding of what is eternal and Godlike in the world," and to see that their objects coincide with the highest aims of humanity. Thus national feeling is placed under the guardianship of reason, morality and civilization. The cult of patriotism as such is to be considered as barbarism; it does, indeed, announce itself to be such by the purposeless wars which it necessarily brings in its train.

In this way the idea of nationality was raised to the level of a valuable ideal of civilization. When civilization began to decline, its other ideals all fell also, but the idea of nationality maintained itself because it had transferred itself to the sphere of reality. It incorporated henceforward all that remained of civilization, and became the ideal which summed up all others. Here, then, we have the explanation of the mentality of our age, which concentrates all the enthusiasm of which it is capable on the idea of nationality, and believes itself to possess in that all moral and spiritual good things.

[pg 050]

But with the decay of civilization the character of the idea of nationality changed. The guardianship exercised over it by the other moral ideals to which it had hitherto been subordinate now ceased, since these were themselves on trial, and the nationalist idea began a career of independence. It asserted, of course, that it was working in the service of civilization, but it was, in truth, only an idea of reality with a halo of civilization round it, and it was guided by no ethical ideals, but only by the instincts which deal with reality.

That reason and morality shall not be allowed to contribute a word to the formation of nationalist ideas and aspirations is demanded by the mass of men to-day as a sparing of their holiest feelings.

If in earlier times the decay of civilization did not produce any such confusion in the sentiments of the various nations, this was because the idea of nationality had not then been raised in the same way to be the ideal of civilization. It was, therefore, impossible that it should insinuate itself into the place of the true ideals of civilization, and through abnormal nationalist conceptions and dispositions bring into active existence an elaborate system of uncivilization.

That in nationalism we have to do not so much with things as with the unhealthy way in which they [pg 051] are dealt with in the imagination of the crowd, is clear from its whole behaviour. It claims to be following a policy of practical results (Realpolitik); in reality it by no means represents the uncompromisingly businesslike view of all the questions of home and foreign policy, but side by side with its egoism displays a certain amount of enthusiasm. Its practical policy is an over-valuation of certain questions of territorial economic interests, an over-valuation which has been elevated to a dogma and idealized, and is now supported by popular sentiment. It fights for its demands without having established any properly thought-out calculation of their real value. In

order to be able to dispute the possession of millions of value, the modern State loaded itself with armaments costing hundreds of millions. Meaning to care for the protection and extension of its trade, it loaded the latter with imposts which imperilled its power of competing with its rivals much more than did any of the measures taken by those rivals.

Its practical politics were, therefore, in truth impracticable politics, because they allowed popular sentiment to come in, and thereby made the simplest questions insoluble. This style of politics put economic interests in the shop window, while it kept in the warehouse the ideas about greatness and conquest which belong to nationalism.

[pg 052]

Every civilized State, in order to increase its power, gathered allies wherever it could. Thus half-civilized and uncivilized races were summoned by civilized ones to fight against the civilized neighbours of the latter, and these helpers were not content with the subordinate _rôle_ which had been assigned to them. They acquired more and more influence on the course of events, till they were at last in a position to decide when the civilized nations of Europe should begin to fight each other about them. Thus has Nemesis come upon us for abandoning our wishes and betraying to the uncivilized world all that we still possessed of things that were of universal value.

It was significant of the unhealthy character of nationalism's "practical" politics that it tried in every possible way to deck itself out with a tinsel imitation of idealism. The struggle for power became one for right and civilization; the alliances for the promotion of their selfish interests which various nations made with one another against all the rest were made to appear to be friendships and spiritual affinities. As such they were dated back into the past, even though history had a great deal more to say about hereditary quarrels than about spiritual relationships.

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[pg 053]

Finally, nationalism was not content with putting aside, in the sphere of politics generally, all attempts to bring into existence a really civilized humanity; it distorted the very idea of civilization itself and talked of national civilization.

Once there was what was known just simply as civilization, and every civilized nation strove to possess it in its purest and most fully developed form. In this respect nationality had in the idea of civilization at that time something much more original and less spoilt than it has in the same idea to-day. If, in spite of this, there was no impulse among the nations to separate the spiritual life of each from that of its neighbours, we have a proof that nationality is not in itself the strong element in the people that demanded this. Such a claim as is made to-day to have a _national civilization_ is an unhealthy phenomenon. It presupposes that the civilized peoples of to-day have lost their healthy nature, and no longer follow instincts, but theories. They percuss and sound their souls to such an extent that these are no longer capable of any natural action. They analyse and describe them so continuously that in thinking of what they ought to be they forget what they actually are. Questions of spiritual differences between races are discussed so subtly, and with such obstinacy and dogmatism, that the talk works like an obsession, and the [pg 054] peculiarities that are said to exist make their appearance like imaginary diseases.

In every department of life more and more effort is devoted to making clearly visible in the results which follow from them the emotions, the ideas, and the reasonings of the mass of the people. Any peculiarity preserved and fostered in this way shows that its natural counterpart has perished. The individual element in the personality of a people no longer, as something unconscious or half conscious, plays with varying lights on the totality of the nation's spiritual life. It becomes an artifice, a fashion, a self-advertisement, a mania. There is bred in the nation a mass of thought, the serious results of which in every department become more evident year by year. The spiritual life of some of the leading civilized nations has already, in comparison with earlier days, taken on a monotonous tone such as makes an observer feel anxious.

The unnatural character of this development shows itself not only in its results, but in the part which it allows to be played by conceit, self-importance, and self-deception. Anything valuable in a personality or a successful undertaking is attributed to some special excellence in the national character. Foreign soil is assumed to be incapable of producing the same or anything similar, and in most countries this vanity has grown to such a [pg 055] height that the greatest follies are no longer beyond its reach.

It goes without saying that there follows a serious decline in the spiritual element in the national civilization. The spirituality is, moreover, only a kind of disguise; it has in reality an avowedly materialist character. It is a distillation from all the external

achievements of the nation in question and appears in partnership with its economic and political demands. While alleged to be grounded in the national peculiarities, nationalist civilization will not, as we should normally expect, remain limited to the nation itself; it feels called upon to impose itself upon others and make them happy! Modern nations seek markets for their civilization, as they do for their manufactures!

National civilization, therefore, is matter for propaganda and for export, and the necessary publicity is secured by liberal expenditure. The necessary phrases can be obtained ready-made and need only be strung together. Thus the world has inflicted on it a competition between national civilizations, and between these civilization itself comes off badly.

The nations of Europe entered the Middle Ages side by side as the heirs of the Greco-Roman world, and lived side by side with the freest mutual intercourse through the Renaissance, the period of the [pg 056] Illuminati, and of the philosophy of more recent times. But we no longer believe that they, with their offshoots in the other continents, form an indivisible unit of civilization. If, however, in this latest age, the differences in their spiritual life have begun to stand out more distinctly, the cause of it is that the level of civilization has sunk. When the tide ebbs, shallows which separate bodies of deep water become visible; while the tide is flowing they are out of sight.

How closely the nations which form the great body of civilized humanity are still interrelated spiritually is shown by the fact that they have all side by side suffered the same decadence.

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With our sense of reality is bound up, further, the false confidence which we have in facts. We live in an atmosphere of optimism, as if the contradictions which show themselves in the world arranged themselves automatically so as to promote well-thought-out progress, and reconciled themselves in syntheses in which the valuable parts of the thesis and the antithesis coalesced.

In justification of this optimism appeal is made, both rightly and wrongly, to Hegel. It cannot be denied that he is the spiritual father of our sense of reality; he is the first thinker who tried to be just [pg 057] to things as they exist. We have been trained by him to realize the method of progress in thesis, antithesis, and synthesis as they show themselves in the course of events. But his optimism was not a simple optimism about facts, as ours is. He lived still in the spiritual world of rationalism, and believed in the power of ethical ideas worked out by reason; that was why he believed also in the certainty of uninterrupted spiritual progress. And it was because this was something upon which he could rely that he undertook to show how it was to be seen in the successive phases of events, and at the same time how it made itself a reality in the stream of outward facts. By emphasizing, however, the progressive purpose, which he finds immanent in the course of events, so strongly that it is possible to forget the ethical-spiritual presuppositions of his belief in progress, he is preparing the way for the despiritualized optimism about reality which has for decades been misleading us. Between the facts themselves there is nothing but an endless series of contradictions.The fresh mediating fact in which they counteract each other so as to make progress possible they cannot of themselves produce. This fact can only assert itself if the contradictions resolve themselves in a reasoned view in which there are ethical ideas about the condition of things which [pg 058] it is sought to realize. These are the formative principles for the new element which is to arise out of the contradictories, and it is only in this reasoned ethical view that the latter cease to be blind, leading to no issue.

It was because we assumed the existence of principles, of progress, in the facts, that we viewed the advance of history, in which our future was being prepared, as progress in civilization, even though evolution condemned our optimism. And even now, when facts of the most terrible character cry out loudly against it, we shrink from giving up our creed. It no longer, indeed, gives us any real enlightenment, but the alternative, which bases optimism on belief in the ethical spirit, means such a revolution in our mode of thought that we find it difficult to take it into consideration.

With our reliance upon facts is bound up our reliance on organizations. The activities and the aims of our time are penetrated by a kind of obsession that if we could only succeed in perfecting or reforming in one direction or another the institutions of our public and social life, the progress demanded by civilization would begin of itself. We are, indeed, far enough from unanimity as to the plan needed for the reform of our arrangements: one section sketches out an anti-democratic plan; [pg 059] others believe that our mistake lies in the fact that democratic principles have not yet been applied consistently; others, again, see salvation only in a Socialist or Communist organization of society. But all agree in attributing our present condition, with its absence of true civilization, to a failure of our institutions; all look for the attainment of such civilization to a new organization of society; all unite in thinking that with new institutions there would arise a new spirit.

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In this terrible confusion are entangled not only the unreflecting masses, but also many of the most earnest amongst us. The materialism of our age has reversed the relation between the spiritual and the actual. It believes that something with spiritual value can result from the working of facts. It was even expected that the war would bring us a spiritual regeneration! In reality, however, the relation between them works in the opposite direction. A spiritual element of real value can, if it is present, influence the moulding of reality so as to bring about desired results, and can thus produce facts in support of itself. All institutions and organizations have only a relative significance. With the most diverse social and political [pg 060] arrangements, the various civilized nations have all sunk to the same depth of barbarism. What we have experienced, and are still experiencing, must surely convince us that the spirit is everything and that institutions count for very little. Our institutions are a failure because the spirit of barbarism is at work in them. The best planned improvements in the organization of our society (though we are quite right in trying to secure them) cannot help us at all until we become at the same time capable of imparting a new spirit to our age.

The difficult problems with which we have to deal, even those which lie entirely in the material and economic sphere, are in the last resort only to be solved by an inner change of character. The wisest reforms in organization can only carry them a little nearer solution, never to the goal. The only conceivable way of bringing about a reconstruction of our world on new lines is first of all to become new men ourselves under the old circumstances, and then as a society in a new frame of mind so to smooth out the opposition between nations that a condition of true civilization may again become possible. Everything else is more or less wasted labour, because we are thereby building not on the spirit, but on what is merely external.

In the sphere of human events which decide the future of mankind reality consists in an inner [pg 061] conviction, not in given outward facts. Firm ground for our feet we find in reasoned ethical ideals. Are we going to draw from the spirit strength to create new conditions and turn our faces again to civilization, or are we going to continue to draw our spirit from our surroundings and go down with it to ruin? That is the fateful question with which we are confronted.

The true sense for reality is that insight which tells us that only through ethical ideas about things can we arrive at a normal relation to reality. Only so can man and society win all the power over events that they are able to use. Without that power we are, whatever we may choose to do, delivered over into bondage to them.

What is going on to-day between nations and within them throws a glaring illumination upon this truth. The history of our time is characterized by a lack of reason which has no parallel in the past. Future historians will one day analyse this history in detail, and test by means of it their learning and their freedom from prejudice. But for all future times there will be, as there is for to-day, only one explanation, viz., that we sought to live and to carry on with a civilization which had no ethical principle behind it.

[pg 062]

CHAPTER IV

THE WAY TO THE RESTORATION OF CIVILIZATION

Civilization-ideals have become powerless. Evolution and decay in the history of civilization. The reform of institutions and the reform of convictions. The individual as the sole agent of the restoration of civilization. The difficulties which beset the restoration of civilization.

The ethical conception of civilization, then, is the only one that can be justified.

But where is the road that can bring us back from barbarism to civilization? Is there such a road at all?

The unethical conception of civilization answers: “No.” To it all symptoms of decay are symptoms of old age, and civilization, just like any other natural process of growth, must after a certain period of time reach its final end. There is nothing, therefore, for us to do, so it says, but to take the causes of this as quite natural, and do our best at any rate to find interesting the unedifying phenomena of its senility, which testify to the gradual loss of the ethical character of civilization.

In the thinking then which surrenders itself to our sense of reality, optimism and pessimism are inextricably intermingled. If our optimism about [pg 063] reality is proved untenable, the optimism which thinks that continuous progress evolves itself among the facts as such, then the spirit which from above contemplates and analyses the situation turns without much concern to the mild pessimistic supposition that civilization has reached its Indian summer.

The ethical spirit cannot join in this little game of "Optimism or pessimism?" It sees the symptoms of decay as what they really are, viz., something terrible. It asks itself with a shudder what will become of the world if this dying process really goes on unchecked. The condition of civilization is a source of pain to it, for civilization is not an object which it is interesting to analyse, but the hope on which its thoughts fly out over the future existence of the race. Belief in the possibility of a renewal of civilization is an actual part of its life; that is why it can no longer quiet itself with what contents the sense of reality as it hovers between optimism and pessimism.

Those who regard the decay of civilization as something quite normal and natural console themselves with the thought that it is not civilization, but a civilization, which is falling a prey to dissolution; that there will be a new age and a new race in which there will blossom a new civilization. But that is a mistake. The earth no longer has in reserve, as it had once, gifted peoples as yet unused, [pg 064] who can relieve us and take our place in some distant future as leaders of the spiritual life. We already know all those which the earth has to dispose of. There is not one among them which is not already taking such a part in our civilization that its spiritual fate is determined by our own. All of them, the gifted and the ungifted, the distant and the near, have felt the influence of those forces of barbarism which are at work among us. All of them are, like ourselves, diseased, and only as we recover can they recover.

It is not the civilization of a race, but that of mankind, present and future alike, that we must give up as lost, if belief in a rebirth of our civilization is a vain thing.

But it need not be so given up. If the ethical is the essential element in civilization, decadence changes into renaissance as soon as ethical activities are set to work again in our convictions and in the ideas which we undertake to stamp upon reality. The attempt to bring this about is well worth making, and it should be world-wide.

It is true that the difficulties that have to be reckoned with in this undertaking are so great that only the strongest faith in the power of the ethical spirit will let us venture on it.

First among them towers up the inability of our generation to understand what is and must be. [pg 065] The men of the Renaissance and the Illuminati of the eighteenth century drew courage to desire the renewal of the world through ideas from their conviction of the absolute indefensibility of the material and spiritual conditions under which they lived. Unless with us, too, the many come to some such conviction, we must continue incapable of taking in hand this work, in which we must imitate them. But the many obstinately refuse to see things as they are, and hold with all their might to the most optimistic view of them that is possible. For this power, however, of idealizing with continually lowering ideals the reality which is felt to be ever less and less satisfying, pessimism also is partly responsible. Our generation, though so proud of its many achievements, no longer believes in the one thing which is all-essential: the spiritual advance of mankind. Having given up the expectation of this, it can put up with the present age without feeling such suffering as would compel it, for very pain, to long for a new one. What a task it will be to break the fetters of unthinking optimism and unthinking pessimism which hold us prisoners, and so to do what will pave the way for the renewal of civilization!

A second difficulty besetting the work which lies before us is that it is a piece of reconstruction. The ideas of civilization which our age needs are not new [pg 066] and strange to it. They have been in the possession of mankind already, and are to be found in many an antiquated formula. We have fundamentally nothing else to do than to restore to them the respect in which they were once held, and again regard them seriously as we bring them into relation with the reality which lies before us for treatment.

To make what is used up usable—is there a harder task? "It is an impossible one," says history. "Never hitherto have worn-out ideas risen to new power among the peoples who have worn them out. Their disappearance has always been a final one."

That is true. In the history of civilization we find nothing but discouragement for our task. Anyone who finds history speaking optimistically lends her a language which is not her own.

Yet from the history of the past we can infer only what has been, not what will be. Even if it proves that no single people has ever lived through the decay of its civilization and a rebirth of it, we know at once that this, which has never happened yet, must happen with us, and therefore we cannot be content to say that the reasoned ethical ideas on which civilization rests get worn out in the course of history, and console ourselves with the reflection that this is exactly in accordance with the ordinary processes of nature. We require to know why it has [pg 067] so happened hitherto, and to draw an explanation, not from the analogy of nature, but from the laws of spiritual life. We want to get into our hands the key of the secret, so that we may with it unlock the new age, the age in which the worn out becomes again unworn and the spiritual and ethical can no longer get worn out. We must study the history of

civilization otherwise than as our predecessors did, or we shall be finally lost.

Why do not thoughts which contribute to civilization retain the convincing power which they once had, and which they deserve on account of their content? Why do they lose the evidential force of their moral and rational character? Why do traditional truths cease to be realities and pass from mouth to mouth as mere phrases?

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Is this an unavoidable fate, or is the well drying up because our thinking did not go down to the permanent level of the water?

Moreover, it is not merely that the past survives among us as something valueless; it may cast a poisonous shade over us. There are thoughts on which we have never let our minds work directly because we found them ready formulated in history. Ideas which we have inherited do not let the truth [pg 068] which is in them come out into active service, but show it through a kind of dead mask. The worn out achievements which pass over from a decadent civilization into the current of a new age often become like rejected products of metabolism, and act as poisons.

Granted that the Teutonic nations received a powerful stimulus to civilization at the Renaissance by reverting to the ideas of Greco-Roman thinkers, not less true is it that for many centuries they had been kept by that same Greco-Roman civilization in a condition of spiritual dependence which was wholly in contradiction to their native character. They took over from it decadent ideas which were for a long time a hindrance to their normal spiritual life, and thence came that strange mixture of strength and weakness which is the chief characteristic of the Middle Ages. The dangerous elements in the Greco-Roman civilization of the past still show themselves in our spiritual life. It is because Oriental and Greek conceptions which have had their day are still current among us that we bleed to death over problems which otherwise would have no existence for us. How much we suffer from the one fact that to-day and for several centuries past our thoughts about religion have been under the hereditary foreign domination of Jewish transcendentalism and Greek metaphysics, and, instead of [pg 069] being able to express themselves naturally, have suffered continual distortion!

Because ideas get worn out in this way, and in this condition hinder the thinking of later generations, there is no continuity in the spiritual progress of mankind, but only a confused succession of ups and downs. The threads get broken, or knotted, or lost, or when tied up again get tied wrongly. Hitherto it has been thought possible to interpret this up-and-down movement optimistically because it was universally held that the Renaissance and the age of the Illuminati were quite natural successors of the Greco-Roman civilization, and it was assumed further that, as a permanent result of this, renewed civilizations would spring up in the place of exhausted ones, and thus continual progress be assured. But this generalization cannot justifiably be drawn from such observations. It was because new peoples came on the scene, who had been only superficially touched by the decadent civilizations and now produced others of their own, that it was possible to see this succession of ups and downs ending in an ascent. As a matter of fact, however, our newer civilization was not in any organic connection with the Greco-Roman, even if it did take its first steps with the help of the crutches which the latter provided; it may be [pg 070] described more truly as the reaction of a healthy spirit against the worn out ideas which were thus offered to it. The essential element in the process was the contact of what was worn out with the fresh thought of young peoples.

To-day, however, all our thought is losing its power in its contact with the worn-out ideas of our expiring civilization, or—in the case of the Hindus and the Chinese—of our own and other expiring civilizations. The up-and-down movement will end, therefore, not in slow progress, but in unbroken descent—unless we can succeed in giving the worn out ideas a renewal of their youth.

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Another great difficulty in the way of the regeneration of our civilization lies in the fact that it must be an internal process, and not an external as well, and that, therefore, there is no place for healthy co-operation between the material and the spiritual. From the Renaissance to the middle of the nineteenth century the men who carried on the work of civilization could expect help towards spiritual progress from achievements in the sphere of external organization. Demands in each of these spheres stood side by side in their programme and were pushed on simultaneously. They were convinced that while working to transform [pg 071] the institutions of public life they were producing results which would call forth the development of the new spiritual life. Success in one sphere strengthened at once the hopes and the energies that were at work in the other. They laboured for the progressive democratization of the State with the idea of thereby spreading through the world the rule of grace and justice.

We, who have lived to see the spiritual bankruptcy of all the institutions which they created, can no longer work in this way simultaneously at the reform of institutions and the revival of the spiritual element. The help which such co-operation would give is denied us. We cannot even reckon any longer on the old co-operation between knowledge and thought. Once these two were allies. The latter fought for freedom and in so doing made a road for the former, and, on the other hand, all the results attained by knowledge worked for the general good of the spiritual life in that the reign of law in nature was more and more clearly demonstrated, and the reign of prejudice was becoming continually more restricted. The alliance also strengthened the thought that the well-being of mankind must be based upon spiritual laws. Thus knowledge and thought joined in establishing the authority of reason and the rational tone of mind.

[pg 072]

To-day thought gets no help from science, and the latter stands facing it independent and unconcerned. The newest scientific knowledge may be allied with an entirely unreflecting view of the universe. It maintains that it is concerned only with the establishment of individual facts, since it is only by means of these that scientific knowledge can maintain its practical character; the co-ordination of the different branches of knowledge and the utilization of the results to form a theory of the universe are, it says, not its business. Once every man of science was also a thinker who counted for something in the general spiritual life of his generation. Our age has discovered how to divorce knowledge from thought, with the result that we have, indeed, a science which is free, but hardly any science left which reflects.

Thus we no longer have available for the renewal of our spiritual life any of the natural external helps which we used to have. We are called upon for a single kind of effort only, and have to work like men who are rebuilding the damaged foundations of a cathedral under the weight of the massive building. There is no progress in the world of phenomena to encourage us to persevere; an immense revolution has to be brought about without the aid of any collateral revolutionary activities.

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[pg 073]

Again, the renewal of civilization is hindered by the fact that it is so exclusively the individual personality which must be looked to as the agent in the new movement.

The renewal of civilization has nothing to do with movements which bear the character of experiences of the crowd; there are never anything but reactions to external happenings. But civilization can only revive when there shall come into being in a number of individuals a new tone of mind independent of the one prevalent among the crowd and in opposition to it, a tone of mind which will gradually win influence over the collective one, and in the end determine its character. It is only an ethical movement which can rescue us from the slough of barbarism, and the ethical comes into existence only in individuals.

The final decision as to what the future of a society shall be depends not on how near its organization is to perfection, but on the degrees of worthiness in its individual members. The most important, and yet the least easily determinable, element in history is the series of unobtrusive general changes which take place in the individual dispositions of the many. These are what precede and cause the happenings, and this is why it is so difficult to understand thoroughly the men and the [pg 074] events of past times. The character and worth of individuals among the mass and the way they work themselves into membership of the whole body, receiving influences from it and giving others back, we can even to-day only partially and uncertainly understand.

One thing, however, is clear. Where the collective body works more strongly on the individual than the latter does upon it, the result is deterioration, because the noble element on which everything depends, viz., the spiritual and moral worthiness of the individual, is thereby necessarily constricted and hampered. Decay of the spiritual and moral life then sets in, which renders society incapable of understanding and solving the problems which it has to face. Thereupon, sooner or later, it is involved in catastrophe.

That is the condition in which we are now, and that is why it is the duty of individuals to rise to a higher conception of their capabilities and undertake again the function which only the individual can perform, that of producing new spiritual-ethical ideas. If this does not come about in a multitude of cases nothing can save us.

A new public opinion must be created privately and unobtrusively. The existing one is maintained by the Press, by propaganda, by organization, and by financial and other influences which are at its [pg 075] disposal. This unnatural way of spreading ideas must be opposed by the natural one, which goes from man to man and relies solely on the truth of the thoughts and the hearer's

receptiveness for new truth. Unarmed, and following the human spirit's primitive and natural fighting method, it must attack the other, which faces it, as Goliath faced David, in the mighty armour of the age.

About the struggle which must needs ensue no historical analogy can tell us much. The past has, no doubt, seen the struggle of the free-thinking individual against the fettered spirit of a whole society, but the problem has never presented itself on the scale on which it does to-day, because the fettering of the collective spirit as it is fettered to-day by modern organizations, modern unreflectiveness, and modern popular passions, is a phenomenon without precedent in history.

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Will the man of to-day have strength to carry out what the spirit demands from him, and what the age would like to make impossible?

In the over-organized societies which in a hundred ways have him in their power, is he destined to become once more an independent personality and [pg 076] to exert influence back upon them? They will use every means to keep him in that condition of impersonality which suits them. They fear personality because the spirit and the truth, which they would like to muzzle, find in it a means of expressing themselves. And their power is, unfortunately, as great as their fear.

There is a tragic alliance between society as a whole and its economic conditions. With a grim relentlessness those conditions tend to bring up the man of to-day as a being without freedom, without self-collectedness, without independence, in short as a human being so full of deficiencies that he lacks the qualities of humanity. And they are the last things that we can change. Even if it should be granted us that the spirit should begin its work, we shall only slowly and incompletely gain power over these forces. There is, in fact, being demanded from the will that which our conditions of life refuse to allow.

And how heavy the tasks that the spirit has to take in hand! It has to create the power of understanding the truth that is really true where at present nothing is current but propagandist truth. It has to depose ignoble patriotism, and enthrone the noble kind of patriotism which aims at ends that are worthy of the whole of mankind, in circles where the hopeless issues of past and present [pg 077] political activities keep nationalist passions aglow even among those who in their hearts would fain be free from them. It has to get the fact that civilization is an interest of all men and of humanity as a whole recognized again in places where national civilization is to-day worshipped as an idol, and the notion of a humanity with a common civilization lies broken to fragments. It has to maintain our faith in the civilized State, even though our modern States, spiritually and economically ruined by the war, have no time to think about the tasks of civilization, and dare not devote their attention to anything but how to use every possible means, even those which undermine the conception of justice, to collect money with which to prolong their own existence. It has to unite us by giving us a single ideal of civilized man, and this in a world where one nation has robbed its neighbour of all faith in humanity, idealism, righteousness, reasonableness, and truthfulness, and all alike have come under the domination of powers which are plunging us ever deeper into barbarism. It has to get attention concentrated on civilization while the growing difficulty of making a living absorbs the masses more and more in material cares, and makes all other things seem to them to be mere shadows. It has to give us faith in the possibility of [pg 078] progress while the reaction of the economic on the spiritual becomes more pernicious every day and contributes to an ever growing demoralization. It has to provide us with a capacity for hope at a time when not only secular and religious institutions and associations, but the men, too, who are looked upon as leaders, continually fail us, when artists and men of learning show themselves as supporters of barbarism, and notabilities who pass for thinkers, and behave outwardly as such, are revealed, when crises come, as being nothing more than writers and members of academies.

All these hindrances stand in the path of the will to civilization. A dull despair hovers about us. How well we now understand the men of the Greco-Roman decadence, who stood before events incapable of resistance, and, leaving the world to its fate, withdrew upon their inner selves! Like them, we are bewildered by our experience of life. Like them, we hear enticing voices which say to us that the one thing which can still make life tolerable is to live for the day. We must, we are told, renounce every wish to think or hope about anything beyond our own fate. We must find rest in resignation.

The recognition that civilization is founded on some sort of theory of the universe, and can be restored only through a spiritual awakening and a will for ethical good in the mass of mankind, compels [pg 079] us to make clear to ourselves those difficulties in the way of a rebirth of civilization which ordinary reflection would overlook. But at the same time it raises us above all considerations of possibility or impossibility. If the ethical spirit provides a sufficient standing ground in the sphere of events for making civilization a reality, then we shall get civilization, provided that we return to a suitable theory of the universe and the convictions to which this properly gives birth.

The history of our decadence preaches the truth that when hope is dead the spirit becomes the deciding court of appeal, and this truth will in the future find in us a sublime and noble fulfilment.

[pg 080]

CHAPTER V

CIVILIZATION AND THEORIES OF THE UNIVERSE

The regeneration of our theory of the universe and the restoration of civilization. A reflective theory of the universe; rationalism and mysticism. The optimistic-ethical theory as a theory of civilization. The regeneration of our ideas by reflection about the meaning of life.

The greatest of all the spirit's tasks is to produce a theory of the universe (_Weltanschauung__(_*_)_), for in such a theory all the ideas, convictions and activities of an age have their roots, and it is only when we have arrived at one which is compatible with civilization that we are capable of holding the ideas and convictions which are the conditions of civilization in general.

What is meant by a theory of the universe? It is the content of the thoughts of society and the individuals which compose it about the nature and object of the world in which they live, and the position and the destiny of mankind and of individual men within it. What significance have the society in which I live and I myself in the world? What do we want to do in the world, what do we [pg 081] hope to get from it, and what is our duty to it? The answer given by the majority to these fundamental questions about existence decides what the spirit is in which they and their age live.

Is not this putting too high the value of a theory of the universe?

At present, certainly, the majority do not, as a rule, attain to any properly thought-out theory, nor do they feel the need of deriving their ideas and convictions from such a source. They are in tune, more or less, with all the tones which pervade the age in which they live.

But who are the musicians who have produced these tones? They are the personalities who have thought out theories of the universe, and drawn from them the ideas, more or less valuable, which are current amongst us to-day. In this way all thoughts, whether those of individuals or those of society, go back ultimately, in some way or other, to a theory of the universe. Every age lives in the consciousness of what has been provided for it by the thinkers under whose influence it stands.

Plato was wrong in holding that the philosophers of a State should also be its governors. Their supremacy is a different and a higher one than that which consists in taking cognizance of laws and ordinances and giving effect to official authority. [pg 082] They are the officers of the general staff who sit in the background thinking out, with more or less clearness of vision, the details of the battle which is to be fought. Those who play their part in the public eye are the subordinate officers who, for their variously sized units, convert the general directions of the staff into orders of the day: namely, that the forces will start at such and such a time, move in this or that direction, and occupy this or that point. Kant and Hegel have commanded millions who had never read a line of their writings, and who did not even know that they were obeying their orders.

Those who command, whether it be in a large or a small sphere, can only carry out what is already in the thought of the age. They do not build the instrument on which they have to play, but are merely given a seat at it. Nor do they compose the piece they have to play; it is simply put before them, and they cannot alter it; they can only reproduce it with more or less skill and success. If it is meaningless, they cannot do much to improve it, but neither, if it is good, can they damage it seriously.

To the question, then, whether it is personalities or ideas which decide the fate of an age, the answer is that the age gets its ideas from personalities. If the thinkers of a certain period produce a worthy theory of the universe, then ideas pass into currency [pg 083] which guarantee progress; if they are not capable of such production, then decadence sets in in some form or other. Every theory of the universe draws after it its own special results in history.

The fall of the Roman Empire in spite of that empire's having over it so many rulers of conspicuous ability, may be traced ultimately to the fact that ancient philosophy produced no theory of the universe with ideas which tended to that empire's preservation. With the rise of Stoicism, as the definitive answer of the philosophic thought of antiquity, the fate of the world down to the Middle Ages was decided. The idea of resignation, noble idea as it is, could not ensure progress in a world-wide empire. The efforts of its

strongest emperors were useless. The yarn with which they had to weave was rotten.

In the eighteenth century, under the rule, in most places, of insignificant rococo-sovereigns and rococo-ministers, a progressive movement began among the nations of Europe which was unique in the history of the world. Why? The thinkers of the Illuminati and of rationalism produced a worthy theory of the universe from which worthy ideas were spread among mankind.

But when history began to shape itself in accordance with these ideas, the thought which had [pg 084] produced the progress came to a halt, and we have now a generation which is squandering the precious heritage it has received from the past, and is living in a world of ruins, because it cannot complete the building which that past began. Even had our rulers and statesmen been less short-sighted than they actually were, they would not in the long run have been able to avert the catastrophe which burst upon us. Both the inner and the outer collapse of civilization were latent in the circumstances produced by the prevalent view of the universe. The rulers, small and great alike, did not [nothing but] act in accordance with the spirit of the age.

With the disappearance of the influence exerted by the _Aufklärung_, rationalism, and the serious philosophy of the early nineteenth century, the seeds were sown of the world-war to come. Then began to disappear also the ideas and convictions which would have made possible a solution on right lines of the controversies which arise between nations.

Thus the course of events brought us into a position in which we had to get along without any real theory of the universe. The collapse of philosophy and the rise and influence of scientific modes of thought made it impossible to arrive at an idealist theory which should satisfy thought. Moreover, our age is poorer in deep thinkers than perhaps any preceding one. There were a few [pg 085] strong spirits who, with varied knowledge, and with devoted efforts, offered the world some patchwork thought; there were some dazzling comets; but that was all that was granted us. Their products in the way of world theories were good enough to interest a circle of academic culture, or to delight a few believing followers, but the people as a whole were entirely untouched.

We began, therefore, to persuade ourselves that it was, after all, possible to get through without any theory of the universe. The feeling that we needed to stir ourselves up to ask questions about the world and life, and to come to a decision upon them, gradually died away. In the unreflective condition to which we had surrendered ourselves, we took, to meet the claims of our own life and the nation's life, the chance ideas provided by our feeling for reality. During more than a generation and a half we had proof enough and to spare that the theory which is the result of absence of theory is the most worthless of all, involving not only ruin to the spiritual life, but ruin universal. For where there is no general staff to think out its plan of campaign for any generation its subordinate officers lead it, as in actual warfare so in the sphere of ideas, from one profitless adventure to another.

The reconstruction of our age, then, can begin [pg 086] only with a reconstruction of a theory of the universe. There is hardly anything more urgent in its claim on us than this which seems to be so far off and abstract. Only when we have made ourselves at home again in the solid thought-building of a theory which can support a civilization, and when we take from it, all of us in co-operation, ideas which can stimulate our life and work, only then can there again arise a society which shall possess ideals with magnificent aims and be able to bring these into effective agreement with reality. It is from new ideas that we must build history anew.

For individuals as for the community, life without a theory of things is a pathological disturbance of the higher capacity for self-direction.

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What conditions must a theory of the universe fulfil to enable it to create a civilization?

First, and defined generally, it must be the product of thought. Nothing but what is born of thought and addresses itself to thought can be a spiritual power affecting the whole of mankind. Only what has been well turned over in the thought of the many, and thus recognized as truth, possesses a natural power of conviction which will work on other minds and will continue to be effective. Only where there is a constant appeal to the need [pg 087] of a reflective view of things are all man's spiritual capacities called into activity.

Our age has a kind of artistic prejudice against a reflective theory of the universe. We are still children of the Romantic movement to a greater extent than we realize. What that movement produced in opposition to the _Aufklärung_ and to rationalism seems to us valid for all ages against any theory that would found itself solely on thought. In such a theory of the universe we can see beforehand the world dominated by a barren intellectualism, convictions governed by mere utility, and a shallow optimism, which

together throw a wet blanket over all human genius and enthusiasm.

In a great deal of the opposition which it offered to rationalism the reaction of the early nineteenth century was right. Nevertheless it remains true that it despised and distorted what was, in spite of all its imperfections, the greatest and most valuable manifestation of the spiritual life of man that the world has yet seen. Down through all circles of cultured and uncultured alike there prevailed at that time a belief in thought and a reverence for truth. For that reason alone that age stands higher than any which preceded it, and much higher than our own.

At no price must the feelings and phrases of [pg 088] Romanticism be allowed to prevent our generation from forming a clear conception of what reason really is. It is no dry intellectualism which would suppress all the manifold movements of our inner life, but the totality of all the functions of our spirit in their living action and interaction. In it our intellect and our will hold that mysterious intercourse which determines the character of our spiritual being. These fundamental ideas which it produces contain all that we can feel or imagine about our destiny and that of mankind, and give our whole being its direction and its value. The enthusiasm which comes from thought has the same relation to that which rises from the cauldron of feeling as the wind which sweeps the heights has to that which eddies about between the hills. If we venture once more to seek help from the light of reason, we shall no longer keep ourselves down at the level of a generation which has ceased to be capable of enthusiasm, but shall follow the deep and noble passion inspired by great and sublime ideals. This will so fill and expand our being that that by which we now live will seem to be merely a petty kind of excitement, and will disappear.

Rationalism is more than a movement of thought which realized itself at the end of the eighteenth and the beginning of the nineteenth centuries. It is a necessary phenomenon in all normal spiritual life. [pg 089] All real progress in the world is in the last analysis produced by rationalism.

It is true that the intellectual productions of the period which we designate historically as the rationalistic are incomplete and unsatisfactory, but the principle, which was then established, of basing our views of the universe on thought and thought alone, is valid for all time. Even if the tree's earliest fruit did not ripen perfectly, the tree itself remains, nevertheless, the tree of life for the life of our spirit.

All the movements that have claimed to take the place of rationalism stand far below it in the matter of achievement. From speculative thought, from history, from feeling, from æsthetics, from science, they tried to construct a theory of the universe, grubbing at haphazard in the world around them instead of excavating scientifically. Rationalism alone chose the right place for its digging, and dug systematically, according to plan. If it found only metal of small value, that was because, with the means at its disposal, it could not go deep enough. Impoverished and ruined as we are because we sought as mere adventurers, we must make up our minds to sink another shaft in the ground where rationalism worked, and to go down through all the strata to see whether we cannot find the gold which must certainly be there.

[pg 090]

To think out to the end a theory of the universe which has been produced by thought—that is the only possible way of finding our bearings amid the confusion of the world of thought to-day.

Philosophical, historical, and scientific questions with which it was not capable of dealing overwhelmed the earlier rationalism like an avalanche, and buried it in the middle of its journey. The new rational theory of the universe must work its way out of this chaos. Leaving itself freely open to the whole influence of the world of fact, it must explore every path offered by reflection and knowledge in its effort to reach the ultimate meaning of being and life, and to see whether it can solve some of the riddles which they present.

The ultimate knowledge, in which man recognizes his own being as a part of the All, belongs, they say, to the realm of mysticism, by which is meant that he does not reach it by the method of ordinary reflection, but somehow or other lives himself into it.

But why assume that the road of thought must suddenly stop at the frontier of mysticism? It is true that pure reason has hitherto called a halt whenever it came into this neighbourhood, for it was unwilling to go beyond the point at which it could still exhibit everything as part of a smooth, logical plan. Mysticism, on its side, always depreciated [pg 091] pure reason as much as it could, to prevent at all costs the idea from gaining currency that it was in any way bound to give an account to reason. And yet, although they refuse to recognize each other, the two belong to each other.

It is in reason that intellect and will, which in our nature are mysteriously bound up together, seek to come to a mutual understanding. The ultimate knowledge that we strive to acquire is knowledge of life, which intellect looks at from without, will from within. Since life is the ultimate object of knowledge, our ultimate knowledge is necessarily our thinking experience of life, but this does not lie outside the sphere of reason, but within reason itself. Only when the will has thought out its relation to the intellect, has come, as far as it can, into line with it, has penetrated it, and in it become logical, is it in a position to comprehend itself, so far as its nature allows this, as a part of the universal will-to-live and a part of being in general. If it merely leaves the intellect on one side, it loses itself in confused imaginings, while the intellect, which, like the rationalism of the past, will not allow that in order to understand life it must finally lose itself in thinking experience, renounces all hope of constructing a deep and firmly based theory of the universe.

[pg 092]

Thus reflection, when pursued to the end, lead somewhere and somehow to a living mysticism which is for all men everywhere a necessary element of thought.

Doubts whether the mass of men can ever attain to that level of reflection about themselves and the world which is demanded by a reflective theory of the universe, are quite justifiable if the man of to-day is taken as an example of the race. But he, with his diminished need of thought, is a pathological phenomenon.

In reality there is given in the mental endowment of the average man a capacity for thought which to the individual makes the creation of a reflective theory of things of his own not only possible, but under normal conditions even a necessity. The great movements of illumination in ancient and modern times help to maintain the confident belief that there is in the mass of mankind a power of thought on fundamentals which can be roused to activity. This belief is strengthened by observation of mankind and intercourse with the young. A fundamental impulse to reflect about the universe stirs us during those years in which we begin to think independently. Later on we let it languish, even though feeling clearly that we thereby impoverish ourselves and become less capable of what is good. We are like springs of water which no longer run [pg 093] because they have not been watched and have gradually become choked with rubbish.

More than any other age has our own neglected to watch the thousand springs of thought; hence the drought in which we are pining. But if we only go on to remove the rubbish which conceals the water, the sands will be irrigated again, and life will spring up where hitherto there has been only a desert.

Certainly there are guides and the guided in the department of world-theories, as in others. So far the independence of the mass of men remains a relative one. The question is only whether the influence of the guides leads to dependence or independence. The latter brings with it a development in the direction of truthfulness; the former means the death of that virtue.

Every being who calls himself a man is meant to develop into a real personality within a reflective theory of the universe which he has created for himself.

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But of what character must the theory be if ideas and convictions about civilization are to be based on it?

That theory of the universe is optimistic which [pg 094] gives existence the preference as against non-existence and thus affirms life as something possessing value in itself. From this attitude to the universe and to life results the impulse to raise existence, in so far as our influence can affect it, to its highest level of value. Thence originates activity directed to the improvement of the living conditions of individuals, of society, of nations and of humanity, from which spring the external achievements of civilization, the lordship of spirit over the powers of nature, and the higher social organization.

Ethics is the activity of man directed to secure the inner perfection of his own personality. In itself it is quite independent of whether the theory of the universe is pessimistic or optimistic. But its sphere of action is contracted or widened according as it appears in connection with a theory of the first or the second type.

In the determinist-pessimistic theory of the universe, as we have it in the thought of the Br■hmans or of Schopenhauer, ethics has nothing whatever to do with the objective world. It aims solely at securing the self-perfection of the individual as this comes to pass in inner freedom and disconnection from the world and the spirit of the world.

But the scope of ethics is extended in proportion [pg 095] as it develops and strengthens a connection with a theory of the universe which is affirmative toward the world and life. Its aim is now the inner perfection of the individual and at the same time the direction of his activity so as to take effect on other men and on the objective world. It is true that in face of the objective world and its spirit ethics no longer holds itself up to man as an aim in itself. By its means man is to become capable of acting among men and in the world as a higher and purer force, and thus to do his part towards the actualization of the ideal of general progress.

Thus the optimistic-ethical theory of the universe works in partnership with ethics to produce civilization. Neither is capable of doing so by itself. Optimism supplies confidence that the world-process has somehow or other a spiritual-sensible aim, and that the improvement of the general relations of the world and of society promotes the spiritual-moral perfection of the individual. From ethics is derived ability to develop the purposive state of mind necessary to produce action on the world and society and to cause the co-operation of all our achievements to secure the spiritual and moral perfection of the individual which is the final end of civilization.

Once we have recognized that the energies which spring out of a theory of the universe, and impel us to [pg 096] create a civilization, are rooted in the ethical and the optimistic, we get light on the question why and how our ideals of civilization got worn out. This question is not to be answered by good or bad analogies from nature. The decisive answer is that they got worn out because we had not succeeded in establishing the ethical and optimistic elements on a sufficiently firm foundation.

If we should analyse the process in which the ideas and convictions that produce civilization reveal themselves, it would be found that whenever an advance has been registered, either the optimist or the ethical element in the theory of the universe has proved more attractive than usual, and has had as its consequence a progressive development. When civilization is decaying there is the same chain of causation, but it works negatively. The building is damaged or falls in because the optimist element or the ethical, or both, give way like a weak foundation. No amount of inquiry will give any other reason for the changes. All imaginable ideas and convictions of that character spring from optimism and the ethical impulse. If these two pillars are strong enough, we need have no fears about the building.

The future of civilization depends, therefore, on whether it is possible for thought to reach a theory of the universe which will have a more secure and [pg 097] fundamental hold on optimism and the ethical impulse than its predecessors have had.

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We Westerners dream of a theory of the universe which corresponds to our impulse to action and at the same time justifies it. We have not been able to formulate such a theory definitely. At present we are in the state of possessing merely an impulse without any definite orientation. The spirit of the age drives us into action without allowing us to attain any clear view of the objective world and of life. It claims our toil inexorably in the service of this or that end, this or that achievement. It keeps us in a sort of intoxication of activity so that we may never have time to reflect and to ask ourselves what this restless sacrifice of ourselves to ends and achievements really has to do with the meaning of the world and of our lives. And so we wander hither and thither in the gathering dusk formed by lack of any definite theory of the universe like homeless, drunken mercenaries, and enlist indifferently in the service of the common and the great without distinguishing between them. And the more hopeless becomes the condition of the world in which this adventurous impulse to action and progress ranges to and fro, the more bewildered [pg 098] becomes our whole conception of things and the more purposeless and irrational the doings of those who have enlisted under the banner of such an impulse.

How little reflection is present in the Western impulse to action becomes evident when this tries to square its ideas with those of the Far East. For thought in the Far East has been constantly occupied in its search for the meaning of life, and forces us to consider the problem of the meaning of our own restlessness, the problem which we Westerners burke so persistently. We are utterly at a loss when we contemplate the ideas which are presented to us in Indian thought. We turn away from the intellectual presumption which we find there. We are conscious of the unsatisfying and incomplete elements in the ideal of cessation from action. We feel instinctively that the will-to-progress is justified not only in its aspect as directed to the spiritual perfection of personality, but also in that which looks towards the general and material.

For ourselves we dare to allege that we adventurers, who take up an affirmative attitude toward the world and toward life, however great and even ghastly our mistakes may be, can yet show not only greater material, but also greater spiritual and ethical, contributions than can those who lie under the ban of a theory of the universe characterized by cessation from action.

[pg 099]

And yet, all the same, we cannot feel ourselves completely justified in the face of these strange Eastern theories. They have in them something full of nobility which retains its hold on us, even fascinates us. This tinge of nobility comes from the fact that these convictions are born of a search for a theory of the universe and for the meaning of life. With us, on the other hand, activist instincts and impulses take the place of a theory of the universe. We have no theory affirming the world and life to oppose to the negative theory of these thinkers, no thought which has found a basis for an optimistic conception of existence to oppose to this other, which has arrived at a pessimistic conception.

The reawakening of the Western spirit must thus begin by our people, educated and simple alike, becoming conscious of their lack of a theory of the universe and feeling the horror of their consequent position. We can no longer be satisfied to make shift with substitutes for such a theory. What is the basis of the will-to-activity and progress which impels both to great actions and to terrible deeds, and which tries to keep us from reflection? We must bend all our energies to the solution of this problem.

There is only one way in which we can hope to emerge from the meaningless state in which we are [pg 100] now held captive into one informed with meaning. Each one of us must turn to contemplate his own being, and we must all give ourselves to co-operative reflection so as to discover how our will to action and to progress may be intellectually based on the way in which we interpret our own lives and the life around us, and the meaning which we give to these.

The great revision of the convictions and ideals in which and for which we live will only take place when, by constantly proclaiming them, we have given currency among our contemporaries to ideas and thoughts other and better than those by which they are dominated at the moment. Only thus will the many come to reflect about the meaning of life and to reorientate, revise and make over again their ideals of action and of progress, asking themselves whether these have a meaning in accord with that which we attribute to our life itself. This personal reflection about final and elemental things is the one and only reliable way of measuring values. My willing and doing have real meaning and value only in proportion as the aims which action sets before itself can be justified as being in direct accord with my interpretation of my own and of other life. All else, however much it may pass current as approved by tradition, usage, and public opinion, is vain and dangerous.

It seems, indeed, a matter for scorn and derision [pg 101] that we should urge men to anything so remote as a return to reflection about the meaning of life at a time when the sufferings and the follies of the nations have become so intense and so extended, when unemployment and poverty and starvation are rife, when power is being dissipated on all sides in the most shameless and senseless way, and when organized human life is dislocated in every direction. But only when the general population begins to reflect in this way will forces come into being which will be able to effect something to counterbalance all this ruin and misery. Whatever other measures it is attempted to carry out will have doubtful and altogether inadequate results.

When in the spring the withered grey of the pastures gives place to green, this is due to the millions of young shoots which sprout up freshly from the old roots. In like manner the revival of thought which is essential for our time can only come through a transformation of the opinions and ideals of the many brought about by individual and universal reflection about the meaning of life and of the world.

But are we sure of being able to think out that affirmation of the world and of life, which is such a powerful impulse in us, into a theory of the world and of life from which a stream of energy productive [pg 102] of intelligible life and action may convincingly and constantly proceed? How are we to succeed in doing what the spirit of the Western world during past generations has in vain toiled to accomplish?

Even if thought, once more awakened, should only attain to an incomplete and unsatisfying theory of the universe, yet this, as the truth to which we have ourselves worked through, would be of more value than a complete lack of any theory at all, or, alternatively, than any sort of authoritative theory to which, neglecting the demands of true thought, we cling on account of its supposed intrinsic value without having any real and thorough belief in it.

The beginning of all spiritual life of any real value is courageous faith in truth and open confession of the same. The most profound religious experience, too, is not alien to thought, but must be capable of derivation from this if it is to be given a true and deep basis. Mere reflection about the meaning of life has already value in itself. If such reflection should again come into being amongst us, the ideals, born of vanity and of suffering, which now flourish in rank profusion like evil weeds among the convictions of the generality of people, would infallibly wither away and die. How much would already be accomplished towards our salvation from our present

circumstances if only we would all give up three minutes every evening to gazing up into the infinite [pg 103] world of the starry heavens and meditating on it, or if in taking part in a funeral procession we would reflect on the enigma of life and death, instead of engaging in thoughtless conversation as we follow behind the coffin! The ideals, born of folly and suffering, of those who make public opinion and direct public events, would have no more power over men if they once began to reflect about eternity and mortality, existence and dissolution, and thus learnt to distinguish between true and false standards, between those which possess real value and those which do not. The old-time rabbis used to teach that the kingdom of God would come if only the whole of Israel would really keep a single Sabbath simultaneously! How much more is it true that the injustice and violence and untruth, which are now bringing so much disaster on the human race, would lose their power if only a single real trace of reflection about the meaning of the world and of life should appear amongst us!

But is there not a danger in challenging men with this question about the meaning of life and in demanding that our impulse to action should justify and clarify itself in such reflection as that of which we have spoken? Shall we not lose, in acceding to this demand, some irreplaceable element of naïve enthusiasm?

[pg 104]

We need not thus be anxious as to how strong or how weak our impulse to action will prove to be when it shall have arrived, as the result of intellectual reflection, at an interpretation of life. Only that has real meaning for life which is given as an element of our interpretation of life. It is not the quantity, but the quality, of activity that really matters. What is needed is that our will-to-action should become conscious of itself and should cease to work blindly.

But perhaps, it may be objected, we shall end in the resignation of agnosticism, and shall be obliged to confess that we cannot discover any meaning in the universe or in life.

If thought is to set out on its journey unhampered, it must be prepared for anything, even for arrival at intellectual agnosticism. But even if our will-to-action is destined to wrestle endlessly and unavailingly with an agnostic view of the universe and of life, still this painful disenchantment is better for it than persistent refusal to think out its position at all. For this disenchantment does, at any rate, mean that we are clear as to what we are doing.

There is, however, no necessity whatever for such an attitude of resignation. We feel that a position of affirmation regarding the world and life is something which is in itself both necessary and valuable. Therefore it is at least likely that a foundation can be [pg 105] found for it in thought. Since it is an innate element of our will-to-live, it must be possible to comprehend it as a necessary corollary to our interpretation of life. Perhaps we shall have to look elsewhere than we have done hitherto for the real basis of that theory of the universe which carries with it affirmation of the world and of life. Previous thought imagined that it could deduce the meaning of life from its interpretation of the universe. It may be that we shall be obliged to resign ourselves to abandon the problem of the interpretation of the universe and to find the meaning of our life in the will-to-live as this exists in ourselves.

The ways along which we have to struggle toward the goal may be veiled in darkness, yet the direction in which we must travel is clear. We must reflect together about the meaning of life; we must strive together to attain to a theory of the universe affirmative of the world and of life, in which the impulse to action which we experience as a necessary and valuable element of our being may find justification, orientation, clarity and depth, may receive a fresh access of moral strength, and be retempered, and thus become capable of formulating, and of acting on, definite ideals of civilization, inspired by the spirit of true humanitarianism.

FOOTNOTES

* _Weltanschauung_. Translated ‘theory of the universe’ throughout the first part and elsewhere in this preface.

* Translated “world-view” throughout the second part of these Lectures.

TRANSCRIBER’S NOTES

The formatting of both the .htm and .txt files followed that of two similar books, The Quest of the Historical Jesus and The Mystery of the Kingdom of God, already in Project Gutenberg.

In the .txt version I have used utf8 encoding and the following markers:

1. italic text surrounded by _ 2. footnote references in the form _(_number_)_

I have included page numbers in the format [pg xxx] for both .htm and .txt.

I made several hyphenation choices, mostly forced by de-hyphenation at the ends of lines:

1. world-theory 2. overcoming 3. self-regarding 4. never-concentrated 5. over-organization 6. over-valuation 7. self-importance 8. rococo-ministers 9. non-existence

In addition, on page 5 of the .pdf file on Internet Archive, the display of this page was corrupted in my copy. As pointed out by an editor, this has been corrected in the current version at Internet Archive.

On page 84 the word “not” in the sentence:

“The rulers, small and great alike, did not act in accordance with the spirit of the age.”

was changed to “[nothing but]”. The original German is:

“Die kleinen und die großen Regierenden taten nichts anderes, als daß sie im Geiste der Zeit handelten.”

Google Translate (4/25/2025) renders this as:

“The small and the big rulers did nothing other than act in the spirit of the times.”

The printed sentence in the book is either a typo or a mis-translation. It does not fit the sense of the author who means that the rulers themselves are not to blame for the collapse of civilization but rather it is the fault of the “spirit of the age”.

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A text-book of veterinary anatomy

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A TEXT-BOOK of VETERINARY ANATOMY

BY

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WITH 588 ILLUSTRATIONS MANY IN COLORS

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TO

KATHERINE OLDHAM SISSON

IN GRATEFUL RECOGNITION OF CONSTANT INSPIRATION AND ENCOURAGEMENT THIS BOOK IS DEDICATED

BY THE AUTHOR

PREFACE

The lack of a modern and well-illustrated book on the structure of the principal domestic animals has been acutely felt for a long time by teachers, students, and practitioners of veterinary medicine. The work here offered is the expression of a desire to close this gap in our literature.

The study of frozen sections and of material which has been hardened by intravascular injection of formalin has profoundly modified our views concerning the natural shape of many of the viscera and has rendered possible much greater precision in topographic statements. The experience of the author during the last ten years, in which almost all of the material used for dissection and for frozen sections in the anatomical laboratory of this University has been hardened with formalin, has demonstrated that many of the current descriptions of the organs in animals contain the same sort of errors as those which prevailed in regard to similar structures in man previous to the adoption of modern methods of preparation.

While the method of treatment of the subject is essentially systematic, topography is not by any means neglected either in text or illustrations; it is hoped that this will render the book of value to the student in his clinical courses and to the practitioner. Embryological and histological data have been almost entirely excluded, since it was desired to offer a text-book of convenient size for the student and a work of ready reference for the practitioner. It is believed that the use of black type for the names of important structures and of small print for certain details or matter of secondary importance will prove useful in this respect.

Veterinary anatomical nomenclature is at present quite chaotic in English-speaking countries. In this work an attempt is made to eliminate some terms which do not appear to the author to fulfil any useful purpose, and others which are clearly erroneous or

otherwise undesirable. In many cases the terms agreed upon by the Congresses at Baden and Stuttgart are adopted either in the original Latin or in anglicized form; otherwise these terms are added in parenthesis. The author favors the substantial adoption of this terminology, but considered it desirable to offer a sort of transitional stage at present.

The original illustrations are chiefly reproductions of photographs, many of which were taken by Mr. F. H. Haskett. The preparation of the pictures for reproduction was carried out by Messrs. J. V. Alteneder and W. J. Norris. The author takes pleasure in expressing his appreciation of the care and skill exercised by these gentlemen in this often difficult task.

The author is under great obligation to Professors Ellenberger and Baum in Dresden, to Professor Schmaltz in Berlin, and to their publishers for permission to use or to copy figures from their most excellent works. Their generosity in this matter has made it possible to supply this text with a larger number of high-class illustrations than is to be found in any other. A few figures have been taken from other sources, and proper credit has been given in each case.

For checking over certain data and for assistance in the correction of the proofs the author is much indebted to his associate, Dr. F. B. Hadley.

The author desires to express his high appreciation of the determination and constant effort of the publishers to do all in their power to render the book worthy of favorable reception by the profession for whom it is intended.

OHIO STATE UNIVERSITY, COLUMBUS, OHIO. SEPTIMUS SISSON.

CONTENTS

INTRODUCTION OSTEOLOGY PAGE THE SKELETON 19 Structure of Bones 20 Development and Growth of Bone 22 Composition and Physical Properties of Bone 23 Descriptive Terms 23 The Vertebral Column 24 The Ribs and Costal Cartilages 25 Costal Cartilages 26 The Sternum 26 The Thorax 27 The Skull 27 Bones of the Thoracic Limb 27 Bones of the Pelvic Limb 29 SKELETON OF THE HORSE 31 Vertebral Column 31 Ribs 43 Sternum 45 Bones of the Skull 47 Cranium 47 Face 57 The Skull as a Whole 65 The Cranial Cavity 69 The Nasal Cavity 71 The Paranasal Sinuses 72 Bones of the Thoracic Limb 74 Bones of the Pelvic Limb 92 SKELETON OF THE OX 112 Vertebral Column 112 Ribs 114 Sternum 115 Bones of the Skull 115 The Skull as a Whole 123 Bones of the Thoracic Limb 127 Bones of the Pelvic Limb 131 SKELETON OF THE PIG 136 Vertebral Column 136 Ribs 138 Sternum 139 Bones of the Skull 139 The Skull as a Whole 144 Bones of the Thoracic Limb 146 Bones of the Pelvic Limb 148 SKELETON OF THE DOG 150 Vertebral Column 150 Ribs 153 Sternum 153 Bones of the Skull 153 The Skull as a Whole 159 Bones of the Thoracic Limb 162 Bones of the Pelvic Limb 165

ARTHROLOGY SYNARTHROSES 169 DIARTHROSES 170 AMPHIARTHROSES 172 ARTICULATIONS OF THE HORSE 172 Joints and Ligaments of the Vertebræ 172 Atlanto-occipital Articulation 176 Costo-vertebral Articulations 177 Costo-chondral Articulations 178 Chondro-sternal Articulations 178 Sternal Joints and Ligaments 178 Articulations of the Skull 179 Articulations of the Thoracic Limb 180 Articulations of the Pelvic Limb 190 ARTICULATIONS OF THE OX, PIG, AND DOG 203

THE MUSCULAR SYSTEM—MYOLOGY THE MUSCLES AND ACCESSORY STRUCTURES 211 FASCIÆ AND MUSCLES OF THE HORSE 213 Panniculus carnosus 213 Fasciæ and Muscles of the Head 213 Fasciæ and Muscles of the Neck 224 Fasciæ and Muscles of the Back and Loins 235 Fasciæ and Muscles of the Tail 238 Muscles of the Thorax 240 Muscles of the Abdomen 245 Muscles of the Thoracic Limb 250 Fasciæ and Muscles of the Pelvic Limb 273 MUSCLES OF THE OX 295 MUSCLES OF THE PIG 311 MUSCLES OF THE DOG 318

SPLANCHNOLOGY—THE DIGESTIVE SYSTEM DIGESTIVE SYSTEM OF THE HORSE 330 The Mouth 330 The Tongue 335 The Teeth 338 The Salivary Glands 346 The Pharynx 348 The Œsophagus 350 The Abdominal Cavity 352 The Peritoneum 353 The Pelvic Cavity 354 The Stomach 357 The Small Intestine 360 The Large Intestine 363 The Pancreas 371 The Liver 373 The Spleen 377 The Peritoneum 379 DIGESTIVE SYSTEM OF THE OX 382 DIGESTIVE SYSTEM OF THE SHEEP 405 DIGESTIVE SYSTEM OF THE PIG 410 DIGESTIVE SYSTEM OF THE DOG 423

THE RESPIRATORY SYSTEM RESPIRATORY SYSTEM OF THE HORSE 436 The Nasal Cavity 436 The Larynx 440 The Trachea 448 The Bronchi 450 The Thoracic Cavity 450 The Pleuræ 451 The Lungs 453 THE THYROID GLAND OF THE HORSE 457 THE THYMUS OF THE HORSE 458 RESPIRATORY SYSTEM OF THE OX 458 RESPIRATORY SYSTEM OF THE PIG 464 RESPIRATORY SYSTEM OF THE DOG 466

THE UROGENITAL SYSTEM URINARY ORGANS OF THE HORSE 469 The Kidneys 469 The Ureters 475 The Urinary Bladder 475 THE ADRENAL BODIES 477 URINARY ORGANS OF THE OX 478 URINARY ORGANS OF THE PIG 481 URINARY ORGANS OF THE DOG 483

THE MALE GENITAL ORGANS MALE GENITAL ORGANS OF THE HORSE 485 The Testicles 485 The Scrotum 487 The Vas Deferens 488 The Spermatic Cord 489 The Tunica Vaginalis 489 Descent of the Testicles 490 The Vesiculæ Seminales 491 The Prostate 493 The Uterus Masculinus 493 The Bulbo-urethral Glands 493 The Penis 494 The Prepuce 496 MALE GENITAL ORGANS OF THE OX 500 MALE GENITAL ORGANS OF THE PIG 504 MALE GENITAL ORGANS OF THE DOG 506

THE FEMALE GENITAL ORGANS GENITAL ORGANS OF THE MARE 508 The Ovaries 508 The Uterine or Fallopian Tubes 511 The Uterus 511 The Vagina 514 The Vulva 514 The Urethra 515 The Mammary Glands 516 GENITAL ORGANS OF THE COW 517 GENITAL ORGANS OF THE SOW 521 GENITAL ORGANS OF THE BITCH 522

ANGIOLOGY THE ORGANS OF CIRCULATION 524 BLOOD-VASCULAR SYSTEM OF THE HORSE 525 The Pericardium 525 The Heart 526 The Pulmonary Artery 535 The Systemic Arteries 535 The Coronary Arteries 537 The Brachiocephalic Trunk or Anterior Aorta 537 Arteries of the Thoracic Limb 556 Branches of the Thoracic Aorta 565 Branches of the Abdominal Aorta 566 Arteries of the Pelvic Limb 578 The Veins 585 The Pulmonary Veins 585 The Systemic Veins 585 The Anterior Vena Cava and its Tributaries 586 The Posterior Vena Cava and its Tributaries 595 THE LYMPHATIC SYSTEM 599 Lymphatic System of the Horse 600 The Lymph Glands and Vessels of the Head and Neck 601 The Lymph Glands and Vessels of the Thorax 603 The Lymph Glands and Vessels of the Abdomen and Pelvis 604 The Lymph Glands and Vessels of the Thoracic Limb 605 The Lymph Glands and Vessels of the Pelvic Limb 606 THE FŒTAL CIRCULATION 606 BLOOD-VASCULAR SYSTEM OF THE OX 608 The Pericardium and Heart 608 The Arteries 609 The Veins 621 LYMPHATIC SYSTEM OF THE OX 623 CIRCULATORY SYSTEM OF THE PIG 626 The Pericardium and Heart 626 The Arteries 627 The Veins 630 Lymphatic System of the Pig 630 CIRCULATORY SYSTEM OF THE DOG 632 The Pericardium and Heart 632 The Arteries 633 The Veins 641 Lymphatic System of the Dog 643

NEUROLOGY—THE NERVOUS SYSTEM GENERAL CONSIDERATIONS 644 NERVOUS SYSTEM OF THE HORSE 648 The Spinal Cord 648 The Brain 652 The Cranial Nerves 676 The Spinal Nerves 692 SYMPATHETIC NERVOUS SYSTEM OF THE HORSE 710 NERVOUS SYSTEM OF THE OX 715 NERVOUS SYSTEM OF THE PIG 720 NERVOUS SYSTEM OF THE DOG 724

ÆSTHESIOLOGY THE SENSE ORGANS AND SKIN OF THE HORSE 734 The Eye 734 The Ear 747 The Skin 761 The Olfactory and Gustatory Apparatus 772 THE SENSE ORGANS AND SKIN OF THE OX 772 THE SENSE ORGANS AND INTEGUMENT OF THE PIG 777 THE SENSE ORGANS AND INTEGUMENT OF THE DOG 779

INDEX 783

VETERINARY ANATOMY

INTRODUCTION

=Anatomy= is the branch of biological science which deals with the form and structure of organisms, both animal and vegetal. It is therefore in close correlation with physiology, which treats of the functions of the body.

Etymologically the word “anatomy” signifies the cutting apart or disassociating of parts of the body. In the earlier phases of its development anatomy was necessarily a purely descriptive science, based on such observations as were possible with the unaided eye and simple dissecting instruments—the scalpel, forceps, and the like. At this time, therefore, the term adequately expressed the nature of the subject. But as the scope of the science extended and the body of anatomical knowledge grew, subdivisions became necessary and new terms were introduced to designate special fields and methods of work. With the introduction of the microscope and its accessories it became possible to study the finer details of structure and minute organisms hitherto unknown, and this field of inquiry rapidly developed into the science of =microscopic anatomy= or =histology= as conventionally distinguished from =gross= or =macroscopic anatomy=. In the same way the study of the changes which organisms undergo during their development soon attained sufficient importance to be regarded on practical grounds as a separate branch known as =embryology=.

This term is usually limited in its application to the earlier phases of development during which the tissues and organs are formed. The term =ontogeny= is used to designate the entire development of the individual. The ancestral history or =phylogeny= of the species is constituted by the evolutionary changes which it has undergone as disclosed by the geological record.

=Comparative anatomy= is the description and comparison of the structure of animals, and forms the basis for their classification. By this means—including extinct forms in the scope of inquiry—it has been possible to show the genetic relationship of various groups of animals and to elucidate the significance of many facts of structure which are otherwise quite obscure. The deductions concerning the general laws of form and structure derived from comparative anatomical studies constitute the science of =morphology= or =philosophical anatomy=. The morphologist, however, deals only with such anatomical details as are necessary to form a basis for his generalizations. The anatomical knowledge required in the practice of medicine and surgery is evidently of a different character and must include many details which are of no particular interest to the morphologist.

=Special anatomy= is the description of the structure of a single type or species, _e. g._, anthropotomy, hippotomy.

=Veterinary anatomy= is the branch which deals with the form and structure of the principal domesticated animals. It is usually pursued with regard to professional requirements, and is therefore largely descriptive in character. As a matter of convenience the horse is generally selected as the type to be studied in detail and to form a basis for comparison of the more essential differential characters in the other animals.

Two chief methods of study are employed—the =systematic= and the =topographic=. In the former the body is regarded as consisting of systems of organs or apparatus which are similar in origin and structure and are associated in the performance of certain functions. The divisions of =systematic anatomy= are:

1. Osteology

2. Arthrology

3. Myology

4. Splanchnology

(1) Digestive System

(2) Respiratory System

(3) Urogenital System

(_a_) Urinary Organs

(_b_) Genital Organs

5. Angiology

6. Neurology

7. Æsthesiology

(1) Sense Organs

(2) Common Integument.

The term =topographic anatomy= designates the methods by which the relative positions of the various parts of the body are accurately determined. It presupposes a fair working knowledge of systematic anatomy.

=Descriptive Terms.=—In order to indicate precisely the position and direction of parts of the body, certain descriptive terms are employed, and must be understood at the outset. In the explanation of these terms it is assumed here that they apply to a quadruped such as the horse in the ordinary standing position. The surface directed toward the plane of support (the ground) is termed =inferior= or =ventral=, and the opposite surface is =superior= or =dorsal=; the relations of parts in this direction are named accordingly. The longitudinal =median plane= divides the body into similar halves. A structure or surface which is nearer than another to the median plane is =internal= or =medial= to it, and an object or surface which is further than another from the median

plane is =external= or =lateral= to it. Planes parallel to the median plane are =sagittal=. =Transverse= or =segmental= planes cut the long axis of the body perpendicular to the median plane, or an organ or limb at right angles to its long axis. A =frontal= plane is perpendicular to the median and transverse planes. The head end of the body is termed =anterior=, =cephalic=, or =cranial=; and the tail end =posterior= or =caudal=; relations of structures with regard to the longitudinal axis of the body are designated accordingly. Certain terms are used in a special sense as applied to the limbs. =Proximal= and =distal= express relative distances of parts from the axis of the body. The anterior face of the thoracic limb from the elbow downward is also termed =dorsal=, and the opposite face =volar=. In the corresponding part of the pelvic limb the terms are =dorsal= and =plantar= respectively. In the same regions =radial= and =ulnar= (thoracic limb), =tibial= and =fibular= (pelvic limb), may be used to designate that side of the extremity on which the corresponding bone is situated; they are therefore equivalent respectively to internal or medial and external or lateral in the animals with which we are concerned.

It is evidently advantageous to employ terms which are as far as possible independent of the position of the body in space and capable of general application, _e. g._, dorsal, ventral, proximal, etc. It is also desirable that the terms internal and external be reserved to indicate relations of depth in cavities or organs, and medial and lateral to designate relations to the median plane. Such terms are coming into more extensive use in human and veterinary anatomy, but the older nomenclature is very firmly established and cannot well be discarded at once and entirely.

OSTEOLOGY

THE SKELETON

The term =skeleton= is applied to the framework of hard structures which supports and protects the soft tissues of animals. In the descriptive anatomy of the higher animals it is usually restricted to the bones and cartilages, although the ligaments which bind these together might well be included.

In zoölogy the term is used in a much more comprehensive sense, and includes all the harder supporting and protecting structures. When the latter are situated externally, they form an =exoskeleton=, derived from the ectoderm. Examples of this are the shells and chitinous coverings of many invertebrates, the scales of fishes, the shields of turtles, and the feathers, hair, and hoofs of the higher vertebrates. The =endoskeleton= (with which we have to deal at present) is embedded in the soft tissues. It is derived chiefly from the mesoderm, but includes the notochord or primitive axial skeleton, which is of entodermal origin.

The skeleton may be divided primarily into three parts: (1) axial; (2) appendicular; (3) splanchnic.

The =axial skeleton= comprises the vertebral column, ribs, sternum, and skull.

The =appendicular skeleton= includes the bones of the limbs.

The =splanchnic skeleton= consists of certain bones developed in the substance of some of the viscera or soft organs, _e. g._, the os penis of the dog and the os cordis of the ox.

The =number= of the bones of the skeleton of an animal varies with age, owing to the fusion during growth of skeletal elements which are separate in the fœtus or the young subject. Even in adults of the same species numerical variations occur, _e. g._, the tarsus of the horse may consist of six or seven bones, and the carpus of seven or eight; in all the domestic mammals the number of coccygeal vertebræ varies considerably.

The bones are commonly divided into four classes according to their shape and function.

(1) =Long bones= (Ossa longa) are typically of elongated cylindrical form with enlarged extremities. They occur in the limbs, where they act as supporting columns and as levers. The cylindrical part, termed the shaft or body (Corpus), is tubular, and incloses the =medullary cavity=, which contains the medulla or marrow.

(2) =Flat bones= (Ossa plana) are expanded in two directions. They furnish sufficient area for the attachment of muscles and afford protection to the organs which they cover.

(3) =Short bones= (Ossa brevia), such as those of the carpus and tarsus, present somewhat similar dimensions in length, breadth, and thickness. Their chief function appears to be that of diffusing concussion. Sesamoid bones, which are developed in the

capsules of some joints or in tendons, may be included in this group. They diminish friction or change the direction of tendons.

(4) =Irregular bones.= This group would include bones of irregular shape, such as the vertebræ and the bones of the cranial base; they are median and unpaired. Their functions are various and not so clearly specialized as those of the preceding classes.

This classification is not entirely satisfactory; some bones, _e. g._, the ribs, are not clearly provided for, and others might be variously placed.

STRUCTURE OF BONES[1]

Bones consist chiefly of =bone tissue=, but considered as organs they present also an enveloping membrane, termed the =periosteum=, the =medulla= or =marrow=, =vessels=, and =nerves=.

The architecture of bone can be studied best by means of longitudinal and cross-sections. These show that the bone consists of an external shell of dense =compact substance=, within which is the more loosely arranged =spongy substance=. In typical long bones the shaft is hollowed to form the =medullary cavity= (Cavum medullare).

[Illustration:

FIG. 1.—FRONTAL SECTION OF LARGE METATARSAL BONE OF HORSE, POSTERIOR PART.]

[Illustration:

FIG. 2.—SAGITTAL SECTION OF LARGE METATARSAL BONE OF HORSE.

_S.C._, Compact substance; _S.s._, spongy substance; _C.m._, medullary cavity; _F.n._, nutrient foramen. Note the greater thickness of the compact substance of the inner and anterior parts of the shaft.]

The =compact substance= (Substantia compacta) differs greatly in thickness in various situations, in conformity with the stresses and strains to which the bone is subjected. In the long bones it is thickest in the middle part of the shaft and thins out toward the extremities. On the latter the layer is very thin, and is especially dense and smooth on joint surfaces.

The =spongy substance= (Substantia spongiosa) consists of delicate bony plates and spicules which run in various directions and intercross. These plates are definitely arranged with regard to mechanical requirements, so that systems of pressure and tension plates can be recognized, in conformity with the lines of pressure and the pull of tendons and ligaments respectively. The intervals (marrow spaces) between the plates are occupied by marrow. The spongy substance forms the bulk of short bones and of the extremities of long bones; in the latter it is not confined to the ends, but extends a variable distance along the shaft also. Some bones (Ossa pneumatica) contain =air-spaces= or =sinuses= within the compact substance instead of spongy bone and marrow. In certain situations the two compact layers of flat bones are not separated by spongy bone, but fuse with each other; in some cases of this kind the bone is so thin as to be translucent, or may even undergo absorption, producing an actual deficiency.

The flat bones of the cranial vault and sides are composed of an outer layer of ordinary compact substance, an inner layer of very dense bone, the =tabula vitrea=, and between these a variable amount of spongy bone, here termed =diploë=.

The =periosteum= is the membrane which invests the outer surface of bone, except where it is covered with cartilage. It consists of an outer protective fibrous layer, and an inner cellular osteogenic layer. During active growth the osteogenic layer is well developed, but later it becomes much reduced. The fibrous layer varies much in thickness, being in general thickest in exposed situations. The adhesion of the periosteum to the bone also differs greatly in various places; it is usually very thin and easily detached where it is thickly covered with muscular tissue which has little or no attachment. The degree of vascularity conforms to the activity of the periosteum.

The =marrow= (Medulla ossium) occupies the interstices of the spongy bone and the medullary cavity of the long bones. There are two varieties in the adult—red and yellow. In the young subject there is only =red marrow= (Medulla ossium rubra), but later this is replaced in the medullary cavity by =yellow marrow= (Medulla ossium flava). The red marrow contains several types of characteristic cells and is a blood-forming substance, while the yellow is practically ordinary adipose tissue.

Since yellow marrow is formed by regressive changes in red marrow, including fatty infiltration and degeneration of the characteristic cells, we find transitional forms or stages in the process. In aged or badly nourished subjects the marrow may

undergo gelatinous degeneration, resulting in the formation of gelatinous marrow.

=Vessels and Nerves.=—It is customary to recognize two sets of =arteries=—the =periosteal= and the =medullary=. The former ramify in the periosteum and give off innumerable small branches which enter minute openings (Volkmann's canals) on the surface and reach the Haversian canals of the compact substance. Other branches enter the extremities of the long bones and supply the spongy bone and marrow in them. In the case of the larger bones—and especially the long bones—the large =medullary= or =nutrient artery= enters at the so-called =nutrient foramen= (Foramen nutricium), passes in a canal (Canalis nutricius) through the compact substance, and ramifies in the marrow; its branches anastomose with the central branches of the periosteal set. The larger =veins= of the spongy bone do not, as a rule, accompany the arteries, but emerge chiefly near the articular surfaces. Within the bone they are destitute of valves.

The =lymph vessels= form perivascular channels in the periosteum and the Haversian canals of the compact substance. Lymph-spaces exist at the periphery of the marrow.

The =nerves= appear to be distributed chiefly to the blood-vessels. Special nerve-endings (Vater-Pacini corpuscles) in the periosteum are to be regarded as sensory, and probably are concerned in mediating the muscle sense (Kopsch).

DEVELOPMENT AND GROWTH OF BONE[2]

The primitive embryonal skeleton consists of cartilage and fibrous tissue, in which the bones develop. The process is termed =ossification= or =osteogenesis=, and is effected essentially by bone-producing cells, called =osteoblasts=. It is customary, therefore, to designate as =membrane bones= those which are developed in fibrous tissue, and as =cartilage bones= those which are preformed in cartilage. The principal membrane bones are those of the roof and sides of the cranium and most of the bones of the face. The cartilage bones comprise, therefore, most of the skeleton. Correspondingly we distinguish =intramembranous= and =endochondral ossification=.

[Illustration:

FIG. 3.—LEFT FEMUR OF YOUNG PIG, EXTERNAL VIEW, TO SHOW DIVISION OF A LONG BONE INTO SHAFT (_s_) AND EXTREMITIES.

Proximal extremity consists of two parts, head (_h_) and trochanter major (_t. m._), which have separate centers of ossification. Distal extremity consists of trochlea (_t_) and condyles (_c_); _e.l._, epiphyseal cartilages; _s.f._, supracondyloid fossa.]

In intramembranous development the process begins at a definite =center of ossification= where the cells (osteoblasts) surround themselves with a deposit of bone. The process extends from this center to the periphery of the future bone, thus producing a network of bony trabeculæ. The trabeculæ rapidly thicken and coalesce, forming a bony plate which is separated from the adjacent bones by persistent fibrous tissue. The superficial part of the original tissue becomes periosteum, and on the deep face of this successive layers of periosteal bone are formed by osteoblasts until the bone attains its definitive thickness.

In endochondral ossification the process is fundamentally the same, but not quite so simple. Osteoblasts emigrate from the deep face of the perichondrium or primitive periosteum into the cartilage and cause calcification of the matrix or ground-substance of the latter. Vessels extend into the calcifying area, the cartilage cells shrink and disappear, forming primary marrow cavities which are occupied by processes of the osteogenic tissue. There is thus formed a sort of scaffolding of calcareous trabeculæ on which the bone is constructed by the osteoblasts. At the same time perichondral bone is formed by the osteoblasts of the primitive periosteum. The calcified cartilage is broken down and absorbed through the agency of large cells called =osteoclasts=, and is replaced by bone deposited by the osteoblasts. The osteoclasts also cause absorption of the primitive bone, producing the marrow cavities; thus in the case of the long bones the primitive central spongy bone is largely absorbed to form the medullary cavity of the shaft, and persists chiefly in the extremities. Destruction of the central part and formation of subperiosteal bone continue until the shaft of the bone has completed its growth.

A typical long bone is developed from three primary centers of ossification, one for the diaphysis or shaft and one for each epiphysis or extremity. Many bones have secondary centers from which processes or apophyses develop.

The foregoing outline accounts for the growth of bones except in regard to length. Increase in length may be explained briefly as follows: Provision for continued ossification at either end of the diaphysis is made by a layer of actively growing cartilage—the

=epiphyseal cartilage=—which intervenes between the diaphysis and the epiphysis. It is evident that so long as this cartilage persists and grows, new bone may continue to be formed at its expense, and increase of length is possible. When the epiphyseal cartilage ceases to grow, it undergoes ossification, the bone is consolidated, and no further increase in length is possible. This fusion takes place at fairly definite periods in the various bones, and it is of value to know the usual times at which it occurs in the larger bones of the limbs at least.

After the bones have reached their full size, the periosteum becomes relatively reduced and inactive so far as its osteogenic layer is concerned; the bone-forming function may be stimulated by various causes, as is well seen in the healing of fractures and the occurrence of bony enlargements.

CHEMICAL COMPOSITION OF BONE

Dried bone consists of =organic= and =inorganic= matter in the ratio of 1 ■ 2 approximately. The animal matter gives toughness and elasticity, the mineral matter hardness, to the bone tissue. Removal of the organic matter by heat does not change the general form of a bone, but reduces the weight by about one-third, and makes it very fragile. Conversely, decalcification, while not affecting the form and size of the bone, renders it soft and pliable. The animal matter when boiled yields gelatin. The following table represents the composition in 100 parts of ox bone of average quality:

Gelatin 33.30 Phosphate of lime 57.35 Carbonate of lime 3.85 Phosphate of magnesia 2.05 Carbonate and chlorid of sodium 3.45 ———— 100.00

PHYSICAL PROPERTIES OF BONE

Fresh dead bone has a yellowish-white color; when macerated or boiled and bleached, it is white. The specific gravity of fresh compact bone is a little over 1.93. It is very hard and resistant to pressure; a 5-millimeter cube of compact bone of the ox will resist pressure up to 852 pounds, if the pressure be applied in the line of the lamellæ (Rauber). Its tensile strength is estimated to be nearly twice that of oak.

DESCRIPTIVE TERMS

The surfaces of the bones present a great variety of eminences and depressions, as well as perforations. The prominences and cavities may be articular, or non-articular, furnishing attachment to muscles, tendons, ligaments or fascia. A number of descriptive terms are used to designate these features, and the following are some of those in general use:

=Process= (Processus) is a general term for a prominence.

A =tuberosity= (Tuber, Tuberositas) is a large, rounded projection; a =tubercle= (Tuberculum) is a smaller one.

The term =trochanter= is applied to a few prominences, _e. g._, the trochanters of the femur.

A =spine= (Spina) or =spinous process= (Processus spinosus) is a pointed projection.

A =crest= (Crista) is a sharp ridge.

A =line= (Linea) is a very small ridge.

A =head= (Caput) is a rounded articular enlargement at the end of a bone; it may be joined to the shaft by a constricted part, the =neck= (Collum).

A =condyle= (Condylus) is an articular eminence which is somewhat cylindrical; a non-articular projection in connection with a condyle may be termed an =epicondyle=.

A =trochlea= is a pulley-like articular mass.

A =glenoid cavity= (Cavitas glenoidalis) is a shallow articular depression, and a =cotyloid cavity= or =acetabulum= is a deeper one.

The term =facet= is commonly applied to articular surfaces of small extent, especially when they are not strongly concave or convex.

The terms =fossa=, =fovea=, =groove= or =sulcus=, and =impression= are applied to various forms of depressions.

A =foramen= is a perforation for the transmission of vessels, nerves, etc.

A =sinus= or =antrum= is an air-cavity.

Other terms, such as =canal=, =fissure=, =notch=, etc., require no explanation.[3]

VERTEBRAL COLUMN

The =vertebral column= (Columna vertebralis) is the fundamental part of the skeleton. It consists of a chain of median, unpaired, irregular bones which extends from the skull to the end of the tail. In the adult certain vertebræ have become fused to form a single bony mass with which the pelvic girdle articulates. Vertebræ so fused are termed =fixed= or ="false" vertebræ= (Vertebræ immobiles), as distinguished from the =movable= or ="true" vertebræ= (Vertebræ mobiles).

The column is subdivided for description into =five regions=, which are named according to the part of the body in which they are placed. Thus the vertebræ are designated as =cervical=, =thoracic= (or dorsal), =lumbar=, =sacral=, and =coccygeal= or =caudal= (Vertebræ cervicales, thoracales, lumbales, sacrales, coccygeæ). The number of vertebræ in a given species is fairly constant in each region except the last, so that the =vertebral formula= may be expressed (for the horse, for example) as follows:

$C_{7}T_{18}L_{6}S_{5}Cy_{15–21}$.

[Illustration:

FIG. 4.—FIRST THORACIC VERTEBRÆ OF HORSE.

To illustrate plan of structure of vertebræ.]

The vertebræ in a given region have special characters by which they may be distinguished from those of other regions, and individual vertebræ have characters which are more or less clearly recognizable. All typical vertebræ have a common plan of structure, which must first be understood. The parts of which a vertebra consists are the =body= or =centrum=, the =arch=, and the =processes=.

The =body= (Corpus vertebræ) is the more or less cylindrical mass on which the other parts are constructed. The anterior and posterior extremities of the body are attached to the adjacent vertebræ by intervertebral fibro-cartilages, and are usually convex and concave respectively. The dorsal surface is flattened and enters into the formation of the vertebral canal, while the ventral aspect is rounded laterally, and is in relation to various muscles and viscera. In the thoracic region the body presents two pairs of demifacets (Foveæ costales) at the extremities for articulation with the heads of two pairs of ribs.

The =arch= (Arcus vertebræ) is constructed on the dorsal aspect of the body. It consists originally of two lateral halves, each of which is considered to consist of a pedicle and a lamina. The pedicles form the lateral parts of the arch, and are cut into in front and behind by the =vertebral notches= (Incisura vertebralis cranialis, caudalis). The notches of two adjacent vertebræ form =intervertebral foramina= for the passage of the spinal nerves and vessels; in some vertebræ, however, these are complete foramina instead of notches. The laminæ are plates which complete the arch dorsally, uniting with each other medially at the root of the spinous process.

The body and the arch form a bony ring which incloses the =vertebral foramen= (Foramen vertebrale); the series of vertebral rings, together with the ligaments which unite them, inclose the =vertebral canal= (Canalis vertebralis), which contains the spinal cord and its coverings and vessels.

The =articular processes=, two =anterior= and two =posterior= (Processus articulares craniales, caudales), project from the borders of the arch on either side. They present joint surfaces adapted to those of adjacent vertebræ, and the remaining surface is roughened for muscular and ligamentous attachment.

The =spinous process= (Processus spinosus) is single, and projects dorsally from the middle of the arch. It varies greatly in form, size, and direction in different vertebræ. It furnishes attachment to muscles and ligaments.

The =transverse processes= (Processus transversi) are two in number and project laterally from the side of the arch, or from the junction of the arch and body. In the thoracic region each has a facet for articulation with the tubercle of a rib (Fovea costalis transversalis). They also give attachment to muscles and ligaments.

Some vertebræ have also a =ventral= or =hæmal spine=.

=Mammillary processes= (Processus mammillares) are found in most animals on the last thoracic and anterior lumbar vertebræ between the transverse and anterior articular processes or on the latter.

=Accessory processes= (Processus accessorii), when present, are situated between the transverse and posterior articular processes.

=Development.=—The vertebræ are developed by ossification in the cartilage which surrounds the notochord and forms the sides of the neural canal. There are =three primary centers of ossification=, one for the body and one for each side of the arch. =Secondary centers= appear later for the summit of the spinous process (except in the cervical region), the extremities of the transverse processes, and the thin epiphyseal plates at the extremities of the body.

Sometimes there are at first two centers for the body which soon fuse. The process of ossification extends from the lateral centers to form not only the corresponding part of the arch, but also the processes and a part of the body next to the root of the arch (Radix arcus). In the horse and ox the body and arch are usually fused at birth, but the epiphyses do not fuse till growth is complete. In the pig, sheep, and dog the body and arch are united at birth by cartilage (neurocentral synchondrosis), but fuse in the first few months.

THE RIBS

The ribs (Costæ) are elongated curved bones which form the skeleton of the lateral thoracic walls. They are arranged serially in pairs which usually correspond in number to the thoracic vertebræ. Each articulates dorsally with the spine and is continued ventrally by a =costal cartilage=. Those which articulate with the sternum by means of their cartilages are termed =sternal= or ="true" ribs= (Costæ sternales s. veræ); the remainder are =asternal= or ="false" ribs= (Costæ asternales s. spuriæ). Ribs at the end of the series which have their ventral ends free in the abdominal wall are named =floating ribs= (Costæ fluctuantes). The intervals between the ribs are termed =intercostal spaces= (Spatia intercostalia).

A typical rib[4] consists of a =shaft= and two =extremities=. The =shaft= (Corpus costæ) is band-like and varies much in length, breadth, and curvature. In the case of some ribs the curvature is not uniform, but is most accentuated at a certain point, termed the =angle of the rib= (Angulus costæ); this occurs at a variable distance from the vertebral end, and is usually marked by a rough ridge. The direction also varies; the first rib is almost vertical, while the remainder slope backward in increasing degree. The =external= surface is convex, and the =internal= flattened from edge to edge; on the latter, close to the posterior border, is the =costal groove= (Sulcus costalis), which fades out ventrally. It contains the intercostal vein. The =anterior= and =posterior borders= are thin and sharp on some ribs, rounded on others.

The =vertebral extremity= (Extremitas vertebralis) consists of the =head=, =neck=, and =tubercle=. The =head= (Capitulum costæ) is the actual end of the rib, and is rounded and somewhat enlarged. It presents two facets (Facies articularis capituli costæ) for articulation with the bodies of two adjacent thoracic vertebræ; these surfaces are separated by a groove in which the conjugal ligament is attached. The =neck= (Collum costæ) joins the head to the shaft. It varies in length and diameter. Its outer surface is rough, its inner smooth. The =tubercle= (Tuberculum costæ) projects backward at the junction of the neck and shaft. It has a facet (Facies articularis tuberculi costæ) for articulation with the transverse process of the posterior vertebra of the two with which the head articulates. The tubercle gradually approaches the head in the posterior ribs, and eventually fuses with it.

The =sternal extremity= (Extremitas sternalis) is commonly slightly enlarged, and has a rough depression in which the costal cartilage is embedded.

=Development.=—The ribs are ossified in cartilage from three centers—one each for the shaft (and sternal end), head, and tubercle; the third center does not occur in the last two ribs.

THE COSTAL CARTILAGES

These (Cartilagines costales) are bars of hyaline cartilage which continue the ribs. Those of the sternal ribs articulate with the sternum, while the remainder overlap and are attached to each other to form the =costal arch= (Arcus costalis).

THE STERNUM

The =sternum= or breast-bone is a median segmental bone which completes the skeleton of the thorax ventrally, and articulates with the cartilages of the sternal ribs laterally. It consists of six to eight bony segments (Sternebræ) connected by intervening cartilage in the young subject. Its form varies with that of the thorax in general and with the development of the clavicles in animals in which they are present. Its anterior extremity, the =manubrium sterni= or =presternum=, is specially affected by the latter factor, being broad and strong when the clavicles are well developed and articulate with it (as in man), relatively small and laterally compressed when they are absent (as in the horse) or rudimentary (as in the dog). The cartilages of the first pair of ribs articulate with it. The =body= or =mesosternum= (Corpus sterni) presents laterally, at the junction of the segments, concave facets (Incisuræ costales) for articulation with the cartilages of the sternal ribs. The posterior extremity or =metasternum= presents the =xiphoid= (or ensiform) =cartilage= (Processus xiphoideus); this is thin and plate-like, as in the horse and ox, or narrow and short, as in the pig and dog.

=Development.=—The cartilaginous sternum is formed by the fusion medially of two lateral bars which unite the ventral ends of the first eight or nine costal cartilages, and is primitively unsegmented. The manubrium ossifies from a single center, but the centers for the other segments appear to be primitively paired. The sternum never becomes completely ossified; details in regard to persisting cartilage will be given in the special descriptions. The layer of compact tissue is for the greater part very thin and the spongy substance is open-meshed and very vascular.

THE THORAX

The skeleton of the thorax comprises the thoracic vertebræ dorsally, the ribs and their cartilages laterally, and the sternum ventrally. The =thoracic cavity= (Cavum thoracis) resembles in shape an irregular truncated cone; it is compressed laterally, especially in front, and the dorsal wall or roof is much longer than the ventral wall or floor. The =anterior aperture= (Apertura thoracis cranialis) is bounded by the first thoracic vertebra dorsally, the first pair of ribs and their cartilages laterally, and the manubrium sterni ventrally. The =posterior aperture= (Apertura thoracis caudalis) is bounded by the last thoracic vertebra, the last pair of ribs, the costal arches, and the anterior part of the xiphoid cartilage.

It may be noted here that the diaphragm (which forms the partition between the thoracic and abdominal cavities) does not follow the costal arches in its posterior attachment, so that the posterior ribs enter also into the formation of the abdominal wall.

THE SKULL

The term skull is usually understood to include all of the bones of the head. The head consists of the cranium and the face, and it is therefore convenient to divide the bones into cranial and facial groups.

The =cranial bones= (Ossa cranii) inclose the brain with its membranes and vessels and the essential organs of hearing. They concur with the facial bones in forming the orbital and nasal cavities, in which the peripheral organs of sight and of smell are situated.

The =facial bones= (Ossa faciei) form the skeleton of the oral and nasal cavities, and also support the larynx and the root of the tongue.

Most of the bones of the skull are flat bones, developed in membrane; those of the cranial base may be classed as irregular, and are cartilage bones. Only two form permanent movable joints with other parts of the skull. The mandible or lower jaw-bone forms diarthrodial joints with the temporal bones, and the hyoid bone is attached to the latter by bars of cartilage. The other bones form immovable joints, most of which disappear with age.

In order to study the separate bones, skulls of young subjects are necessary, since later most of the lines of demarcation become effaced. The relations of each bone to its surroundings should be specially noted, since the final object is to understand the skull as a whole. In the descriptions which follow the skull is considered with its long axis horizontal, and that of the horse will serve as a type.

THE BONES OF THE THORACIC LIMB

The thoracic limb consists of four chief segments, viz., the shoulder girdle, the arm, the forearm, and the forefoot or manus.

The =shoulder girdle= (Cingulum extremitatis thoracicæ), when fully developed, consists of three bones—the =scapula= or shoulder-blade, the =coracoid=, and the =clavicle= or collar-bone. In the domesticated mammals only the scapula, a large, flat bone, is well developed, and the small coracoid element has fused with it, while the clavicle is either absent or is a small rudiment embedded in the mastoido-humeralis muscle. There is therefore no articulation of the shoulder with the axial skeleton.

The shoulder girdle is fully developed in birds and the lower mammals (monotremata). In the higher mammals the coracoid is reduced to the coracoid process of the scapula, and the development of the clavicle is in conformity with the function of the limb. Thus in typical quadrupeds, such as the horse and ox, in which the forelimbs are used only for support and locomotion, the clavicle is absent. Other animals which use these limbs for grasping, burrowing, climbing, etc. (_e.g._, man, apes, moles), have well-developed clavicles which connect the scapula with the sternum.

The =arm= (Brachium) contains a single long bone, the humerus or arm bone.

In the =forearm= (Antibrachium) are two long bones, the =radius= and =ulna=. These vary in relative size and mobility. In the horse and ox the two bones are fused, and the lower part of the limb is fixed in the position of pronation. The radius is placed in front and supports the weight. The ulna is well developed only in its upper part, which forms a lever for the extensor muscles of the elbow. In the pig the ulna is the larger and longer of the two bones, but is closely attached to the back of the radius. In the dog the ulna is also well developed and a small amount of movement is possible between the two bones.

The =forefoot= or =hand= (Manus) consists of three subdivisions, viz., the =carpus=, =metacarpus=, and =digit= or =digits=.

The =carpus=, popularly termed the “knee” in animals, and homologous with the wrist of man, contains a group of short bones (Ossa carpi). These are typically eight in number and are arranged in two transverse rows—a proximal or antibrachial, and a distal or metacarpal. The bones of the proximal row, named from the radial to the ulnar side (_i. e._, from within outward), are the =radial=, =intermediate=, =ulnar=, and =accessory= carpal bones. The bones of the distal row are designated numerically, in the same direction, as =first=, =second=, =third=, and =fourth= carpal bones.

This nomenclature, introduced by Gegenbaur, and now used largely by comparative anatomists, seems decidedly preferable to the variety of terms borrowed from human anatomy and based on the form of the bones in man. The following table of synonyms in common use is appended for comparison. The Latin terms and abbreviated notations are given in parenthesis.

Radial (Os carpi radiale, Cr) Scaphoid Intermediate (Os carpi intermedium, Ci) Semilunar Ulnar (Os carpi ulnare, Cu) Cuneiform Accessory (Os carpi accessorium, Ca) Pisiform First carpal (Os carpale primum, C1) Trapezium Second carpal (Os carpale secundum, C2) Trapezoid Third carpal (Os carpale tertium, C3) Os magnum Fourth carpal (Os carpale quartum, C4) Unciform

The central carpal bone (Os carpi centrale) is omitted, since it is not a separate element in the animals under consideration here.

The =metacarpus= contains typically five =metacarpal bones= (Ossa metacarpalia I–V), one for each digit; they are long bones and are designated numerically from within outward. This arrangement occurs in the dog, although the first metacarpal is much smaller than the others, and the second and fifth are somewhat reduced. Further reduction has taken place in the other animals, resulting in the perissodactyl and artiodactyl forms. In the horse the first and fifth metacarpals are absent, the third is the large supporting metacarpal bone and carries the single digit, while the second and fourth are much reduced. In artiodactyls (_e. g._, ox, sheep, pig) the third and fourth are the chief metacarpals and carry the well developed digits; they are fused in the ox and sheep. The others are variously reduced or absent as noted in the special descriptions to follow.

The fossil remains of the ancestors of the existing Equidæ illustrate in a most complete manner the reduction which has occurred in this respect. The earliest known ancestor of the horse, Eohippus or Hyracotherium of the Lower Eocene, had four well developed metacarpal bones, each of which carried a digit; the first metacarpal bone was small. Eleven intermediate stages show the gradual evolution of the race from this primitive animal, which was about the size of the domestic cat. There is reason to believe that earlier forms had five digits.

The =digits= (Digiti manus) are homologous with the fingers of man, and are typically five in number. They are designated numerically from the radial to the ulnar side, in correspondence with the metacarpus. The full number is present in the dog. In the ox and pig the third and fourth are well developed and support the weight, while the second and fifth are reduced. The existing horse has a single digit, the third of his polydactyl ancestors. The skeleton of each fully developed digit consists of three

=phalanges= and certain =sesamoid bones=. The =first= or =proximal phalanx= (Phalanx prima) articulates with the corresponding metacarpal bone above and with the =second= or =middle phalanx= (Phalanx secunda) below. The =third= or =distal phalanx= (Phalanx tertia) is inclosed in the hoof or claw, and is modified to conform to the latter. The =sesamoid bones= (Ossa sesamoidea) are developed along the course of the flexor tendons or in the joint capsules. Two =proximal sesamoids= (Ossa sesamoidea phalangis primæ) occur at the flexor side of the metacarpo-phalangeal joint and form a pulley for the flexor tendon. The =distal sesamoids= (Ossa sesamoidea phalangis tertiæ) are similarly placed between the deep flexor tendon and the joint between the second and third phalanx; they are absent in the dog, which has a small sesamoid on the extensor side of the metacarpo-phalangeal joints, and often at the proximal interphalangeal joint also.

Numerous cases are recorded of the occurrence of supernumerary digits (hyperdactylism) in the horse and other animals. In some pigs, on the other hand, the two chief digits are fused, and the condition appears to be inherited.

THE BONES OF THE PELVIC LIMB

The pelvic limb, like the thoracic, consists of four segments, viz., the pelvic girdle, thigh, leg, and the hind foot or pes; the last is subdivided into tarsus, metatarsus, and digits.

The =pelvic girdle= (Cingulum extremitatis pelvinæ) consists of the =os coxæ= or hip bone, which joins its fellow of the opposite side ventrally at the symphysis pelvis, and articulates very firmly with the sacrum dorsally. The two coxal bones, together with the sacrum and the first two or three coccygeal vertebræ, constitute the bony pelvis. The os coxæ consists originally of three flat bones, the =ilium=, =ischium=, and =pubis=, which meet at the acetabulum, a large cotyloid cavity that articulates with the head of the femur. These three parts are fused before growth is complete, but are considered separately for convenience of description. The =ilium= (Os ilium) is situated in the lateral wall of the pelvis, the =pubis= (Os pubis) in the anterior part, and the =ischium= (Os ischii) in the posterior part of the ventral wall.

The =thigh= (Femur), like the arm, contains a single large, long bone, the =femur= or thigh bone (Os femoris). This articulates with the acetabulum above and the tibia and patella below.

The skeleton of the leg (Crus) comprises three bones (Ossa cruris), viz., the =tibia=, =fibula=, and =patella=. The =tibia= is a large prismatic long bone which supports the weight, and articulates below with the tibial tarsal bone. The =fibula= is situated along the outer border of the tibia, from which it is separated by the =interosseous space= of the leg. It is much more slender than the tibia and does not articulate with the femur. In the pig and dog it has a complete shaft and two extremities, but in the horse and ox it is much reduced and otherwise modified. The =patella= or “knee-cap” is a short bone which articulates with the trochlea of the distal end of the femur; it is to be regarded as a large sesamoid bone intercalated in the tendon of the quadriceps femoris muscle.

The =tarsus= or “hock” consists of a group of short bones (Ossa tarsi) numbering five to seven in the different animals. The proximal or crural row consists of two bones, the =tibial= and =fibular tarsals=; the former is situated at the inner or tibial side, and has a trochlea for articulation with the distal end of the tibia; the latter, situated externally, has a process, the =tuber calcis=, which projects upward and backward and constitutes a lever for the muscles which extend the hock joint. The distal or metatarsal row consists of four bones when seven tarsal elements are present, as in the pig and dog. They are best designated numerically as =first tarsal=, =second tarsal=, etc. The =central tarsal= is interposed between the rows.

The preceding terms are anglicized abbreviations of those introduced by Gegenbaur into comparative anatomy. The Latin names and synonyms are given in the following table.

Tibial (Os tarsi tibiale, Tt.) Astragalus or Talus Fibular (Os tarsi fibulare, Tf.) Calcaneus or Os calcis Central (Os tarsi centrale, Tc.) Scaphoid or Navicular First Tarsal (Os tarsale primum, T1) First or internal cuneiform Second Tarsal (Os tarsale secundum, T2) Second or middle cuneiform Third Tarsal (Os tarsale tertium, T3) Third or external cuneiform Fourth Tarsal (Os tarsale quartum, T4) Cuboid.

The =metatarsal= and =digital bones= resemble in general those of the corresponding regions of the thoracic limb; the differential features will be noted in the special descriptions.

[Illustration:

FIG. 5.—SKELETON OF HORSE, WITH OUTLINE OF CONTOUR OF BODY.

_1.H._, Atlas; _7.H._, seventh cervical vertebra; _1.R._, first thoracic vertebra; _17.R._, seventeenth thoracic vertebra; _1.L._, first lumbar vertebra; _6.L._, sixth lumbar vertebra; _K_, sacrum; _1.S._, first coccygeal vertebra; _16.S._, sixteenth coccygeal vertebra; _6.R._, sixth rib; _6.K._, costal cartilage; _18.R._, last rib; 1, scapula; 1′, cartilage of scapula; 2, spine of scapula; 4, humerus; 4′ external epicondyle of humerus; 5, external tuberosity of humerus; 6, deltoid tuberosity; 7, shaft of ulna; 8, olecranon; 9, radius; 10, carpus; 11, accessory carpal bone; 12, metacarpus; 13, digit; 14, sternum; 14″, xiphoid cartilage; 15, ilium; 16, 16′, external and internal angles of ilium; 17, ischium; 18, femur (shaft); 19, trochanter major; 27, trochanter minor; 28, trochanter tertius; 20, patella; 21, tibia (shaft); 21′, external condyle of tibia; 23, fibula; 22, tarsus; 24, tuber calcis; 25, metatarsus; 26, digit. (After Ellenberger-Baum, Anat. für Künstler.)]

THE SKELETON OF THE HORSE

The skeleton of the horse consists of 205 bones, as shown in the following table.

Vertebral column 54 Ribs 36 Sternum 1 Skull (including auditory ossicles) 34 Thoracic limbs 40 Pelvic limbs 40 ———— 205

In this enumeration the average number of coccygeal vertebræ is taken to be 18, the temporal and os coxæ are not divided into parts, the usual number of carpal and tarsal elements is taken, and the sesamoids are included.

THE VERTEBRAL COLUMN

The vertebral formula of the horse is $C_{7}T_{18}L_{6}S_{5}Cy_{15–21}$.

[Illustration:

FIG. 6.—CERVICAL VERTEBRÆ OF HORSE, DORSAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 7.—CERVICAL VERTEBRÆ OF HORSE, VENTRAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE CERVICAL VERTEBRÆ

These are quadrangular, massive, and longer than the vertebræ of other regions; they decrease in length from the second to the last. The =third=, =fourth=, and =fifth= are typical, and have the following characters:

1. The =bodies= are long as compared with those of other vertebræ. Each presents a median =ventral spine= or =crest=, which becomes more prominent as it is traced backward, and is tuberculate at its posterior end. The =lateral aspect= is concave. The =dorsal surface= has a flat central area which is narrow in the middle of the vertebræ, and wide at either end; it gives attachment to the superior common ligament. On either side of this area is a groove which lodges the longitudinal spinal vein. These lateral grooves are connected at the middle of the surface by a transverse furrow, in which there are several foramina through which veins emerge from the spongy substance of the body. The =anterior extremity= presents a head which has an oval articular surface, strongly convex, and wider above than below. The =posterior extremity= is larger and has a nearly circular cotyloid cavity.

[Illustration:

FIG. 8.—LAST CERVICAL AND FIRST THORACIC VERTEBRÆ OF HORSE, LATERAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

2. The =arches= are large and strong. They are perforated on either side by a foramen which communicates with the foramen transversarium. The vertebral notches are large.

3. The =articular processes= are large. Their articular surfaces are extensive, oval in outline, and slightly concave; the anterior ones are directed upward and inward, the posterior downward and outward. The remaining surface is mainly roughened for ligamentous and muscular attachment. A crest connects the articular processes of the same side on the fourth and fifth; on the third it does not reach the anterior process.

4. The =transverse processes= are large and plate-like. Each arises by two roots, one from the arch and one from the body; between these is the =foramen transversarium=, through which the vertebral artery passes. The process divides externally into

anterior and posterior branches, which are thickened and rough for muscular attachment.

5. The =spinous process= is represented by a crest (Crista spinosa), which widens behind, and is connected by ridges with the posterior articular processes.

The =sixth= cervical vertebra has the following distinctive features: It is shorter and wider than the fifth. The =arch= is large, especially posteriorly. The =posterior articular= processes are shorter, thicker and further apart; they are connected with the anterior ones by a thick ridge. The =spinous process= is less rudimentary; it is half an inch or more (ca. 1.5 cm.) in height. The =transverse processes= have three branches; the third part is a thick, almost sagittal plate, which forms with its fellow and the body a wide ventral groove on the posterior part of the vertebra; the other branches correspond to those of the typical vertebræ, but are short and thicker. The =foramen transversarium= is large; below its posterior end is a fossa. The =ventral crest= is small and is less prominent posteriorly.

The third branch of the transverse process and the fossa are sometimes absent on one side.

The =seventh= cervical vertebra is readily distinguished by the following characters: It is =shorter= and =wider= than the others. The =body= is flattened dorso-ventrally and wide, especially behind; here it has a =demifacet= on either side for articulation with part of the head of the first rib. The =arch= and its =notches= are large. The =anterior articular processes= are wider and longer than the posterior pair. The =spinous process= is an inch or more (ca. 3 cm.) in height. The =transverse process= is undivided, and has no foramen transversarium. The ventral crest is replaced by a pair of tubercles.

In some specimens a large foramen transversarium is present on one side or (rarely) on both.

[Illustration:

FIG. 9.—ATLAS OF HORSE, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 10.—ATLAS OF HORSE, POSTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE ATLAS

This vertebra is decidedly atypical in form and structure. The body and spinous process are absent. It has the form of a strong ring, from which two curved plates, the =wings=, project laterally. The ring incloses a very large vertebral foramen, and consists of two =lateral masses= connected by =dorsal= and =ventral arches=.

The =lateral masses= (Massæ laterales) present two deep oval =anterior articular cavities= (Foveæ articulares craniales) which receive the occipital condyles; they are separated by a wide notch above and a narrow one below. The outer margin is also notched, and a triangular non-articular depression cuts into the inner part of each cavity. The =posterior articular surfaces= (Facies articulares caudales) are somewhat saddle-shaped; they are confluent on the ventral arch below, but are widely separated above, and do not conform in shape to the corresponding surfaces of the axis.

The =dorsal arch= (Arcus dorsalis) presents a median =dorsal tubercle= (Tuberculum dorsale) and is concave below. It is perforated on either side near its anterior margin by the =intervertebral foramen=. The =anterior border= is deeply notched, and the =posterior= is thin and concave.

The =ventral arch= (Arcus ventralis) is thicker, narrower, and less curved than the dorsal. On its lower surface is the =ventral tubercle= (Tuberculum ventrale), into which the terminal tendon of the longus colli muscle is inserted. The upper face has posteriorly a transversely concave articular surface (Fovea dentis), on which the dens or odontoid process of the axis rests. In front of this is a transverse rough excavation for the attachment of the odontoid ligament.

The =wings= (Alæ) are modified transverse processes. They are extensive curved plates which project outward, downward, and backward from the lateral masses. The dorsal surface is concave. Between the ventral aspect of the wing and the lateral mass is a cavity, the =fossa atlantis=; in this there is a foramen which opens into the vertebral canal. The =border= is thick and rough. Two foramina perforate each wing. The anterior one, the =foramen alare=, is connected with the intervertebral foramen by a short groove. The posterior one is the =foramen transversarium=.

=Development.=—The atlas ossifies from =three= or =four centers=, one or two for the ventral arch, and one on either side for each lateral mass, wing, and half of the dorsal arch. At birth the bone consists of three pieces—the ventral arch and two lateral parts, which are separated by a layer of cartilage in the dorsal median line. These parts are usually fused at about six months.

[Illustration:

FIG. 11.—FIRST THREE CERVICAL VERTEBRÆ OF HORSE, LATERAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE AXIS

The =axis= (Epistropheus) is the longest of the vertebræ, and is characterized by the presence of the odontoid process, which projects from the anterior part of the body.

The =body= has a median ventral crest which terminates in a tubercle behind. The anterior extremity presents centrally the =odontoid process= (Dens); this has a convex articular surface ventrally for articulation with the ventral arch of the atlas, and two rough depressions for the attachment of the odontoid ligament dorsally. Flanking this on either side are the modified =anterior articular processes=, which have saddle-shaped articular surfaces confluent below with that of the dens. The posterior extremity has the usual cavity.

The =arch= presents in the young subject a notch on each side of its anterior border; this is converted into a foramen by a ligament which usually ossifies later. The posterior border has the usual notches.

The =posterior articular processes= are typical.

The =transverse processes= are small, single, and project backward. The =foramen transversarium= is small.

The =spinous process= is very large and strong. Its free border is rough, thickens posteriorly, and is continued to the articular processes by two ridges. The lateral surfaces are concave and rough for muscular attachment.

=Development.=—The axis has =six= or =seven centers= of ossification. In addition to the usual five, one or two appear for the dens, which is regarded as the displaced body of the atlas. A nucleus behind the dens, which remains distinct to three or four years of age, is considered by Lesbre to be the head of the axis.

[Illustration:

FIG. 12.—OCCIPITAL BONE AND FIRST THREE CERVICAL VERTEBRÆ OF HORSE, DORSAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE THORACIC VERTEBRÆ

These (Vertebræ thoracales) are usually eighteen in number in the horse, but there are sometimes nineteen, rarely seventeen. As regional characters we note the surfaces for articulation with the ribs and the length and form of the spinous processes. Those in the middle of the series are the most typical and present the following features:

1. The =bodies= are short and constricted in the middle. The ends are expanded and have articular surfaces which are not strongly curved. On the upper part of each side are anterior and posterior =costal facets= (Fovea costalis cranialis, caudalis), which, with those of adjacent vertebræ, form sockets for the heads of the ribs.

2. The =arches= are small. Their posterior notches are relatively large and are often converted into foramina.

[Illustration:

FIG. 13.—THIRD, FOURTH, AND FIFTH THORACIC VERTEBRÆ OF HORSE, LATERAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

3. The =articular processes= are small. The anterior pair are in fact represented only by two oval facets on the anterior part of the laminæ which face almost directly upward. The posterior pair spring from the base of the spinous process; their facets face almost directly downward.

4. The =transverse processes= are short, thick, and tuberous at the free end. Each has a =facet= (Fovea transversaria) for articulation with the tuberosity of the rib which has the same serial number.

5. The =spinous process= is large, narrow, and slopes upward and backward. The anterior border is thin, the posterior wider and furrowed. The summit is expanded and rough.

The =first thoracic vertebra= is easily recognized by the following specific characters: The body is wide and flattened dorso-ventrally. In front it has a head like the cervical vertebræ, and behind a cavity somewhat deeper than any other thoracic vertebra. Two =costal facets= are found on either side, and a well-marked spine ventrally. The =arch= is large and strong, and has large notches. The =articular processes= are much larger than those of other thoracic vertebræ, and resemble a good deal those of the seventh cervical in form. The =transverse processes= are short and thick, and each has on its ventral aspect a large concave facet for articulation with the tubercle of the first rib. The spinous process is curved backward and tapers to a point. Its length is usually about three or four inches (ca. 8 to 10 cm.). It may be mistaken at first glance for the last cervical, but is promptly identified by the three costal facets on each side and the length of the spine.

The =last thoracic vertebra= is distinguished by the absence of the posterior pair of costal facets, and the confluence of the anterior pair with those on the transverse processes.

[Illustration:

FIG. 14.—THIRD THORACIC VERTEBRÆ AND UPPER PART OF RIB OF HORSE, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 15.—LOWER PART OF NINTH THORACIC VERTEBRA OF HORSE, POSTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The serial position of others may be determined at least approximately by the following data: (1) The bodies gradually diminish in length and width to the middle of the region and then increase slightly. Their costal facets become smaller and less concave from first to last. The ventral crest is distinct on three or four vertebræ at either end of the region. (2) The transverse processes diminish in size and are placed lower down as they are traced backward. Their costal facets become smaller and lower in position; on the last (and sometimes on its predecessor also) it fuses with the costal facet of the body. The upper non-articular part of the process gradually becomes more sharply defined, and in the last four or five separates to form the =mammillary process=. (3) The spinous processes increase in length to the third and fourth, and then gradually diminish to the fifteenth, beyond which they have about the same length. The backward inclination is most pronounced in the second, the sixteenth is vertical, and the last two are directed a little forward. The longest spines (_i. e._, those of the withers) are the thickest and have expanded summits which remain more or less cartilaginous; the others are more plate-like, and are surmounted by a thick lip. The second spine is more than twice as large as the first. The summits of the fourth and fifth usually form the highest point of the withers.

=Development.=—There are =six= or =seven centers=, three for the body, two for the arch, and one for the spinous process; some of the latter have an additional center for the summit.

THE LUMBAR VERTEBRÆ

The =lumbar vertebræ= (Vertebræ lumbales) are usually six in number in the horse. They are characterized by the size and form of their transverse processes.

The =bodies= of the first three are triangular on cross-section, and present a distinct ventral crest. From the fourth backward they become wider and flatter and the ventral crest fades out.

[Illustration:

FIG. 16.—FIRST THORACIC VERTEBRA AND UPPER PART OF FIRST RIB OF HORSE, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =arches= of the first two or three are about equal in size and similar to that of the last thoracic; from the fourth they decrease noticeably in breadth and height.

[Illustration:

FIG. 17.—LAST TWO THORACIC AND FIRST LUMBAR VERTEBRÆ OF HORSE, LATERAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =anterior articular processes= are fused with the mammillary processes, and present superiorly concave surfaces for articulation with the posterior pair of the preceding vertebra. The =posterior articular processes= project distinctly from the arch at the base of the spinous process, and have ventrally convex articular surfaces, which fit into the grooved surfaces of the anterior pair of the next vertebra.

The =transverse processes= are large plates, flattened dorso-ventrally, which project outward and usually curve slightly downward; their length increases to the third and fourth, and then diminishes to the last, which is the shortest. The first one or two usually curve somewhat backward, the last two decidedly forward. Those of the fifth have an oval concave facet on the inner part of the posterior border for articulation with the sixth process; the latter has a corresponding convex facet on the anterior border, and a larger concave surface on the posterior border for articulation with the wing of the sacrum. Sometimes the fifth process has a small surface for articulation with the fourth. The inner part of the sixth process is thick, the outer part thinner, narrower, and curved forward. The inner part of the fifth is also somewhat thickened.

The =spinous processes= resemble those of the last two thoracic vertebræ. They are usually about equal in height, but minor differences are common, and the width diminishes in the last three.

=Development.=—This is similar to that of the thoracic vertebræ. The extremities of the transverse processes remain cartilaginous for some time after ossification is otherwise complete.

[Illustration:

FIG. 18.—SECOND LUMBAR VERTEBRA OF HORSE, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The transverse processes of this region are considered equivalent to the proper transverse process + the costal element, and hence the distinctive term processus lateralis (s. costarius) has been proposed. The occurrence of a lumbar rib in connection with the transverse process of the first lumbar is not rare. Reduction of the number to five has been observed frequently, and may or may not be compensated by an additional thoracic vertebra. This variation is not more common in certain races as Sanson and others have maintained. Very few cases are recorded of seven lumbar vertebræ—especially with the normal thoracic number. An anomalous vertebra with mixed thoracic and lumbar characters sometimes occurs at the junction of the two regions.

THE SACRUM

The =sacrum= (Os sacrum) is formed by the fusion of five vertebræ usually, and is conveniently described as a single bone. It is triangular in form and is wedged in between the ilia, with which it articulates very firmly on each side. Its long axis is gently curved, and slightly oblique, so that the posterior end is a little higher than the anterior. It presents two surfaces, two borders, a base, and an apex.

The =dorsal surface= presents centrally the five sacral spines, which are directed upward and backward, and have (with the exception of the first) tuberous summits which are sometimes bifid.

The first spine is relatively thin and narrow, and is not so high as the internal angle of the ilium. The second is the longest, and the height diminishes rapidly to the last. The bases of the spines are often fused in old subjects.

On either side of the spines is a groove, in which are the four =dorsal sacral foramina= (Foramina sacralia dorsalia); the dorsal branches of the sacral nerves emerge through them.

The =ventral= or =pelvic surface= (Facies pelvina) is concave in its length, wide in front, narrow behind. It is marked by four more or less distinct =transverse lines= (Linæ transversæ), which indicate the demarcation of the bodies of the vertebræ. At the ends of these lines are the =ventral sacral foramina= (Foramina sacralia ventralia), which are larger than the dorsal series and diminish in size from first to last; they transmit the ventral divisions of the sacral nerves.

The dorsal and ventral foramina communicate with the sacral canal and are together equivalent to the usual intervertebral foramina.

[Illustration:

FIG. 19.—SACRUM OF HORSE, DORSO-LATERAL VIEW.

_C_, Body of first sacral vertebra; _A_, arch of first vertebra; _Cs_, sacral canal; _P.s._ 1–5, sacral spines; _P.t._, wings of sacrum; 1, 1′, surfaces for articulation with transverse processes of last lumbar vertebra; _F.a._, auricular surface; 2, 2′, articular processes; 3–6, dorsal sacral foramina; 7, interarcuate space; 8, lateral border; _h_, apex. (Struska, Anat. d. Haustiere.)]

The =lateral borders= are rough, thick in front, thin behind.

The =base= (Basis ossis sacri) is directed forward, and is relatively very wide. It presents centrally the =body= of the first sacral segment, which is wide transversely, flattened dorso-ventrally, and has a rounded surface which articulates with the last lumbar vertebra through the medium of an intervertebral fibro-cartilage. The ventral margin projects slightly, forming the =promontory= (Promontorium). Above the body is the entrance to the sacral canal, flanked by a pair of =articular processes=, which project upward and forward from the arch, and have concave surfaces internally for articulation with those of the last lumbar vertebra. On each side of these is a smooth notch which is converted into a foramen by apposition with the last lumbar. The lateral parts of the base, the =wings= or =alæ= (Alæ sacrales), are strong prismatic masses with pointed ends, which result from the fusion of the first with part of the second transverse process. Each has in front a large, oval, slightly convex surface for articulation with the transverse process of the last lumbar. Posteriorly there is an elongated oval area which faces upward, backward, and outward. This is the =auricular surface= (Facies auricularis), which articulates with the ilium; it is slightly concave in its length, and somewhat rough and irregular. The rest of the dorsal surface of the wing is roughened for ligamentous attachment, while the ventral surface is smooth.

The =apex= (Apex ossis sacri) is the posterior aspect of the last sacral vertebra and is quite small. It presents the elliptical flattened surface of the body, above which is the triangular posterior opening of the sacral canal, surmounted by the last sacral spine. There is a pair of narrow notches between the arch and body, above which rudiments of articular processes may occur.

The name =sacral canal= (Canalis sacralis) is applied to that part of the vertebral canal which traverses the sacrum. Its anterior part is large and has the form of a triangle with the angles rounded off; its width is about twice its height. Traced backward it is seen to diminish in size rapidly, and the posterior opening is quite small and triangular.

The term =lateral part= (Pars lateralis) designates the portion external to the foramina, which results from the fusion of the transverse processes.

[Illustration:

FIG. 20.—FIRST COCCYGEAL VERTEBRA OF HORSE, LEFT VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 21.—FIRST COCCYGEAL VERTEBRA OF HORSE, DORSAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

=Development.=—The several sacral vertebræ ossify in the typical manner. Separate centers for costal elements in the lateral parts have not yet been found in the domesticated animals. Fusion begins in front, and is usually not complete behind till near adult age. The lateral parts unite before the bodies. It is rather curious that the epiphyseal plates of adjacent segments unite with each other before they fuse with the main portion of the bodies.

THE COCCYGEAL VERTEBRÆ

These (Vertebræ coccygeæ) vary considerably in number, but eighteen may be taken as an average. From first to last they become reduced in size and, with the exception of a few at the beginning of the series, consist of bodies only. The first three have bodies which are somewhat flattened dorso-ventrally, constricted in the middle, and have at the ends slightly convex, elliptical, articular surfaces. The ventral surface has a median groove for the coccygeal artery. The arch is small and triangular; it is formed of two flat plates which are prolonged to form a short spinous process with a thickened and often double summit. The anterior notches are absent. Functional articular processes are not present, but small rudiments of the anterior pair commonly occur. The transverse

processes are relatively large plates which project horizontally outward. Further back the arch becomes incomplete, open above, and soon disappears; the transverse processes gradually fade out, and the vertebræ are reduced to cylindrical rods of diminishing size. The last one has a pointed end.

=Variations.=—The number is said by good observers to vary between fourteen and twenty-one. In old age the first is often fused with the sacrum, and sometimes with the second. The arch of the third may be open.

THE VERTEBRAL COLUMN AS A WHOLE

In the mid-dorsal line is the series of =spinous processes=, which are low ridges in the cervical region with the exception of the second and seventh, reach their maximum height at the fourth and fifth thoracic vertebræ, and diminish to the fifteenth or sixteenth thoracic. Behind this they are about equal in height as far as the last lumbar and first sacral, which are somewhat lower. The second sacral spine is about as high as the middle lumbar; behind this they diminish rather rapidly in height and fade out about the third coccygeal. Their =inclination= backward is most decided at the second thoracic, diminishes from the sixth or seventh to the fifteenth or sixteenth, which is vertical and is termed the =anticlinal= or =diaphragmatic vertebra.= Behind this they are inclined a little forward until the sacrum is reached; here there is an abrupt change to the backward inclination, so that a considerable interspinous angle is formed.

On either side of the spinous processes is a =vertebral groove= which contains the deep muscles of the spine. The floor of the groove is formed by the laminæ and articular processes. It is wide in the neck and narrows progressively in the back.

Viewed from the side, the column presents a series of curves. When the head and neck are in the ordinary neutral position, the anterior part of the cervical spine forms a gentle curve, concave ventrally. The posterior cervical and first thoracic vertebræ form a more pronounced curve in the opposite direction. At the junction of the cervical and thoracic regions there is a marked change of direction, forming a ventral projection or angle. At the second thoracic vertebra a gentle curve, concave ventrally, begins. This is continued to the lumbo-sacral junction, where there is a change of direction, and hence a promontory. The sacrum has a variable, but never very pronounced, ventral concave curvature, which is continued in a much accentuated form in the coccygeal region. It may be remarked that a line through the summits of the spines does not correspond to these curves formed by the bodies.

The =vertebral canal=, of course, corresponds in curvature to the bodies. Its =caliber= varies greatly at different points. The greatest diameter (ca. 5 cm.) is in the atlas, where it contains the dens of the axis in addition to the spinal cord, and provision must be made for extensive movement. It is very much smaller in the axis (ca. 2.5 cm. wide, 3 cm. high). It widens considerably at the junction of the cervical and thoracic regions to accommodate the cervical enlargement of the spinal cord. Beyond this it diminishes, and is smaller in the middle of the back than at any preceding point; this is correlated with the small size of the spinal cord and the very limited movement of the spine. At the middle of the lumbar region it again widens considerably to contain the lumbar enlargement of the spinal cord. The caliber diminishes very rapidly from the second sacral segment backward, and the canal ceases to be complete at the fourth coccygeal vertebra.

The =articular processes= are very large and wide apart in the neck, greatly reduced and much closer together in the back, larger and interlocking in the lumbar region.

The =transverse processes= are large and outstanding in the neck, where they form the outer boundary of a ventral groove occupied by the longus colli muscle. In the back they are short and stout, and are characterized by the facets for the tubercles of the ribs. On the first thoracic vertebra this facet is large, deeply concave, and situated almost directly outward from the cavity for the head of the rib; traced backward it becomes smaller and flatter, and gradually comes to lie behind the cavity for the head of the rib, with which it is fused on the last and often also on the next to the last thoracic vertebra. The processes in the lumbar region have a characteristic elongated plate-like form. In the sacral region they are fused to form the wings and lateral parts of the sacrum. In the coccygeal region they are at first of considerable size relatively, but undergo rapid reduction, and disappear at the fifth or sixth vertebra.

The cavities for the heads of the ribs diminish progressively in size and depth from first to last.

The =mammillary processes= are usually distinct on the fourteenth to the seventeenth thoracic vertebræ. In front of these they blend with the transverse, behind with the anterior articular processes.

The length of the vertebral column (including the intervertebral fibro-cartilages) in a horse of medium size is about 260 to 265 cm. (ca. 8 feet 8 inches to 8 feet 10 inches). The relative lengths of the various regions appear to vary most in the neck and back.

The table below gives the measurements in centimeters in a trotting stallion of medium size and in an adult Percheron stallion. The percentages are in round numbers.

■■■

inclines a little forward, the second is about vertical, while behind this they slope backward in increasing degree, so that a plane tangent to the ventral ends of the last pair cuts the third lumbar vertebra. The =head= and =tubercle= diminish in size from first to last. Their relative positions change in that the tubercle of the first rib lies almost directly outward from the head, while further back it gradually comes to lie behind it. The =neck= is longest on the longest ribs, and is absent on the last two or three. A costo-transverse foramen is formed between the neck and the transverse process.

=Development.=—The ribs ossify in cartilage from =three centers=, one each for the shaft, head, and tubercle; the third center is absent in some of the posterior ribs.

=Variations.=—A nineteenth rib on one side or both is not rare. It is usually imperfectly developed and quite variable. In some cases it is a mere strip of cartilage connected by ligament with the first lumbar transverse process; in other cases it is ossified, and may be fused with the process; in others again it is connected with an additional presacral vertebra which may be thoracic or lumbar or ambiguous in character. It is commonly floating, but may be attached to the eighteenth. Reduction in number is uncommon. Fusion of adjacent ribs sometimes occurs.

THE COSTAL CARTILAGES

[Illustration:

FIG. 23.—STERNUM AND COSTAL CARTILAGES OF HORSE, VENTRAL VIEW. (After Ellenberger-Baum, Anat. f. Künstler.)]

The first costal cartilage is an inch or more (2.5 to 3 cm.) in length. The upper part is very wide and thick. The sternal end is small. The two articulate with each other as well as with the sternum. The cartilages of the other sternal ribs increase progressively in length and become more rounded. The sternal end is expanded and has an elliptical convex facet for articulation with the sternum. The cartilages of the asternal ribs are long, slender, and pointed. The ninth is the longest, and is very firmly attached to the eighth; behind this they diminish progressively in size, and are attached to each other by elastic tissue. Except in the case of the first, the cartilage does not continue the direction of the rib, but forms with the latter an angle which is open in front, and decreases in obtuseness from second to last.

More or less extensive ossification is to be regarded as a normal occurrence, especially in the cartilages of the sternal ribs.

THE STERNUM

The sternum of the horse is shaped somewhat like a canoe; it is compressed laterally, except in its posterior part, which is flattened dorso-ventrally. It is inclined obliquely so that the posterior end is about six to eight inches (15 to 20 cm.) lower than the anterior.

The =dorsal surface= has the form of a very narrow isosceles triangle with the apex in front. It is concave longitudinally, flattened transversely.

The =lateral surfaces= are convex above, slightly concave below, and diminish in extent behind. Each presents on its upper part seven =articular cavities= (Foveæ costales), which receive the sternal ends of the second to the eighth costal cartilages inclusive. These cavities are situated in series at the intersternebral junctions. The first four are elliptical in outline with the long diameter vertical, and are separated by considerable regular intervals. The others are progressively smaller, more circular, and closer together. The area below these cavities gives attachment to the pectoral muscles.

[Illustration:

FIG. 24.—STERNUM OF HORSE, LATERAL VIEW.

The sternebræ are designated by Roman numerals and the costal facets by ordinary figures.]

The =dorso-lateral= borders separate the dorsal and lateral surfaces. They give attachment to the lateral branches of the sternal ligament.

The =ventral border= forms the prominent keel-like crest of the sternum (Crista sterni) which may be felt in the living animal; it fades out behind.

[Illustration:

FIG. 25.—ANTERIOR APERTURE OF THORAX OF HORSE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =anterior extremity= or =manubrium sterni=[5] can be distinctly felt in the central furrow of the breast. It consists of a laterally compressed cartilaginous prolongation, commonly called the =cariniform cartilage=. Its lateral surfaces are flat and furnish attachment to muscles of the breast and neck. The ventral border is rounded, and is continued backward on the body of the bone. The dorsal border is concave and has an articular cavity for the first pair of costal cartilages.

The =posterior extremity= is formed by the =xiphoid= or =ensiform cartilage= (Processus xiphoideus). This is a thin plate, connected in front with the last bony segment by a relatively thick, narrow neck, and expanding in nearly circular form behind and laterally. Its dorsal surface is concave, and gives attachment to the diaphragm. The ventral surface is convex. The free margin is very thin.

=Development.=—At birth the sternum of the horse consists of seven bony segments or sternebræ united by intersternebral cartilages. The last two sternebræ fuse in the second month, but the others do not usually unite completely even in old age. The sternebræ consist of very vascular spongy bone covered by a very thin layer of compact substance. The adult sternum thus consists to a very considerable extent of persisting cartilage, viz., the intersternebral cartilages, the ventral keel, and the extremities; in old age these undergo partial ossification.

THE THORAX

The bony thorax of the horse is remarkably compressed laterally in its anterior part, but widens greatly behind. The =anterior aperture= is oval and very narrow below; in a horse of medium size its greatest width is about 4 inches (10 cm.), and its height 7 to 8 inches (ca. 18 to 20 cm.). The =ventral wall= or =floor= is about 10 inches (40 cm.) long, and the =dorsal wall= or =roof= about 38 to 40 inches (95 to 100 cm.) long. The height from the last segment of the sternum to the seventh or eighth thoracic vertebra is about twice that of the anterior aperture; this is due to the obliquity and divergence of the roof and floor. The greatest width of the posterior aperture is about 20 to 24 inches (50 to 60 cm.). The intercostal spaces increase in width from the first to the seventh or eighth, and then diminish. Their average width is about 1¼ to 1½ inches (3 to 3.5 cm.).

THE BONES OF THE SKULL

(A) BONES OF THE CRANIUM

The bones of the cranium (Ossa cranii) are the Occipital, Sphenoid, Ethmoid, Interparietal, Parietal, Frontal, and Temporal. The first four are single, the others paired.

[Illustration:

FIG. 26.—SKULL, ATLAS, AND AXIS OF HORSE, LATERAL VIEW.

8, Body of mandible; 28′, horizontal (molar) part of ramus; 30, vertical part of ramus; 9, zygomatic process of squamous temporal; 11, coronoid process of mandible; 12, supraorbital process; 13″, paramastoid (styloid) process of occipital; 19, orbit; 20, malar bone; 21, lacrimal bone; 22, nasal bone; 23, premaxilla; 23′, nasal process of premaxilla; 25, 29, canine teeth; 26, maxilla; 27, facial crest; 31, condyle of mandible; 32, atlas; 33, axis; x, wing of atlas; e, naso-maxillary notch. (After Ellenberger-Baum, Anat. für Künstler.)]

THE OCCIPITAL BONE

The =occipital bone= (Os occipitale) is situated at the posterior part of the cranium, of which it forms the posterior wall and part of the ventral wall or base.[6]

Its lower part is perforated centrally by a large, almost circular opening, the =foramen magnum= (Foramen occipitale magnum), at which the brain and spinal cord join. The foramen is bounded laterally and dorsally by the =lateral parts= of the bone, and ventrally by the =basilar part= or =process=. Above the lateral parts—but not entering into the formation of the foramen magnum—is the =squamous part=.

[Illustration:

FIG. 27.—LINE DRAWING OF POSTERIOR HALF OF BASE OF SKULL OF HORSE, WITHOUT MANDIBLE. (Key to Fig. 28.)

1, Incisura carotica; 2, incisura ovalis; 3, incisura spinosa; 4, external orifice of parieto-temporal canal; 5, Eustachian canal; 6, petro-tympanic fissure; 7, external auditory canal; 8, hyoid process; 9, Vidian groove; 10, supraorbital process; _A_, basilar part of occipital; _B_, body of sphenoid; _C_, temporal wing of sphenoid; _D_, squamous temporal bone; _E_, petrous temporal bone; _F_, orbital part of frontal bone.]

The =lateral parts= (Partes laterales) bear the =occipital condyles= (Condyli occipitales), which articulate with the atlas. The condyles are obliquely placed, wide apart dorsally, and separated by a small interval ventrally. The articular surface is curved so sharply in the dorso-ventral direction as to form a blunt ridge externally. The cranial surface is concave and smooth. External to the condyle is the =paramastoid= or =styloid process= (Processus jugularis), a strong flattened bar of bone which projects downward and backward; its external surface is convex and roughened for muscular attachment. Between the root of this process and the condyle is a smooth depression, the =condyloid fossa= (Fossa condyloidea inferior); in this is the =hypoglossal foramen= (Foramen hypoglossi), which transmits the nerve of like name.

The =basilar part= or =process= (Pars basilaris) is a strong, somewhat prismatic bar which extends forward from the ventral margin of the foramen magnum. It is much narrower in front than behind. The ventral surface is rounded. The cranial surface is concave and smooth; its posterior part, supports the medulla, and its anterior part has a shallow cavity on which the pons rests. The lateral borders are thin and sharp, and form the inner margin of the =foramen lacerum= (Foramen lacerum et jugulare). The anterior end has, in the young subject, a semicircular, flat, pitted surface which is attached to the body of the sphenoid bone by a layer of cartilage; in the adult there is complete fusion. On the ventral aspect of the junction are tubercles for the attachment of the ventral straight muscles of the head.

[Illustration:

FIG. 28.—VENTRAL SURFACE OF SKULL OF HORSE, POSTERIOR HALF WITHOUT MANDIBLE.

The skull is inclined slightly. (Notation on key Fig. 27.)]

The =squamous part= (Squama occipitalis) is the somewhat quadrilateral mass situated above the lateral portions, from which it remains distinct till the second year. The =outer surface= is crossed by a very prominent ridge, the =occipital crest=; the middle part of this is thick, transverse in direction, and forms the highest point of the skull when the head is in the ordinary position; laterally it becomes thinner and runs downward and forward to join the temporal crest.[7] The crest divides the surface into two very unequal parts; the small anterior area (Planum parietale) presents a median ridge which is the posterior part of the external sagittal crest; the large area below the crest (Planum nuchale) also has a central eminence, the =external occipital protuberance=, on the sides of which the funicular part of the ligamentum nuchæ is attached. The =internal surface= is concave and presents a deep central depression and two shallower lateral ones which adapt it to the surface of the cerebellum.

The occipital bone is connected by suture with the interparietal, two parietals, and two temporals, and by synchondrosis with the sphenoid; the condyles articulate with the atlas.

=Development.=—The occipital ossifies in cartilage from =four centers=, and consists at birth of four pieces as described above.[8] The lateral parts unite with the basilar at three to four months, and with the squama in the second year, when the bone is consolidated.

The parieto-occipital suture and the spheno-occipital synchondrosis are obliterated about the fifth year usually. The temporo-occipital suture partially ossifies in old subjects.

THE SPHENOID BONE

The =sphenoid bone= (Os sphenoidale) is situated in the base of the cranium, its central part lying in front of the basilar part of the occipital. It consists of a central part, the body, two pairs of wings, and two pterygoid processes.

The =body= (Corpus) is a cylindrical bar, flattened dorso-ventrally, and wider in front than behind. Its =ventral surface= (Facies externa) is convex in the transverse direction; and its anterior part is concealed to a large extent by the vomer and pterygoid bones. The =cerebral surface= (Facies cerebralis) presents the following features: (1) In front is a raised, flattened part which is subdivided by a median elevation into two slightly concave lateral areas; this part has a posterior, thin, free margin (Limbus sphenoidalis), which overlies the entrance to the optic foramina. (2) Just behind this and at a lower level is a smooth transverse depression, the

=optic groove= (Sulcus chiasmatis), on which the optic chiasma rests. (3) From each end of this groove the =optic foramen= passes forward and outward to terminate in the posterior part of the orbital fossa.[9] (4) Near the posterior end is a central depression, the =hypophyseal= or =pituitary fossa= (Fossa hypophysea), which lodges the hypophysis cerebri or pituitary body. On each side of this is an ill-defined groove for the internal carotid artery and the cavernous sinus. The =anterior end= is expanded, and is excavated to form the =sphenoidal sinuses.= These cavities extend back as far as the optic groove, and are usually continuous in front with the cavities in the vertical parts of the palate bones; they are separated by a complete septum which is not always median.[10] The =posterior end= is flat and is joined to the basilar part of the occipital; at the line of junction there is dorsally a transverse elevation, the =spheno-occipital= crest (Crista sphenooccipitalis).

The =orbital wings= (Alæ orbitales) curve upward and somewhat outward from the sides of the body of the presphenoid. Their =inner= or =cerebral surfaces= are concave, and are marked by =digital impressions= (Impressiones digitatæ) for the gyri of the cerebrum. The =external surface= is convex and is largely concealed by the overlapping temporal wing and the squamous temporal and frontal bones; a narrow part of it (Facies orbitalis) is uncovered on the inner wall of the orbital cavity at the sphenoidal notch of the frontal bone. The =dorsal border= unites with the frontal bone at the spheno-frontal suture. The =anterior border= joins the ethmoid at the spheno-ethmoidal suture; at its lower part it concurs with the frontal in the formation of the =ethmoidal= (or internal orbital) =foramen=. The =posterior border= is overlapped by the temporal wing and the squamous temporal. The =root= of the wing is perforated by the =optic foramen=. Immediately below and behind the latter (_i. e._, beneath the root) is the =foramen lacerum orbitale= or =orbital fissure=. Below this, and separated from it usually by a thin plate, is a larger opening, the =foramen rotundum=, which is bounded externally by the root of the pterygoid process. Behind these foramina is the =pterygoid crest= (Crista pterygoidea), which is continued downward and forward on the pterygoid process; on its upper part may be found the small and inconstant =trochlear= (or pathetic) =foramen=. Just behind the crest is the =temporal foramen= (For. alare parvum), through which the anterior deep temporal artery emerges from the alar canal of the pterygoid process.

The =temporal wings= (Alæ temporales) extend outward and somewhat upward from the body of the postsphenoid; they are irregularly quadrilateral in outline. The =external surface= (Facies temporalis) enters into the formation of the infratemporal fossa, and bears the pterygoid process on its anterior part; at the junction with the body there is a small groove for the pterygoid nerve. The =internal surface= (Facies cerebralis) presents, at the junction with the body, two longitudinal =grooves= (Sulci nervorum). The outer groove is the larger, and leads forward to the foramen rotundum; it contains the maxillary nerve. The inner groove conducts to the orbital fissure, and contains the third, sixth, and ophthalmic nerves. The outer groove is bounded externally by a thin overhanging crest, on which is a small groove for the fourth nerve. The remainder of the surface is concave and supports the pyriform lobe of the brain. The =dorsal border= joins the squamous temporal at the spheno-squamous suture. The =anterior border= joins the orbital wing. The =posterior border= forms the anterior boundary of the foramen lacerum; it presents =three notches=, which are (from within outward) the carotid, oval, and spinous (Incisura carotica, ovalis, spinosa). The angle of junction of the dorsal and posterior borders articulates with the parietal bone.

The =pterygoid processes= (Processus pterygoidei) arise from the temporal wings and the body. They project downward and forward, and curve outward at the lower part. The root is perforated by the =alar canal= (Canalis alaris),[11] which transmits the internal maxillary artery. From this canal a branch leads upward and forward to open at the temporal foramen. The =external surface= is concave, and is marked by lines for muscular attachment. The =internal surface= is largely concealed by the overlapping palate and pterygoid bones, with which it concurs in the formation of the =pterygoid= or =Vidian canal=.

=Development.=—The sphenoid is ossified in cartilage, and consists in early life of two distinct parts, the presphenoid and postsphenoid. The former develops from two centers, one in each wing; the latter has three centers, one for the body and one for each wing. The pterygoid processes ossify from the centers of the temporal wings.

=Variation.=—The dorsal border of the orbital wing may come to the surface through a defect in the frontal bone at the place where the horn process is situated in animals which have frontal horns.

THE ETHMOID BONE

The =ethmoid= (Os ethmoidale) is situated in front of the body and orbital wings of the sphenoid. It projects forward between the orbital plates of the frontal bones and enters into the formation of the cranial, nasal, and paranasal cavities.[12] It consists of four parts—the cribriform plate, two lateral masses, and the perpendicular plate.

The =cribriform plate= (Lamina cribrosa) is a sieve-like partition between the cranial and nasal cavities. Its margin joins the orbital wings of the sphenoid laterally, and the cranial plate of the frontal bones dorsally. Its =cranial surface= is divided into two parts by a median ridge, the =crista galli=, which is the intracranial portion of the perpendicular plate. Each half forms a deep oval cavity, the =ethmoidal= or =olfactory fossa=, which lodges the olfactory bulb. The plate is perforated by numerous small foramina for the passage of the olfactory nerve filaments, and on either side is the much larger =ethmoidal foramen.= The =nasal surface= is convex, and has the lateral masses attached to it.

The =lateral masses= or =labyrinth= project forward from the cribriform plate into the posterior part of the nasal cavity, which they nearly fill. Each mass is somewhat conical in shape, with the base attached to half of the cribriform plate. The =inner surface= is separated by a narrow space from the perpendicular plate. The =outer surface= is convex and faces chiefly into the frontal and maxillary sinuses, but is attached behind to the inner wall of the orbital cavity; it is covered by a very thin layer of bone, the =lamina papyracea.= The mass consists of a large number of delicate, scroll-like plates of bone, termed =ethmoturbinals= or =ethmoidal cells.= These are attached to the lamina papyracea, and are separated by narrow intervals termed =ethmoidal meatuses=, which communicate with the nasal cavity. In the living animal the ethmoturbinals are covered with mucous membrane.

[Illustration:

FIG. 29.—CROSS-SECTION OF LATERAL MASS OF ETHMOID BONE OF HORSE.]

The lateral mass is a very complex structure, the arrangement of which may be studied on cross-sections of decalcified specimens with the mucous membrane retained. Each mass consists of six turbinals which extend almost to the perpendicular plate and are termed =endoturbinals=. These diminish in size from above downward; the largest is attached to the nasal bone, and is hence usually called the naso-turbinal or superior turbinal; the second is much smaller, and is very commonly termed the great ethmoid cell. Between the endoturbinals are twenty-one small =ecto=turbinals, and all are beset with secondary and tertiary coiled lamellæ.

The =perpendicular plate= or =mesethmoid= (Lamina perpendicularis) is median, and forms the posterior part of the septum nasi. Its =lateral surfaces= are nearly plane, but are marked below by some grooves and ridges; they are covered by the nasal mucous membrane. The =anterior border= is irregular and is continuous with the septal cartilage. The =posterior border= projects into the cranial cavity as a ridge, the =crista galli.= The =dorsal border= joins the frontal bones at their line of junction—the frontal suture. The =ventral border= is received into the groove of the vomer.

=Development.=—The ethmoid develops in cartilage from five centers, two for each lateral mass, and one for the perpendicular plate; from the latter ossification extends into the cribriform plate. At birth the perpendicular and cribriform plates are entirely cartilaginous. By the time ossification is complete the ethmoid has united with surrounding bones to such an extent that it cannot be separated intact for study.

[Illustration:

FIG. 30.—SKULL OF HORSE, DORSAL VIEW.

12, Supraorbital process; 14, parietal bone; 14′, external sagittal crest; 15, frontal bone; 15′, frontal crest; 21, lacrimal bone; 22, nasal bone; 26, maxilla; 24, incisor teeth. (After Ellenberger-Baum, Anat. für Künstler.)]

THE INTERPARIETAL BONE

This bone (Os interparietale) is centrally placed between the squamous part of the occipital and the parietal bones. It is usually described as a single bone, although it ossifies from two chief lateral centers, and is sometimes distinctly paired in skulls of young foals.

The =external surface= (Facies externa) is quadrilateral and is flat and smooth in the very young foal; later it presents the median external sagittal crest.

The =internal surface= (Facies cerebralis) presents the =internal occipital protuberance=, a three-sided process which projects downward and forward into the cranial cavity between the cerebral hemispheres and the cerebellum; it has three concave surfaces and three sharp borders which form part of the tentorium osseum.

The =posterior border= is thick; it joins the squamous part of the occipital bone. The =lateral= and =anterior borders= are united by suture with the parietal bones.

=Development.=—The interparietal ossifies in membrane from two chief lateral centers.[13] It fuses first with the parietals, somewhat later with the occipital, but the period at which this union takes place is quite variable.

THE PARIETAL BONES

The two =parietal bones= (Ossa parietalia) form the greater part of the roof of the cranium; they unite in the median line, forming the =sagittal suture=. Each is quadrilateral in outline and has two surfaces and four borders.

The =external surface= (Facies parietalis) is convex, and is marked by a more or less prominent curved line, the =external sagittal crest=; this is median in its posterior part, and is continuous with the crest of like name on the occipital bone; in front it curves outward and is continuous with the frontal crest. The surface external to the crest (Planum temporale) enters into the formation of the temporal fossa, and is roughened for the attachment of the temporal muscle.

The =internal= or =cerebral surface= (Facies cerebralis) is concave. It presents numerous =digital impressions= (Impressiones digitatæ) which correspond to the gyri of the cerebrum. There are also furrows (Sulci vasculosi) for the meningeal arteries. Along the inner border there is a =sagittal groove= (Sulcus sagittalis) for the superior longitudinal sinus.

The =anterior border= joins the frontal bone at the =parieto-frontal suture= (Sutura coronalis).

The =posterior border= meets the occipital bone at the =parieto-occipital suture= (Sutura lambdoidea). Below this junction it curves inward and concurs with the temporal bone in the formation of the =parieto-temporal canal= (Meatus temporalis). A =transverse groove= (Sulcus transversus) connects this canal with the sagittal sulcus.

The =internal border= is thick and serrated. It joins its fellow at the =sagittal suture=, and (in the young subject) meets the interparietal at the =interparietal suture=. The line of junction is marked internally by the =internal sagittal crest= (Crista sagittalis interna).

The =external border= is beveled and is overlapped by the squamous temporal bone, forming the parieto-temporal suture (Sutura parieto-squamosa). The angle of junction of the external and posterior borders articulates with the posterior angle of the temporal wing of the sphenoid.

=Development.=—Each parietal bone ossifies in membrane from a single center. In the young foal the central part of the bone is much more convex than in the adult and forms a prominence similar to the pronounced tuber parietale of the young child; the external sagittal crest is not present, and the external surface is smooth.

The sagittal suture is usually closed at four years, the parieto-occipital at five years, and the parieto-temporal at twelve to fifteen years.

THE FRONTAL BONES

The =frontal bones= (Ossa frontalia) are situated on the limits of the cranium and face, between the parietals behind and the nasal bones in front. Each is irregularly quadrilateral, and consists of frontal, orbital, and temporal parts.

The =frontal part= (Pars naso-frontalis) forms the basis of the forehead. Its =external surface= (Facies frontalis) is nearly flat, and is smooth and subcutaneous; it is separated from the temporal part by the external frontal crest (Crista frontalis externa). At the junction with the orbital part the =supraorbital= or =zygomatic process= (Proc. zygomaticus) curves outward and downward to join the zygomatic arch. The process partially separates the orbit from the temporal fossa; its root is perforated by the =supraorbital foramen=, or presents instead a notch on its anterior border; its upper surface is convex, while the lower or orbital surface is concave and smooth, forming a shallow fossa for the lacrimal gland (Fossa glandulæ lacrimalis). The =internal surface= enters into the formation of the cranial cavity and the frontal sinus. The cranial surface presents digital impressions for the cerebral gyri. The two plates of the bone separate and diverge in front, and thus inclose a large air-space which is part of the =frontal sinus=. The cranial plate curves downward and articulates with the cribriform plate of the ethmoid bone; the facial plate extends forward and joins the nasal and lacrimal bones.

The =orbital part= (Pars orbitalis) forms the major part of the inner wall of the orbital cavity. It is separated from the frontal part by a prominent ridge which is part of the orbital margin. Its =external= or =orbital surface= is concave and smooth, and presents superiorly a small depression (Fovea trochlearis), which is bridged by a small bar of cartilage, around which the superior oblique muscle of the eye is reflected. The lower border concurs with the orbital wing of the sphenoid in the formation of the ethmoidal or internal orbital foramen. The =internal surface= faces into the frontal sinus and gives attachment to the lateral mass of the ethmoid.

The =temporal part= is separated from the orbital part by the deep =sphenoidal notch= (Incisura sphenoidalis), which is occupied by the orbital wing of the sphenoid. Its =external surface= forms part of the inner wall of the temporal fossa. The =internal surface= is largely covered by the orbital wing of the sphenoid in the young subject, but later forms part of the wall of the frontal sinus.

The principal connections of the frontal bone are as follows: (1) The inner border joins its fellow at the =frontal suture=. (2) The anterior border meets the nasal and lacrimal at the =naso-frontal= and =fronto-lacrimal sutures=. (3) Laterally it forms the =spheno-frontal= suture with the orbital wing of the sphenoid, and also joins the palate bone and maxilla. (4) Posteriorly it meets the parietal at the =parieto-frontal= (or coronal) =suture=, and articulates below this with the squamous temporal. (5) The extremity of the supraorbital process unites with the zygomatic process of the temporal bone.

=Development.=—Each ossifies in membrane from one center which appears in the root of the supraorbital process. In the new-born foal there is a slit between the cranial plate and the orbital and temporal plates which receives the cartilaginous margin of the orbital wing of the sphenoid.

THE TEMPORAL BONES

The =temporal bone= (Os temporale) forms the greater part of the lateral wall of the cranium. It is situated between the occipital behind, the parietal above, the frontal in front, and the sphenoid below. It consists of two distinct parts, =squamous= and =petrous=.

1. The =squamous temporal= (Squama temporalis) is a shell-like plate which has two surfaces and four borders.

The =internal surface= (Facies cerebralis) is largely overlapped by the surrounding bones, but its central part is free and presents digital impressions and vascular grooves.

The =external surface= (Facies temporalis) is convex, and enters into the formation of the temporal fossa. From its lower part there springs the =zygomatic process= (Processus zygomaticus), which forms the external boundary of the temporal fossa. It is at first directed outward, and is wide and flattened dorso-ventrally. It then turns forward, becomes narrower, and is twisted so that its surfaces are internal and external. Its anterior end is pointed and joins the zygomatic process of the malar bone, with which it forms the =zygomatic arch= (Arcus zygomaticus). The narrow anterior part has a convex outer surface and a concave inner one. Its upper border has a rough area for articulation with the supraorbital process of the frontal. Its lower border is wide and rough. The wide posterior part presents on its ventral face a surface for articulation with the condyle of the mandible. This surface consists of a transversely elongated =condyle= (Tuberculum articulare), behind which is the =glenoid fossa= (Fossa mandibularis). The fossa is limited behind by the =postglenoid process=, the anterior surface of which is articular. Behind this process is a fossa in which is the external opening of the parieto-temporal canal. The dorsal surface is concave and forms the outer boundary of the temporal fossa. The superior border is sinuous and is continuous behind with the temporal crest.

The =posterior process= (Processus posterior) springs from the posterior part of the squama. Its external surface is crossed by the temporal crest, which forms here the outer limit of the temporal fossa. The internal surface forms the outer boundary of the parieto-temporal canal, and is elsewhere applied to the petrous portion. It divides into two branches, upper and lower; the upper branch unites with the occipital bone, while the lower one curves downward behind the external auditory process and overlaps the mastoid process.

The =superior border= of the squamous temporal articulates with the parietal, forming the =parieto-temporal suture=. The =inferior border= joins the temporal wing of the sphenoid at the =spheno-squamous suture=. The =anterior border= unites with the frontal bone, and the =posterior= with the parietal.

2. The =petrous temporal= (Os petrosum) is placed between the occipital behind and the parietal in front, and is largely overlapped externally by the squamous temporal. It has the form of a four-sided pyramid, the base of which is ventral.

The =external surface= is mainly concealed by the squamous temporal, but two features are visible. A short tube of bone, the =external auditory process=, protrudes from the lowest part through the notch of the squamous temporal. The process is directed outward, upward, and a little forward. It gives attachment to the annular cartilage of the ear. Its lumen, the =external auditory meatus= (Meatus acusticus externus), conducts to the cavity of the middle ear (tympanum) in the dry skull, but is separated from it by the tympanic membrane in the natural state. The =mastoid process= projects ventrally in the interval between the posterior process of the squamous temporal and the root of the paramastoid (or styloid) process of the occipital bone; its outer surface is crossed by a curved groove which leads to the parieto-temporal canal.

The =internal surface= faces into the cerebellar fossa of the cranium. It is concave and smooth but irregular. In its lower part is the entrance to a short canal, the =internal auditory meatus=, which transmits the seventh and eighth cranial nerves.

The fundus of the meatus is divided by a crest into a superior and an inferior fossa. In the superior one is the origin of the =facial canal=, which curves through the bone and opens externally at the stylo-mastoid foramen; it transmits the facial (seventh cranial) nerve. The inferior fossa presents small foramina for the passage of fibers of the auditory (eighth cranial) nerve.

Behind the meatus and near the posterior margin of the surface is the slit-like opening of the aquæductus vestibuli, covered by a scale of bone. Below this is a narrow fissure, the orifice of the aquæductus cochleæ.

The =anterior surface= looks upward and forward. The outer part articulates with the parietal bone and the inner part faces into the cerebral fossa of the cranium. A sharp border, the =petrosal crest= (Crista petrosa), separates this surface from the inner one.

The =posterior surface= joins the lateral part of the occipital bone.

The =base forms= the outer boundary of the foramen lacerum basis cranii. It is very irregular and presents a number of important features. The =hyoid process= is a short rod which projects downward and forward below the base of the external auditory process, inclosed in a bony tube; it is connected by a bar of cartilage with the hyoid bone. The =stylo-mastoid foramen= is situated between the root of the hyoid process and the mastoid process; it is the external opening of the facial canal, through which the facial nerve emerges. The =bulla ossea= is a considerable eminence situated centrally; it is thin-walled and incloses a cavity which is part of the tympanum. The =muscular process=[14] is a sharp spine which projects downward and forward from the anterior part of the base; it gives origin to the tensor and levator palati muscles. External to the root of the preceding is the small =petro-tympanic= or =Glaserian fissure= (Fissura petro-tympanica) for the passage of the chorda tympani nerve. The osseous =Eustachian tube= is a semicanal at the inner side of the root of the muscular process; it leads to the tympanum. At the inner side of the preceding is the slit-like orifice of the petrosal canal, which communicates with the facial canal.

The =apex= projects upward and backward between the squamous temporal and the occipital bone.

=Development.=—The petrous temporal may be regarded as consisting of petro-mastoid and tympanic parts. The latter includes the external auditory process, the bulla ossea, and the muscular process; it is developed in membrane. The petro-mastoid is developed in the cartilaginous ear capsule. Its petrous part consists of very dense bone which contains the labyrinth or internal ear and forms the inner wall of the tympanum.

The =parieto-temporal canal= (Meatus temporalis) is a continuation of the transverse groove which extends outward from the base of the tentorium osseum. It is directed downward, forward, and somewhat outward, and opens externally in front of the root of the auditory process. It is bounded by the squamous temporal externally, the petrous behind, and the parietal in front and internally. Several foramina open from it into the temporal fossa. It contains a large vein (Vena cerebralis dorsalis), the continuation of the transverse sinus of the dura mater.

The =foramen lacerum basis cranii= (Foramen lacerum et jugulare) is a large irregular opening in the cranial base, bounded internally by the basilar part of the occipital bone, externally by the petrous temporal, and in front by the temporal wing of the sphenoid. It consists of a large anterior part (Foramen lacerum anterius), and a narrow posterior part (Foramen lacerum posterius s. jugulare). It transmits the internal carotid artery, the middle meningeal artery, the mandibular, ninth, tenth, and eleventh cranial nerves, and the inferior cerebral vein.

In the fresh state the foramen is occupied by a dense fibrous membrane which is perforated by apertures for the various structures transmitted. Thus there are three openings in front for the internal carotid artery, the mandibular nerve, and the middle meningeal artery; these are (from within outward) the foramen caroticum, ovale, spinosum.

(B) BONES OF THE FACE

The bones of the face (Ossa faciei) are the Maxilla, Premaxilla, Palatine, Pterygoid, Nasal, Lacrimal, Malar, Superior Turbinal, Inferior Turbinal, Vomer, Mandible, and Hyoid. The last three are single, the others paired.

THE MAXILLAE

The =maxillæ= are the principal bones of the upper jaw and carry the upper cheek teeth. They are situated on the lateral aspect of the face, and articulate with almost all of the facial bones and the frontal and temporal also. For description each may be divided into a body and two processes.

The =body= (Corpus maxillæ) presents two surfaces, two borders, and two extremities. The =external= or =facial surface= (Facies lateralis) is somewhat concave in front and convex behind. On its posterior part is a horizontal ridge, the =facial= or =zygomatic crest= (Crista facialis); in a skull of medium size its anterior end is about an inch and a half (3 to 4 cm.) above the third or fourth cheek tooth, and it is continued behind by a corresponding ridge on the malar bone. About two inches (5 cm.) above and a little in front of the anterior end of the crest is the =infraorbital foramen= (Foramen infraorbitale); this is the external opening of the infraorbital canal.

In the young horse the anterior part of the surface is convex over the embedded parts of the teeth. As the latter are extruded the surface flattens and becomes concave in old subjects.

The =internal= or =nasal surface= (Facies nasalis) is concave dorso-ventrally; it forms the greater part of the lateral wall of the nasal cavity. Its upper part is crossed obliquely forward and downward by the shallow =lacrimal groove= (Sulcus lacrimalis), which contains the naso-lacrimal duct; in the adult the posterior part of the groove is converted into a canal, which is continuous with that on the inner surface of the lacrimal bone. Below the groove is the =inferior turbinal crest= (Crista conchalis inferior), to which the inferior turbinal bone is attached. Lower down and parallel with the turbinal crest is the =palatine process=, which projects inward like a shelf. Behind this the surface is rough for articulation with the palate bone; this area is crossed by a groove which concurs with a furrow on the palate bone in the formation of the =palatine canal=. The posterior part of the bone is excavated to form part of the maxillary sinus.

The =superior border= is irregular and scaly. Its anterior part is grooved and its posterior part beveled for articulation with the nasal process of the premaxilla and the nasal and lacrimal bones.

The =inferior= or =alveolar border= (Processus alveolaris) is thick, and presents six large cavities, the =alveoli=, for the cheek teeth. The alveoli are separated by transverse =interalveolar septa=. There is often a small alveolus for the first premolar ("wolf tooth") close to the first large one. Further forward the border is narrow and forms part of the =interdental= or =interalveolar space= (Margo interalveolaris). Behind the last alveolus is a rough area, the =alveolar tuberosity=.

The =anterior extremity= is pointed. It joins the premaxilla, and forms with it the alveolus for the canine tooth.

The =posterior extremity= forms a rounded prominence, the =maxillary tuberosity= (Tuber maxillare). Internal to the tuberosity is a deep cavity, the maxillary hiatus, in which are three foramina. The upper one, the =maxillary foramen=, leads into the infraorbital canal. The lower one, the =posterior palatine foramen=, is the entrance to the palatine canal. The =sphenopalatine foramen= perforates the inner wall of the hiatus and opens into the nasal cavity.

The =zygomatic= or =temporal process= (Processus temporalis) projects backward above and external to the tuberosity; it is overlapped by the corresponding part of the malar and also articulates with the zygomatic process of the temporal. A small curved plate extends inward from it and joins the frontal and palate bones, forming part of the floor of the orbit.

The =palatine process= (Processus palatinus) is a plate which projects horizontally inward from the lower part of the inner surface of the body. It forms the greater part of the basis of the hard palate. Its =superior= or =nasal surface= is smooth and concave transversely; on its anterior part, close to the inner border, is a shallow groove in which the organ of Jacobson is situated. The inferior or =palatine surface= is slightly concave from side to side, and presents along its outer part the =palatine groove= (Sulcus palatinus). The groove is a continuation of the palatine canal, and contains the palatine artery and nerve. The =internal border= unites with its fellow to form the median palatine suture; its nasal aspect bears the nasal crest, which forms, with that of the opposite process, a groove for the vomer. The =posterior border= unites with the horizontal part of the palate bone at the

transverse palatine suture.

[Illustration:

FIG. 31.—UPPER JAW OF HORSE ABOUT FOUR AND A HALF YEARS OLD, VENTRAL VIEW.

1, 1, Posterior nares; 2, vomer; 3, horizontal part of palate bone; 4, anterior palatine foramen; 5, palatine groove; 6, transverse palatine suture; 7, median palatine suture; 8, palate process of maxilla; 9, palate process of premaxilla; 10, foramen incisivum; 11, malar bone; 12, maxilla; 13, anterior end of facial crest; 14, interalveolar space; I. 1–3, incisor teeth; _C_, canine tooth; _P1_, first premolar or "wolf" tooth.]

The =infraorbital= or =superior dental canal= extends almost horizontally from the maxillary foramen to the infraorbital foramen. It is placed at the upper edge of the inner plate of the maxilla, and traverses the maxillary sinus. Near the infraorbital foramen it gives off a small canal (Canalis alveolaris incisivus) which lies above the roots of the premolars and extends also into the premaxilla, carrying vessels and nerves to the teeth there.

=Development.=—The maxilla ossifies in membrane below and external to the cartilaginous nasal capsule. It has one chief center and a supplementary one in the region of the deciduous canine tooth (Martin).

THE PREMAXILLAE

The =premaxillæ= (Ossa incisiva) form the anterior part of the upper jaw and carry the incisor teeth. Each consists of a body and two processes, nasal and palatine.

The =body= is the thick anterior part which carries the incisor teeth. Its =labial= or =superior= surface is convex and smooth, and is related to the upper lip. The =palatine= or =inferior surface= is concave and presents a foramen a little behind its middle.[15] The =internal surface= is rough, and joins the opposite bone; it is marked by a curved groove, which forms with that on the opposed surface, the incisive =foramen= (Foramen incisivum). The =alveolar border= (Limbus alveolaris) separates the palatine and labial surfaces; it is curved and thick, and presents three alveoli for the incisor teeth; behind the third alveolus it is rounded and free, forming part of the =interalveolar space=.

The =nasal process= (Processus nasalis) projects backward and upward from the body, forming here the lateral wall of the nasal cavity. The two =surfaces=, =facial= and =nasal=, are smooth and rounded. The =superior border= is free, thick, and smooth. The =inferior border= is dentated and joins the maxilla; at its anterior end it forms with the latter the alveolus for the permanent canine tooth.[16] The =posterior extremity= fits into the interval between the nasal bone and the maxilla.

The =palatine process= (Processus palatinus) is a thin plate which forms the anterior part of the basis of the hard palate. Its =nasal= or =superior surface= has a longitudinal ridge which forms with that of the other side a groove for the septal cartilage. The =palatine= or =inferior surface= is flat. The =internal border= is serrated and meets its fellow at the median palatine suture. The =external border= is separated from the maxilla and the nasal process by the =palatine cleft= (Fissura palatina). The =posterior extremity= fits into the interval between the vomer and the palatine process of the maxilla.

=Development.=—The premaxilla ossifies from a single center. Fusion of the two bones is complete at the end of the third or the beginning of the fourth year.

THE PALATINE BONES

The =palatine bones= (Ossa palatina) are situated on either side of the posterior nares, and form the posterior margin of the hard palate. Each is twisted so as to form a horizontal and a perpendicular part.

The =horizontal part= (Pars horizontalis) is a narrow plate which forms the posterior part of the hard palate. It presents smooth =nasal= and =palatine surfaces=. The =internal border= meets its fellow at the median palatine suture, on the nasal aspect of which is the nasal crest. The =anterior border= joins the palate process of the maxilla at the transverse palatine suture, and forms with it the anterior palatine foramen. The =posterior border= is concave and free; it gives attachment to the aponeurosis of the soft palate.

The =perpendicular part= (Pars perpendicularis) is more extensive and forms the outer boundary of the posterior nares. The =nasal= or =internal surface= is in the greater part of its extent concave and smooth; it is marked by a narrow rough area to which the pterygoid bone is attached. Below this the bone curves outward, forming the pterygoid process. The =maxillary= or =external

surface= (Facies maxillaris) presents three areas for consideration. The largest articulates with the maxilla; it is rough and is crossed by a groove which enters into the formation of the palatine canal. Behind this is a smooth part which assists in forming the =pterygo-palatine fossa=. The rough area below this is overlapped by the pterygoid process of the sphenoid bone. The =superior border= is perforated by the =sphenopalatine foramen=. Behind the foramen the two plates of the bone separate to inclose part of the =sphenopalatine sinus=. The inner plate curves inward to articulate with the vomer. The outer plate joins the maxilla and frontal and the orbital wing of the sphenoid.

=Development.=—The palatine bone ossifies in membrane from a single center.

THE PTERYGOID BONES

The =pterygoid bones= (Ossa pterygoidea) are narrow, thin, bent plates, situated on either side of the posterior nares. Each has two surfaces and two extremities. The =internal surface= is smooth, and forms part of the boundary of the posterior nares. The =external surface= articulates with the palatine, vomer, and sphenoid, concurring with the last in the formation of the =pterygoid= or =Vidian canal=. The =anterior extremity= is free, turned slightly outward, and forms the =hamulus=, a pulley around which the tendon of the tensor palati muscle is reflected.

=Development.=—The pterygoid ossifies in membrane from a single center.

THE NASAL BONES

The =nasal bones= (Ossa nasalia) are situated in front of the frontal bones and form the greater part of the roof of the nasal cavity. They have an elongated triangular outline, wide behind, pointed in front. Each presents two surfaces, two borders, a base, and an apex.

The =external= or =facial surface= is smooth and is convex transversely; the profile contour is usually slightly wavy, with a depression about its middle and a variably prominent area in front.

The =internal= or =nasal surface= is smooth and concave from side to side. About in its middle it presents the =superior turbinal crest= (Crista conchalis dorsalis), which is parallel with the inner border, and has the superior turbinal bone attached to it. Most of this surface faces into the nasal cavity, but its posterior part enters into the formation of the frontal sinus; the latter area is marked off by an oblique ridge.

The =internal border= is straight, and meets the opposite bone at the =nasal suture=.

The =external border= is irregular. Its anterior third is free and concurs with the nasal process in forming the =naso-maxillary notch= (Incisura naso-maxillaris). Behind this it is scaly for articulation with the end of the nasal process, the maxilla, and the lacrimal, forming the =naso-maxillary= and =naso-lacrimal sutures=.

The =base= or posterior end is beveled and overlaps the frontal bone, forming the =naso-frontal suture=.

The =apex= is pointed and thin.

=Development.=—Each nasal bone ossifies in membrane from a single center. The nasal suture does not close completely even in old age. In some cases the two plates separate to inclose a small air-space in the posterior part.

THE LACRIMAL BONES

The =lacrimal bones= (Ossa lacrimalia) are situated at the anterior part of the orbit, and extend forward on the face to the posterior border of the maxilla. Each presents three surfaces and a circumference.

The external aspect is clearly divided into orbital and facial parts by the orbital margin. The =orbital surface= (Facies orbitalis) is triangular in outline, smooth and concave; it forms part of the inner and front wall of the orbit. Near the orbital margin it presents a funnel-like =fossa= for the lacrimal sac (Fossa sacci lacrimalis), which is the entrance to the osseous lacrimal canal. Behind this is a depression in which the inferior oblique muscle of the eye takes origin. The =facial surface= (Facies facialis) is more extensive, and has the form of an irregular pentagon. It is slightly convex and smooth in the foal, flattened in the adult. It usually bears the small =lacrimal tubercle=, situated nearly an inch (ca. 2 cm.) from the orbital margin.

The =nasal= or =internal surface= (Facies nasalis) faces into the frontal and maxillary sinuses. It is concave and very irregular, and is crossed almost horizontally by the =osseous lacrimal canal= (Canalis lacrimalis osseus).

The =orbital margin= (Margo orbitalis) is concave, rough above, smooth below.

The =circumference= articulates above with the frontal and nasal bones, below with the malar and maxilla, in front with the maxilla, and behind with the frontal. The various sutures so formed are designated by combinations of the names of the bones.

=Development.=—Each ossifies in membrane from a single center.

THE MALAR BONES

The =malar= or =zygomatic bones= (Ossa zygomatica) are placed between the lacrimal above and the maxilla below and in front. Each is irregularly triangular in outline and presents three surfaces, three borders, a base, and an apex.

The =facial surface= is smooth, slightly convex, wide in front, and narrow behind. At its lower part it presents the =facial= or =zygomatic crest=, which is continuous in front with the similar ridge on the maxilla and behind with the zygomatic process of the temporal; the crest is rough below, where the masseter muscle is attached to it.

The =orbital surface= is separated from the facial surface by the concave =orbital margin=. It is concave and smooth, and forms part of the lower and front wall of the orbit.

The =nasal surface= is concave and faces into the maxillary sinus. In the young foal a considerable part of it articulates with the maxilla.

The =superior border= articulates with the lacrimal chiefly, but to a small extent behind with the maxilla also.

The =inferior border= and the =base= articulate with the maxilla.

The =apex= is beveled above and is overlapped by the zygomatic process of the temporal bone.

=Development.=—Each ossifies in membrane from one or two centers.

THE TURBINAL BONES

These (Ossa turbinata) are delicate, scroll-like bones, four in number, which are attached to the lateral walls of the nasal cavity. They project into the cavity and greatly diminish its extent. Each is composed of a very thin lamina, cribriform in many places, and covered on both sides with mucous membrane in the fresh state. They are arranged in two pairs, superior and inferior.

The =superior= or =naso-turbinal= (Concha dorsalis)[17] is somewhat cylindrical in form, small at its anterior part, and flattened transversely. It is attached to the turbinal crest of the nasal bone and the nasal plate of the frontal bone. The anterior part is rolled like a scroll one and a half times, thus inclosing a cavity which communicates with the middle meatus nasi. The arrangement is best seen on a cross-section (Fig. 37). The posterior part is not rolled, but its lower border is attached to the lateral nasal wall, thus helping to inclose a large space which is part of the frontal sinus. This cavity is separated from that of the scroll-like part by a transverse septum. The =internal surface= is flattened, and is separated from the septum nasi by a narrow interval, the =common meatus= (Meatus nasi communis). Another narrow passage, the =superior meatus= (Meatus nasi superior), separates the upper surface from the roof of the nasal cavity. The space between the lower surface and the inferior turbinal is the =middle meatus= (Meatus nasi medius). The anterior extremity is prolonged toward the nostril by two small bars of cartilage.

The =inferior= or =maxillo-turbinal bone= (Concha ventralis) is shorter and smaller posteriorly than the upper one. It is attached to the inferior turbinal crest, and consists, like the upper one, of an anterior coiled and a posterior uncoiled portion.

To express briefly the mode of coiling of the two bones of the same side we may say that they are rolled toward the septum and each other.

The inferior and posterior borders of the posterior part are attached to the maxilla, thus helping to inclose a cavity which is part of the maxillary sinus. The lower surface is separated from the floor of the nasal cavity by the =inferior meatus= (Meatus nasi inferior), which is much larger than the other nasal passages. The anterior extremity is prolonged to the nostril by a curved bar of cartilage.

=Development.=—Each ossifies in cartilage from a single center.

THE VOMER

The =vomer= is a median unpaired bone, which assists in forming the lower part of the septum nasi. It is composed of a thin lamina which is bent (except in its posterior part) so as to form a narrow groove (Sulcus septi narium), in which the lower part of the perpendicular plate of the ethmoid bone and the septal cartilage are received. The =lateral surfaces=, right and left, are highest near the posterior end and diminish gradually to the anterior end; they are slightly convex dorso-ventrally, and are covered by the nasal mucous membrane during life. The =inferior border= is thin and free in its posterior third, and divides the posterior nares into right and left halves; in the remainder of its extent it is wider and is attached to the nasal crest. The =anterior extremity= lies above the ends of the palatine processes of the premaxillæ. The =posterior extremity= consists of two =wings= (Alæ vomeris) which extend outward below the body of the presphenoid; posteriorly they form a notch (Incisura vomeris), and laterally join the palate and pterygoid bones.

=Development.=—The vomer is primitively double, and ossifies from a center on either side in the membrane covering the cartilaginous septum nasi; the two laminæ then fuse below and form a groove.

THE MANDIBLE

The =mandible= or =inferior maxilla= (Mandibula) is the largest and the only movable bone of the face. The two halves of which it consists at birth unite during the second or third month, and it is usually described as a single bone. It carries the lower teeth, and articulates by its condyles with the squamous temporal on either side. It consists of a body and two rami.[18]

The =body= (Corpus mandibulæ) is the thick anterior part which bears the incisor teeth. It presents two surfaces and a border. The =lingual= or =superior surface= (Facies lingualis) is smooth and slightly concave; during life it is covered by mucous membrane, and the tip of the tongue overlies it. The =labial= or =mental surface= (Facies mentalis) is convex and is related to the lower lip. It is marked by a median furrow which indicates the position of the primitive symphysis mandibulæ. The curved =alveolar border= (Limbus alveolaris) presents six alveoli for the incisor teeth, and a little further back two alveoli for the canine teeth in the male; in the mare the latter are usually absent or small.

The =rami= (Rami mandibulæ) extend backward from the body and diverge to inclose the =submaxillary space= (Spatium mandibulare). Each ramus is bent so as to consist of a horizontal part (Pars molaris) which bears the lower cheek teeth, and a vertical part (Ramus mandibulæ) which is expanded and furnishes attachment to powerful muscles; the term =angle= is applied to the most prominent part of the curve. The ramus presents two surfaces, two borders, and two extremities. The =external surface= is smooth and slightly convex from edge to edge on the horizontal part; at the junction with the body it presents the =mental foramen= (Foramen mentale), which is the external opening of the mandibular or inferior dental canal. On the vertical part it is somewhat concave and presents a number of rough lines for the attachment of the masseter muscle. The =internal surface= of the horizontal part is smooth, and presents a shallow longitudinal depression in its middle; above this there is often a faint mylo-hyoid line for the attachment of the muscle of like name. At the lower part of the junction with the body there is a small fossa for the attachment of the genio-hyoid and genio-glossus muscles. On the vertical part the surface is concave, and is marked in its lower and posterior part by rough lines for the attachment of the internal pterygoid muscle. In front of its middle is the =mandibular= or =inferior maxillary foramen= (Foramen mandibulare), which is the posterior orifice of the =mandibular= or =inferior dental canal= (Canalis mandibulæ). The canal curves downward and passes forward below the cheek teeth, opening externally at the mental foramen; it is continued into the body of the bone as a small canal (Canalis alveolaris incisivus), which carries the vessels and nerves to the incisor teeth. The =superior= or =alveolar border= forms anteriorly part of the interalveolar space; here it is thin. Behind this it is thick and is excavated by six alveoli for the lower cheek teeth. Behind the last alveolus it curves sharply upward and is narrow and rough. In the young foal there is commonly a small alveolus for the vestige of the first premolar ("wolf tooth") close to the first large one. The =inferior border= of the horizontal part is nearly straight; it is thick and rounded in the young horse, becoming narrower and sharp in old subjects. At its posterior part there is a smooth impression (Incisura vasorum) where the facial vessels and parotid duct turn round the bone. Behind this point the border curves sharply upward, forming the =angle= (Angulus mandibulæ); this part is thick and has two roughened lips, internal and external, separated by a considerable intermediate space; near the condyle it becomes narrower. The =anterior extremity= joins the body. The =superior extremity= comprises the =coronoid process= in front and the =condyle= behind, the two being separated by the =sigmoid notch= (Incisura mandibulæ), through which the nerve to the masseter muscle passes. The =coronoid process= (Processus coronoideus) is thin transversely and curved slightly

inward and backward. It projects upward in the temporal fossa, and furnishes insertion to the temporal muscle. The =condyle= (Capitulum mandibulæ) lies at a much lower level than the end of the coronoid process. It is elongated transversely and articulates with the squamous temporal through the medium of an articular disc. The part below the condyle is usually termed the =neck= (Collum mandibulæ); on its antero-internal part is a depression (Fovea pterygoidea) for the attachment of the external pterygoid muscle. The middle of the vertical part of the ramus consists to a large extent of a single plate of compact substance which may be so thin in places as to be translucent.

=Development.=—The mandible develops from two chief centers in the connective tissue which overlies the paired Meckel's cartilages. At birth it consists of two symmetrical halves which meet at a median symphysis. Fusion usually occurs in the second or third month.

=Age changes.=—These are associated largely with the growth and later with the reduction of the teeth. In the young horse, in which the teeth are large and are in great part embedded in the bone, the body is thick and strongly curved, and the horizontal part of the ramus is also thick. Later, as the teeth are extruded from the bone, the body becomes flattened and narrower, and the horizontal part of the ramus is thinner, especially in its lower part; the angle and the impression in front of it are more pronounced.

THE HYOID BONE

The =hyoid bone= (Os hyoideum) is situated chiefly between the vertical parts of the rami of the mandible, but its upper part extends somewhat further back. It is attached to the petrous temporal bones by rods of cartilage, and supports the root of the tongue, the pharynx, and larynx. It consists of a body, a lingual process, and three pairs of cornua.

The =body= or =basihyoid= (Basis ossishyoidei) is a short transverse bar, compressed dorso-ventrally. The upper surface is concave and smooth in its middle, and presents at each end a convex facet or tubercle for articulation with the small cornu. The lower surface is slightly roughened for muscular attachment. The anterior border carries medially the lingual process. The posterior border is concave and smooth in its middle, and carries on either side the thyroid cornu. The body, the lingual process, and the thyroid processes are fused together, and may be compared to a spur or a fork with a very short handle.

The =lingual process= (Processus lingualis) projects forward medially from the body, and is embedded in the root of the tongue during life. It is compressed laterally and has a blunt-pointed free end. The lateral surfaces are slightly concave. The upper border is narrow, the lower thick and irregular.

The =thyroid cornua= or =thyrohyoids= (Cornua laryngea)[19] extend backward and upward from the lateral parts of the body. They are compressed laterally (except at their junction with the body), and their posterior ends are connected with the anterior cornua of the thyroid cartilage of the larynx.

The =small cornua= or =keratohyoids= (Cornua minora) are short rods which are directed upward and forward from either end of the upper surface of the body. Each is somewhat constricted in its middle part and has slightly enlarged ends. The lower end has a small concave facet which articulates with the body. The upper end articulates with the great cornu, or with the middle cornu when present.

[Illustration:

FIG. 32.—HYOID BONE OF HORSE, VIEWED FROM THE SIDE AND SOMEWHAT FROM IN FRONT.

_a_, Body; _b_, lingual process; _c_, thyroid cornu; _c′_, cartilage of _c_; _d_, small cornu; _e_, middle cornu; _f_, great cornu; _f′_, muscular angle of great cornu; _g_, cartilage of great cornu. (Ellenberger-Baum, Anat. d. Haustiere.)]

The =great cornua= or =stylohyoids= are much the largest parts of the bone. They are directed upward and backward, and are connected above with the base of the petrous temporal bones. Each is a thin plate, seven or eight inches (ca. 18 to 20 cm.) long, which is slightly curved in its length, so that the external surface is concave and smooth. The internal surface is convex and smooth. The borders are thin. The upper extremity is large and forms two angles; the upper angle is connected by a rod of cartilage with the hyoid process of the petrous temporal bone; the lower angle is somewhat thickened and rough for muscular attachment. The lower extremity is small, and articulates with the small or the middle cornu.

The =middle cornua= or =epihyoids= are small wedge-shaped pieces or nodules interposed between the small and great cornua. They are usually transitory, and unite with the great cornua in the adult.

=Development.=—The hyoid ossifies in the cartilages of the second and third visceral arches. Each part has a separate center, except the lingual process, which ossifies by extension from the body. The latter has primarily two centers (Martin).

THE SKULL AS A WHOLE

The skull of the horse has the form of a long four-sided pyramid, the base of which is posterior. It is convenient to exclude the mandible and hyoid from present consideration. The division between the cranium (Cranium cerebrale) and the face (Cranium viscerale) may be indicated approximately by a transverse plane through the anterior margins of the orbits.

The =superior= or =frontal surface= (Norma frontalis) is formed by the upper part of the occipital, the interparietal, parietal, frontal, and nasal bones. It may be divided into parietal, frontal, nasal, and premaxillary regions. The parietal region extends from the occipital crest to the parieto-frontal or coronal suture. It is marked medially by the =external sagittal crest=, which bifurcates in front, the branches becoming continuous with the =frontal crests=. The latter curve outward to the root of the supraorbital process. The =frontal region= is the widest part of the surface, and is smooth and almost flat. It is bounded in front by the naso-frontal suture. On either side of it is the root of the =supraorbital process=, pierced by the =supraorbital foramen=. The =nasal region= is convex from side to side, wide behind, narrow in front. Its profile is in some cases nearly straight; in others it is undulating, with a variably marked depression about its middle and at the anterior end. The =premaxillary region= presents the =osseous nasal aperture= (Apertura nasalis ossea) and the =foramen incisivum=.

[Illustration:

FIG. 33.—CRANIAL AND ORBITAL REGIONS OF SKULL OF HORSE, LATERAL VIEW. THE ZYGOMATIC ARCH AND SUPRAORBITAL PROCESSES HAVE BEEN SAWN OFF.

1, Occipital condyle; 2, condyloid fossa; 3, paramastoid or styloid process; 4, occipital crest; 5, external occipital protuberance; 6, external auditory meatus; 7, mastoid process; 8, hyoid process; 9, stylo-mastoid foramen; 10, muscular process; 11, foramen lacerum anterius; 12, postglenoid process; 13, glenoid cavity; 14, temporal condyle; 15, Vidian groove; 16, alar canal of pterygoid process indicated by arrow; 17, temporal foramen; 18, ethmoidal foramen; 19, optic foramen; 20, foramen lacerum orbitale; 21, maxillary foramen; 22, sphenopalatine foramen; 23, posterior palatine foramen; 24, supraorbital foramen (opened); 25, lacrimal fossa; 26, depression for origin of obliquus oculi inferior; 27, facial crest; 28, maxillary tuberosity; 29, alveolar tuberosity; 30, hamulus of pterygoid bone; _S.o._, supraoccipital; _P_, parietal; _S_, squamous temporal; _B.o._, basioccipital; _B.s._, basisphenoid; _A.t._, temporal wing of sphenoid; _A.o._, orbital wing of sphenoid; _Pt.p._, pterygoid process of sphenoid; _P.p._, perpendicular part of palate bone; _F,F′_, facial and orbital parts of frontal bone; _L,L′_, orbital and facial parts of lacrimal bone; _M_, facial part of malar bone; _M.x._, maxilla; _a_, parieto-occipital suture; _b_, parieto-temporal or squamous suture; _c_, _d_, spheno-squamous suture; _e_, palato-frontal suture; _f_, fronto-lacrimal suture.]

The =lateral surface= (Norma lateralis) may be divided into cranial, orbital, and maxillary or preorbital regions.

The =cranial region= presents the temporal fossa, the zygomatic arch, and the outer part of the petrous temporal bone.

The =temporal fossa= is bounded internally by the sagittal and frontal crests, externally by the temporal crest and the zygomatic arch, and behind by the occipital crest. Its upper and middle parts are rough for the attachment of the temporal muscle. In its lower posterior part are several =foramina= which communicate with the parieto-temporal canal. The fossa is continuous in front with the orbital cavity.

The =zygomatic arch= is formed by the zygomatic processes of the temporal, malar, and maxilla. Its ventral face presents the =condyle= and =glenoid cavity= for articulation with the lower jaw, through the medium of the articular disc. Behind the glenoid cavity is the =postglenoid process=.

The =external auditory process= projects outward through a deep notch in the lower margin of the squamous temporal below the temporal crest. A little further back is the =mastoid process=, crossed in its upper part by a groove for the mastoid artery.

The =orbital region= comprises the orbit and the pterygo-palatine =fossa=.

The =orbit= is a cavity which incloses the eyeball, with the muscles, vessels, and nerves associated with it. It is not separated in the skeleton from the temporal fossa. The =long axis= of the cavity, taken from the optic foramen to the middle of the =inlet=, is directed forward, outward, and slightly upward. The =inner wall= (Paries medialis) is complete and extensive. It is concave and

smooth, and is formed by the frontal and lacrimal and the orbital wing of the sphenoid. In its extreme anterior part is the fossa for the lacrimal sac. Behind this is a small depression in which the inferior oblique muscle of the eye arises; here the plate which separates the orbit from the maxillary sinus is very thin. The =upper wall= (Paries superior) is formed by the frontal and to a small extent by the lacrimal bone. It presents the supraorbital foramen, which perforates the root of the supraorbital process. The =lower wall= (Paries inferior) is very incomplete, and is formed by the malar, the zygomatic process of the temporal, and to a small extent by the maxilla. The =external boundary= (Paries lateralis) is the supraorbital process. At the extreme posterior part is the =orbital group of foramina=. Four are situated in front of the pterygoid crest. Of these, the uppermost is the =ethmoidal= or =internal orbital foramen=, which transmits the ethmoidal vessels and nerve. The =optic foramen= is situated a little lower and further back; it transmits the optic nerve. Immediately below the optic is the =foramen lacerum orbitale=, which transmits the ophthalmic, third, sixth, and sometimes the fourth nerve; commonly there is a very small =trochlear= or =pathetic foramen= in the crest for the last-named nerve. The =foramen rotundum= is below the foramen lacerum, from which it is separated by a thin plate; it transmits the superior maxillary nerve. The =alar canal= opens in common with the foramen rotundum, and the anterior opening of the pterygoid or Vidian canal is also found here. The =temporal foramen= (For. alare parvum) is just behind the pterygoid crest and on a level with the foramen lacerum. It is the upper opening of a canal which leads from the alar canal, and through it the anterior deep temporal artery emerges. The =inlet= of the orbital cavity (Aditus orbitæ) is circumscribed by a complete bony ring, which is nearly circular. Its antero-inferior part (Margo infraorbitalis) is smooth and rounded; the remainder (Margo supraorbitalis) is rough and irregularly notched. During life the cavity is completed by the periorbita or ocular sheath, a conical fibrous membrane, the apex of which is attached around the optic foramen.

Below the orbital cavity is the =pterygo-palatine fossa=. Its wall is formed by the pterygoid process, the perpendicular part of the palate bone, and the tuber maxillare. Its deep anterior part (maxillary hiatus) contains three foramina. The upper one, the =maxillary foramen=, is the entrance to the infraorbital canal, which transmits the infraorbital nerve and vessels. The =sphenopalatine foramen= transmits vessels and nerves of like name to the nasal cavity. The lower foramen, the =posterior palatine=, transmits the palatine artery and nerve to the palatine canal. The upper part of the fossa is smooth, and is crossed by the internal maxillary artery and the maxillary nerve. The lower part is chiefly roughened for the attachment of the internal pterygoid muscle, but is crossed in front by a smooth groove in which the palatine vein lies.

The =maxillary= or =preorbital region= is formed chiefly by the maxilla, but also by the premaxilla, and the facial parts of the lacrimal and malar bones. Its contour is approximately triangular, the base being posterior. It offers two principal features. The =facial crest= extends forward from the lower margin of the orbit, and ends abruptly at a point about an inch and a half (3 to 4 cm.) above the third or fourth cheek tooth;[20] its inferior aspect is rough for the attachment of the masseter muscle. The =infraorbital foramen= is situated in a transverse plane about an inch (ca. 2 to 3 cm.) in front of the end of the crest and about two inches (5 cm.) above it. The foramen opens forward, and through it the infraorbital artery and nerve emerge. The surface over the premolar teeth varies greatly with age, in conformity with the size of the embedded parts of the teeth. In the young horse the surface here is strongly convex, the outer plate of bone is thin and even defective sometimes in places, and the form of the teeth is indicated by eminences (Juga alveolaria). In the old animal the surface is concave on account of the extrusion of the teeth from the bone. The downward curve of the premaxilla is pronounced in the young subject, very slight in the aged.

The =inferior= or =basal surface= (Norma basalis), exclusive of the mandible, consists of cranial, guttural, and palatine regions.

The =cranial region= (Basis cranii externa) extends forward to the vomer and pterygoid processes (Fig. 28). At its posterior end is the =foramen magnum=, flanked by the =occipital condyles=. External to the latter is the =condyloid fossa=, in which is the =hypoglossal foramen=, which transmits the hypoglossal nerve and the condyloid artery and vein. Further outward are the =paramastoid= or =styloid processes= (Processus jugulares) of the occipital bone. Extending forward centrally is a prismatic bar, formed by the basilar part of the occipital and the body of the sphenoid bone; at the junction of these parts are tubercles for the attachment of the ventral straight muscles of the head. On either side of the basilar part of the occipital is the =foramen lacerum basis cranii=, bounded externally by the base of the petrous temporal bone. In front of these the region becomes very wide on account of the lateral extension of the =zygomatic processes=, bearing on the ventral aspect the =condyle= and =glenoid cavity= for articulation with the mandible. Beyond this the process turns forward and joins the =zygomatic process= of the malar, completing the zygomatic arch and the surface for the attachment of the masseter muscle. On either side of the body of the sphenoid is the infratemporal fossa, formed by the temporal wing and the root of the pterygoid process of the sphenoid bone. It is bounded in front by the pterygoid crest, which separates it from the orbit and the pterygo-palatine fossa. In it is the =pterygoid= or =alar foramen=, which transmits the internal maxillary artery. A little lower is the entrance to the pterygoid (Vidian) =canal=.

The =guttural region= presents the pharyngeal orifice of the nasal cavity. This is elliptical and is divided in its depth medially by the vomer into two =posterior nares= or =choanæ=. It is bounded in front and laterally by the palate and pterygoid bones, behind by the vomer. It is flanked by the hamular process of the pterygoid bones. The plane of the opening is nearly horizontal, and the length is about twice the width.

The =palatine region= comprises a little more than half of the entire length of the base of the skull (Fig. 31). The =hard palate= (Palatum durum) is concave from side to side, and in its length also in the anterior part. It is formed by the palatine processes of the premaxillæ and maxillæ, and the horizontal parts of the palate bones. It is circumscribed in front and laterally by the =superior alveolar arch=, in which the upper teeth are implanted. The =interalveolar space= (Margo interalveolaris) is that part of the arch in which alveoli are not present. Behind the last alveolus is the =alveolar tuberosity=, and internal to this is a =groove= for the palatine vein. In the middle line is the =median palatine suture= (Sutura palatina mediana). In the line of the suture, a little behind the central incisors, is the =foramen incisivum=, through which the palato-labial artery passes. On either side, parallel with the alveolar part of the maxilla, is the =palatine groove= (Sulcus palatinus), which contains the palatine vessels and nerve. It is continuous at the anterior palatine foramen with the palatine canal, which is situated between the maxilla and the palate bone. The =palatine cleft= (Fissura palatina) is the narrow interval along the outer margin of the palatine process of the premaxilla; it is closed in the fresh state by cartilage. Scattered along each side of the palate are several vascular foramina. The =transverse palatine suture= (Sutura palatina transversa) is about half an inch from the posterior border. The latter is in a plane through the last molar teeth, and is concave and free.

[Illustration:

FIG. 34.—CRANIAL CAVITY OF HORSE AS SEEN ON SAGITTAL SECTION OF SKULL.

_O_, Frontal sinus; _r_, sphenoidal sinus; _t_, cerebral compartment of cranium; 1–3, ridges (juga) corresponding to fissures of lateral surface of cerebrum; 4, groove for middle cerebral artery; 5, entrance to for. lacerum orbitale; 6, entrance to optic foramen; 7, 8, grooves on sphenoid bone; 9, incisura spinosa; 9′, groove for middle meningeal artery; 10, fossa for pyriform lobe of cerebrum; 11, incisura ovalis; 12, incisura carotica; 13, internal auditory meatus; 14, foramen lacerum basis cranii; 15, hypoglossal foramen; 16, petrous temporal; 17, orifice of aquæductus vestibuli; 18, orifice of aquæductus cochleæ; 19, foramen magnum; 20, petrosal crest; 21, two plates of frontal bone; 22, supraoccipital; 23, basioccipital; 24, tentorium osseum; 25, body of sphenoid. (After Ellenberger-Baum, Top. Anat. d. Pferdes.)]

The =posterior= or =nuchal surface= (Norma occipitalis) is formed by the occipital bone. It is trapezoidal in outline, wider below than above, concave dorso-ventrally, convex transversely. It is separated from the superior surface by the =occipital crest=, and from the lateral surfaces by the =superior curved lines= (Lineæ nuchæ superiores). Below the crest are two rough areas for the attachment of the complexus muscles. A little lower is a central eminence on the sides of which the ligamentum nuchæ is attached. At the lowest part centrally is the =foramen magnum=, at which the brain and spinal cord meet; this is bounded laterally by the =occipital condyles=, which are flanked by the =paramastoid= or =styloid processes= (Processus jugulares).

The =apex= of the skull is formed by the bodies of the premaxillæ and mandible, carrying the incisor teeth.

THE CRANIAL CAVITY

This cavity incloses the brain, with its membranes and vessels. It is relatively small and is ovoid in shape.

The =superior wall= or =roof= (Calvaria) is formed by the supraoccipital, interparietal, parietal, and frontal bones. In the middle line is the internal sagittal crest, which joins the crista galli in front, and furnishes attachment to the falx cerebri. Posteriorly the crest is continued by the sharp anterior margin of the =tentorium osseum=, which projects downward and forward into the cavity, and gives attachment to the tentorium cerebelli by its sharp lateral edges. Behind this the roof is grooved centrally for the middle lobe or vermis of the cerebellum. Transverse grooves pass from the base of the tentorium osseum to the parieto-temporal canals. The anterior part of the roof is hollowed by the frontal sinus. The occipital part is very thick and strong.

The =lateral walls= are formed by the occipital, parietal, temporal, and frontal bones, and in part by the orbital wings of the sphenoid. Each is crossed obliquely by the =petrosal crest=, which concurs with the projecting margin of the parietal bone and the tentorium osseum in dividing the cavity into cerebral and cerebellar compartments. Behind the crest is a depression for the lateral lobe (hemisphere) of the cerebellum. Below this are the internal auditory meatus and the openings of the aquæductus vestibuli and aquæductus cochleæ.

[Illustration:

FIG. 35.—FLOOR OF CRANIAL CAVITY OF HORSE.

The roots of the cranial nerves are shown on the left side and are designated by number. _I_, Anterior cranial fossa; _II_, middle cranial fossa; _III_, posterior cranial fossa; _a_, ethmoidal fossa; _b_, ethmoidal foramen; _c_, foramen for nasal branch of ophthalmic artery; _d_, orbital wing of sphenoid bone; _e_, optic fossa; _f_, sella turcica; _g_, spheno-occipital crest; _h_, _h′_, dotted line indicating contour of pituitary body; _h″_, slight elevation representing dorsum sellæ; _i_, _k_, grooves for nerves and cavernous sinus; _l_, depression for pyriform lobe of cerebrum; _m_, groove for middle meningeal artery; _n_, depression for pons; _o_, foramen lacerum anterius; _p_, foramen lacerum posterius; _q_, incisura carotica; _q′_, incisura ovalis; _q″_, incisura spinosa; _r_, depression for medulla oblongata; _s_, hypoglossal foramen; _t_, internal auditory meatus; _u_, foramen magnum; _v_, frontal sinus; _w_, zygomatic process of temporal bone; _x_, section of petrous temporal; _y_, section of occipital bone; _z_, crista galli; 1, 1′, 1″, dotted lines indicating position of olfactory tracts and peduncle. (After Ellenberger-Baum, Top. Anat. d. Pferdes.)]

The roof and lateral walls are marked by digital impressions and vascular grooves.

The =inferior wall= or =floor= (Basis cranii interna) may be regarded as forming three fossæ. The =anterior fossa= (Fossa cranii anterior) supports the frontal and olfactory parts of the cerebrum. It is formed chiefly by the presphenoid, and lies at a higher level than the middle fossa. In front the fossa is divided medially by the =crista galli=, lateral to which are the deep =ethmoidal= or =olfactory fossæ= for the olfactory lobes. The =ethmoidal= or =internal orbital foramen= perforates the cranial wall at the outer side of these fossæ. Further back the central part of the surface is slightly elevated, and is flanked by shallow depressions which support the olfactory peduncles. Posteriorly is a bony shelf which covers the entrance to the =optic foramina=; the edge of this shelf and the posterior borders of the orbital wings of the sphenoid may be taken as the line of demarcation between the anterior and middle fossæ. The =middle fossa= (Fossa cranii media) is the widest part of the cavity. It extends backward to the internal spheno-occipital and petrosal crests, thus corresponding to the postsphenoid. In its middle is a small fossa, the sella turcica, in which the pituitary body, or hypophysis cerebri, is situated. On either side are two grooves for nerves; the inner one transmits the ophthalmic, third, and sixth nerves to the foramen lacerum orbitale; the outer one leads to the foramen rotundum, and lodges the maxillary nerve. External to the grooves is a depression for the pyriform lobe of the cerebrum. The =posterior fossa= (Fossa cranii posterior) corresponds to the basilar part of the occipital bone. It contains the medulla, pons, and cerebellum. In front is a median depression (Fossa pontis) for the pons. The surface behind this is concave transversely and slopes gently downward to the foramen magnum; it supports the medulla. On either side are the =foramen lacerum basis cranii= and the =hypoglossal foramen=.

The =anterior= or =nasal wall= is formed by the cribriform plate of the ethmoid, which separates the cranium from the nasal cavity. It is perforated by numerous foramina for the passage of the olfactory nerve-bundles.

[Illustration:

FIG. 36.—MEDIAN SECTION OF SKULL OF HORSE WITHOUT THE MANDIBLE.

The septum nasi is removed, but the mucous membrane on the turbinal bones is retained. _a_, _a′_, Superior turbinal bone, dotted line indicating limit between anterior coiled part and posterior uncoiled part; _b_, _b′_, superior turbinal folds, inclosing bars of cartilage; _c_, fold of mucous membrane formed by union of _b_ and _b′_; _d_, _d′_, anterior coiled and posterior uncoiled part of inferior turbinal, dotted line indicating septum between them; _e_, _f_, inferior turbinal folds, former (alar fold) inclosing bar of cartilage; _g_, _h_, _i_, superior, middle, inferior meatus; _o_, _o′_, frontal sinus; partial septum between _o_ and _o′_; _q_, nasal part of frontal sinus (nasal sinus); _r_, lateral mass of ethmoid bone; _s_, sphenoidal sinus; _t_, cranial cavity; _u_, opening made in superior turbinal bone at point where drainage of frontal sinus may be obtained. (After Ellenberger, in Leisering's Atlas.)]

THE NASAL CAVITY

The =nasal cavity= (Cavum nasi) is a longitudinal passage which extends through the upper part of the face. It is divided into right and left halves by a median =septum nasi=. The =lateral walls= are formed by the maxilla, premaxilla, and the perpendicular part of the palate bones. Attached to them are the turbinal bones, which subdivide each nasal fossa into three =meatuses= (Meatus nasi). This wall is crossed obliquely by the =canal= and =groove= for the =naso-lacrimal duct=, and its posterior part is perforated by the =sphenopalatine foramen=. The =superior wall= or =roof= is formed by the frontal and nasal bones. It is concave from side to side,

and nearly straight longitudinally, except in the posterior part, where it curves downward. It presents a median elevation, the =nasal crest=. The =inferior wall= or =floor= is formed by the palatine processes of the premaxillæ and maxillæ, and the horizontal parts of the palate bones. It is wider but considerably shorter than the roof. It is concave transversely, and nearly horizontal from before backward, except in the posterior third, where there is a slight declivity. The anterior part presents a median groove for the cartilaginous septum, and a furrow for the organ of Jacobson on either side. On either side of the palatine processes of the premaxillæ is the =palatine cleft=.

The =septum nasi= is incomplete in the macerated skull. It is formed by the perpendicular plate of the ethmoid behind, and the vomer below. In the fresh state it is completed by a plate of cartilage.

The =superior meatus= (Meatus nasi superior) is a narrow passage between the roof and the superior turbinal bone. It ends at the cribriform plate of the ethmoid. The =middle meatus= (Meatus nasi medius) is the space between the two turbinal bones. In its posterior part is the very narrow opening into the maxillary sinus. The =inferior meatus= (Meatus nasi inferior) is the channel along the floor which is overhung by the inferior turbinal bone. It is much the largest and is the direct path between the anterior and posterior nares.

The external aperture is bounded by the nasal bones and the premaxillæ.

[Illustration:

FIG. 37.—CROSS-SECTION OF NASAL REGION OF SKULL OF HORSE; THE SECTION PASSES THROUGH THE ANTERIOR END OF THE FACIAL CREST, AND BETWEEN THE THIRD AND FOURTH CHEEK TEETH.

_a_, Superior, _b_, inferior turbinal bone; _c_, _d_, cavities of _a_ and _b_; _e_, common meatus; _f_, _g_, _h_, superior, middle, inferior meatus; _i_, _k_, passages to cavities of turbinal bones; _l_, naso-lacrimal duct; _m_, infraorbital canal; _n_, anterior end of maxillary sinus; _o_, septal cartilage. (After Ellenberger, in Leisering's Atlas.)]

[Illustration:

FIG. 38.—CROSS-SECTION OF NASAL REGION OF SKULL OF HORSE; THE SECTION IS CUT ABOUT HALFWAY BETWEEN THE ORBIT AND THE ANTERIOR END OF THE FACIAL CREST, AND PASSES BETWEEN THE FIFTH AND SIXTH CHEEK TEETH.

_a_, Superior, _b_, inferior turbinal bone; _c_, _d_, cavities of _a_ and _b_; _e_, common meatus; _f_, superior, _g_, middle, _h_, inferior meatus; _i_, placed over ridge in maxillary sinus; _k_, communication between outer and inner (turbinal) part of maxillary sinus; _l_, naso-maxillary opening; _m_, naso-lacrimal canal; _n_, infraorbital canal. (After Ellenberger, in Leisering's Atlas.)]

The posterior extremity or fundus is separated from the cranial cavity by the cribriform plate of the ethmoid, and is largely occupied by the lateral masses of that bone.

THE PARANASAL SINUSES

Connected directly or indirectly with the nasal cavity, of which they are diverticula, are four pairs of air-sinuses (Sinus paranasales), viz., maxillary, frontal, sphenopalatine, and ethmoidal.

The =maxillary sinus= (Sinus maxillaris) is the largest. Its external wall is formed by the maxilla, the lacrimal, and the malar. It is bounded internally by the maxilla, the inferior turbinal, and the lateral mass of the ethmoid bone. It extends backward to a transverse plane in front of the root of the supraorbital process, and its anterior limit is indicated approximately by a line drawn from the anterior end of the facial crest to the infraorbital foramen. Its upper boundary corresponds to a line drawn backward from the supraorbital foramen parallel to the facial crest. The floor is formed by the alveolar part of the maxilla; it is very irregular and is crossed by bony plates running in various directions. The last three cheek teeth project up into the cavity to an extent which varies with age; they are covered by a thin plate of bone. The cavity is divided into anterior and posterior parts by an oblique =septum=. The outer margin of the septum is commonly about one and a half to two inches (ca. 3.5 to 5 cm.) from the anterior end of the facial crest; from here it is directed inward, backward, and upward. The upper part of the septum (formed by the posterior end of the inferior turbinal bone) is very delicate and usually cribriform.

The position of the septum is quite variable. It is not rare to find it further forward, and in some cases it is further back than is stated above. In the recent state, _i. e._, when covered by the mucous membrane on both surfaces, it is nearly always complete, but in very exceptional cases there is an opening of variable size in the upper part.

The =anterior compartment=, often called the =inferior maxillary sinus=, is partially divided by the infraorbital canal into an external maxillary part and an internal smaller turbinal part. The latter communicates with the middle meatus by a very narrow slit situated at its highest part. The =posterior compartment=, often called the =superior maxillary sinus=, is also crossed by the infraorbital canal, internal to which it opens freely into the sphenopalatine sinus. It communicates dorsally with the frontal sinus through the large oval =fronto-maxillary opening=, situated at the level of the osseous lacrimal canal and the corresponding part of the inner wall of the orbit; the orifice is commonly about one and a half to two inches (ca. 4 to 5 cm.) long and an inch or more (2 to 3 cm.) wide. Just in front of this, and covered by a thin plate, is the narrow =naso-maxillary fissure= (Aditus naso-maxillaris), by which the sinus opens into the posterior part of the middle meatus.

The foregoing statements refer to the arrangement in the average adult animal. In the foal the cavity (with the exception of its turbinal part) is largely occupied by the developing teeth. In horses five to six years of age the maxillary part of the sinus is still filled up to a large degree by the embedded parts of the teeth. As the teeth are extruded to compensate the wear, more and more of the cavity becomes free, until in old age only the short roots project up in the floor, covered by a layer of bone. Other facts in this connection will be given in the description of the teeth. In exceptional cases the posterior part of the inferior turbinal is smaller than usual and leaves a considerable interval, through which the maxillary sinus communicates with the nasal cavity.

[Illustration:

FIG. 39.—SKULL OF HORSE, LATERAL VIEW WITHOUT MANDIBLE. THE SINUSES ARE OPENED UP.

_a_, Posterior part, _b_ and _c_, anterior part of frontal sinus; _d_, roof of superior meatus; _e_, lateral mass of ethmoid bone; _f_, _f′_, naso-lacrimal duct, exposed in its posterior part; _g_, _h_, posterior and anterior compartments of maxillary sinus (also designated as superior and inferior maxillary sinuses); _i_, septum between _g_ and _h_; _k_, lower limit of upper thin and partly membranous portion of septum; _l_, infraorbital canal; _m_, turbinal part of maxillary sinus; _n_, bullous prominence of inferior turbinal; _o_, orbit; _p_, infraorbital foramen; _q_, continuation of infraorbital canal to premaxilla; _r_, limit of maxillary sinus. (After Ellenberger, in Leisering's Atlas.)]

The =frontal sinus= (Sinus concho-frontalis) consists of frontal and turbinal parts. The frontal part is bounded chiefly by the two plates of the frontal bone, but its floor is formed in part by the lateral mass of the ethmoid. It extends forward to a plane through the anterior margins of the orbits, backward to one through the temporal condyles, and outward into the root of the supraorbital process. It is separated from the sinus of the opposite side by a complete =septum=. It is partially subdivided by a number of bony plates. The turbinal part is situated in the posterior part of the superior turbinal bone, roofed in by the nasal and lacrimal bones. It extends forward to a transverse plane about half-way between the anterior margin of the orbit and the end of the facial crest. Behind it is in free communication with the frontal part over the lateral mass of the ethmoid. It is separated from the nasal cavity by the thin turbinal plate. The frontal and maxillary sinuses communicate through the large opening described above.

The =sphenopalatine sinus= (Sinus sphenopalatinus) consists of two parts which communicate under the lateral mass of the ethmoid. The sphenoidal (posterior) part is excavated in the body of the presphenoid. The palatine (anterior) part is between the two plates of the perpendicular part of the palate bone, under the lateral mass of the ethmoid; it communicates freely with the maxillary sinus. The septum between the right and left sinuses is not usually median in the sphenoidal part.

In about one-third of the cases (according to Paulli) the sphenoidal and palatine parts are separated by a transverse septum, and the sphenoidal part then communicates only with the lower ethmoidal meatuses.

The term =ethmoidal sinus= is often applied to the cavity of the largest ethmoturbinal. It communicates with the maxillary sinus.

[Illustration:

FIG. 40.—SKULL OF HORSE, DORSAL VIEW, WITH SINUSES EXPOSED BY REMOVAL OF THE OUTER PLATE OF BONE.

_1_, Frontal bone; _2_, nasal bone; _3_, lacrimal bone; _4_, maxilla; _a_, posterior part of frontal sinus; _a′_, middle part of frontal sinus; _b_, anterior (turbinal) part of frontal sinus; _c_, lateral mass of ethmoid bone; _d_, roof of superior meatus; _e_,

fronto-maxillary opening; _f_, naso-maxillary opening below plate which forms the anterior margin of _e_; _g_, _h_, posterior and anterior compartments of maxillary sinus—often called the superior and inferior maxillary sinuses; _i_, septum between _g_ and _h_; _k_, orbit; _l_, point at which superior turbinal bone may be perforated to obtain drainage into nasal cavity. (After Ellenberger, in Leisering's Atlas.)]

THE BONES OF THE THORACIC LIMB THE SCAPULA

The =scapula= is a flat bone, situated on the anterior part of the lateral wall of the thorax, and extending obliquely from the vertebral end of the seventh or eighth rib to the sternal end of the first rib. It is curved slightly and slopes outward in adaptation to the form of the thoracic wall. It is triangular in outline, and has two surfaces, three borders, and three angles.

The =external surface= or =dorsum= (Facies lateralis s. dorsalis) is divided into two fossæ by the =spine= (Spina scapulæ), which extends from the vertebral border to the neck of the bone, where it gradually subsides. The free edge of the spine is thick, rough, and in great part subcutaneous. A little above its middle is a variable prominence, the =tubercle= of the spine (Tuber spinæ), to which the trapezius muscle is attached. The =supraspinous fossa= (Fossa supraspinata) is situated in front of the spine, and the =infraspinous fossa= (Fossa infraspinata) behind it. The former is much the smaller of the two; it is smooth and is occupied by the supraspinatus muscle. The infraspinous fossa lodges the infraspinatus muscle; it is wide and smooth in its upper part, narrower below, where it is marked by several rough lines for the attachment of the teres minor muscle; near the neck is the nutrient foramen, and a little lower is a vascular groove.

[Illustration:

FIG. 41.—LEFT SCAPULA OF HORSE, EXTERNAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =costal surface= or =venter= (Facies costalis) is hollowed in its length by the =subscapular fossa= (Fossa subscapularis); this occupies nearly the whole of the lower part of the surface, but is pointed above and separates two rough triangular areas (Facies serrata), to which the serratus magnus is attached. In the lower third there is a vascular furrow with several branches.

The =anterior= or =cervical border= (Margo cranialis) is convex and rough above, concave and smooth below.

The =posterior= or =dorsal border= (Margo caudalis) is slightly concave. It is thick and rough in its upper third, thin in its middle, and thickens again below.

The =superior= or =vertebral border= (Margo dorsalis s. basis) carries the =scapular cartilage= (Cartilago scapulæ). In the young subject the edge of the bone is thick, and is pitted by impressions into which the cartilage fits. The cartilage is the unossified part of the fœtal scapula. Its lower edge fits the depressions and elevations of the bone. It thins out toward the free edge, which is convex and lies alongside of the upper parts of the vertebral spines. In front it continues the line of the scapula, but behind it forms a rounded projection. The lower part of the cartilage undergoes more or less ossification, so that the vertebral border of the bone in old subjects is thin, irregular, and porous.

[Illustration:

FIG. 42.—LEFT SCAPULA OF HORSE, COSTAL SURFACE.—(After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =anterior= or =cervical angle= (Angulus cranialis) is at the junction of the anterior and vertebral borders and lies opposite to the second thoracic spine. It is relatively thin and is about a right angle.

The =posterior= or =dorsal angle= (Angulus caudalis) is thick and rough; its position can be determined readily in the living animal.

The =inferior= or =articular angle= (Angulus glenoidalis) is joined to the body of the bone by the =neck= of the scapula (Collum scapulæ). It is enlarged, especially in the sagittal direction. It bears the =glenoid cavity= (Cavitas glenoidalis) for articulation with the head of the humerus. The cavity is oval in outline, and its margin is cut into in front by the =glenoid notch= (Incisura glenoidalis), and is rounded off externally; just above its postero-external part is a tubercle to which a tendon of the teres minor is attached. The =bicipital tuberosity= or =tuber scapulæ= is the large rough prominence in front, to which the tendon of origin of the biceps brachii is attached; projecting from its inner side is the small =coracoid process= (Processus coracoideus), from which the coraco-brachialis muscle arises.

=Development.=—The scapula has four centers of ossification, viz., one each for the body of the bone, the bicipital and coracoid processes, the anterior part of the glenoid cavity, and the tuber spinæ. The last ossifies after birth and fuses with the spine about the third year. The bicipital tuberosity and coracoid fuse with the body of the bone about the end of the first year.

In old subjects the spongy substance disappears at the middle part of the fossæ, so that the bone consists here of a thin layer of compact substance. Considerable ossification of the cartilage is usual, the borders become much rougher, the muscular lines are more pronounced, and a medullary cavity may appear in the neck. Much variation occurs in dimensions and slope. The average ratio between the length and breadth (scapular index) is about 1 ■ 0.5, but in many cases the base is relatively wider. The inclination on a horizontal plane varies from 50 to 65 degrees. Exceptionally the coracoid process reaches a length of an inch or more (2½ to 3 cm.), and the chief nutrient foramen may be on the posterior border or in the subscapular fossa.

[Illustration:

FIG. 43.—DISTAL END OF LEFT SCAPULA OF HORSE, END VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE HUMERUS

The =humerus= is a long bone which extends from the shoulder above, where it articulates with the scapula, to the elbow below and behind, where it articulates with the radius and ulna. It is directed obliquely downward and backward, forming an angle of about 55 degrees with a horizontal plane. It may be divided into a shaft and two extremities.

[Illustration:

FIG. 44.—PROXIMAL END OF LEFT HUMERUS OF HORSE, END VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =shaft= or =body= (Corpus humeri) is irregularly cylindrical and has a twisted appearance. It may be regarded as having four surfaces. The =external surface= is smooth and is spirally curved, forming the =musculo-spiral groove= (Sulcus musculi brachialis), which contains the brachialis muscle; the groove is continuous with the posterior surface above and winds around toward the front below. The =internal surface= is nearly straight in its length, rounded from side to side, and blends with the anterior and posterior surfaces. Just above its middle is the =internal= or =teres tubercle= (Tuberositas teres), to which the tendon of the latissimus dorsi and teres major muscles is attached. The =nutrient foramen= is in the lower third of this surface. The =anterior surface= is triangular, wide and smooth above, narrow and roughened below. It is separated from the external surface by a distinct border, which bears on its upper part the =deltoid tuberosity= (Tuberositas deltoidea). From the latter a rough line curves upward and backward to the outer surface of the neck, and gives origin to the external head of the triceps muscle. Below the tuberosity the border inclines forward, becomes less salient, and ends at the coronoid fossa. The =posterior surface= is rounded from side to side and smooth.

[Illustration:

FIG. 45.—LEFT HUMERUS OF HORSE, INTERNAL SURFACE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 46.—LEFT HUMERUS OF HORSE, EXTERNAL SURFACE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =proximal extremity= consists of the head, neck, two tuberosities, and the bicipital groove. The =head= (Caput humeri) presents an almost circular convex articular surface, which is about twice as extensive as the glenoid cavity of the scapula, with which it articulates. In front of the head is a fossa, in which are several foramina. The neck (Collum humeri) is well defined behind, but is practically absent elsewhere. The =external tuberosity= (Tuberculum majus) is placed antero-externally, and consists of two parts; the anterior part forms the outer boundary of the bicipital groove and gives attachment to the external branch of the supraspinatus muscle; the posterior part gives attachment to the short insertion of the infraspinatus, while its outer surface is coated with cartilage, over which the chief tendon of the same muscle passes to be inserted into a triangular facet on the outer aspect of the anterior part. The =internal tuberosity= (Tuberculum minus) is less salient, and consists of anterior and posterior parts; the anterior part forms the inner boundary of the bicipital groove, and furnishes insertion to the inner branch of the supraspinatus above, and the posterior deep pectoral muscle below; the posterior part gives attachment to the subscapularis muscle. The =bicipital= or =intertubercular groove= (Sulcus intertubercularis) is situated in front; it is bounded by the anterior parts of the tuberosities, and is subdivided by an intermediate ridge. The groove is covered in the fresh state by cartilage, and lodges the

tendon of origin of the biceps brachii muscle. Just below the intermediate ridge is a small fossa in which several foramina open.

[Illustration:

FIG. 47.—LEFT HUMERUS OF HORSE, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =distal extremity= has an oblique surface for articulation with the radius and ulna, which consists of two condyles of very unequal size, separated by a ridge. The =internal condyle= (Condylus medialis) is much the larger, and is crossed by a sagittal groove, on the anterior part of which there is usually a synovial fossa. Posteriorly the groove extends upward considerably above the rest of the articular surface and reaches the olecranon fossa, and this part articulates with the semilunar notch of the ulna. The =external condyle= (Condylus lateralis) is much smaller and is placed somewhat lower and further back, giving the extremity an oblique appearance; it is marked by a wide shallow groove. The =coronoid fossa= (Fossa coronoidea) is situated in front above the groove on the internal condyle; it furnishes origin to part of the extensor carpi, and external to it is a rough depression from which the anterior or common extensor of the digit arises. Behind and above the condyles are two thick ridges, the epicondyles. The =internal= or =flexor epicondyle= (Epicondylus medialis s. flexorius) is the more salient; it furnishes origin to flexor muscles of the carpus and digit, and presents internally a tubercle for the attachment of the internal lateral ligament of the elbow joint. The =external= or =extensor epicondyle= (Epicondylus lateralis s. extensorius) bears externally the =external supracondyloid crest= (Crista condyloidea lateralis), which forms here the outer boundary of the musculo-spiral groove, and gives origin to the extensor carpi. Below this is a rough excavation in which the external lateral ligament is attached. The lower border of the epicondyle gives attachment to the flexor carpi externus. Between the epicondyles is the deep =olecranon fossa= (Fossa olecrani).

=Development.=—The humerus ossifies from six centers, viz., three primary centers for the shaft and epiphyses, and three secondary centers for the external tuberosity, the deltoid tuberosity, and the internal condyle. The proximal end fuses with the shaft at about three and one-half years, the distal at about one and a half years of age.

THE RADIUS

The =radius= is much the larger of the two bones of the forearm in the horse. It extends in a vertical direction from the elbow, where it articulates with the humerus, to the carpus below. It is gently curved, the convexity being anterior. It consists of a shaft and two extremities.

The =shaft= (Corpus radii) is curved in its length, somewhat flattened from before backward, and expanded at its ends. It presents for description two surfaces and two borders. The =anterior surface= (Facies dorsalis) is smooth, slightly convex in its length, and rounded from side to side. The =posterior surface= (Facies volaris) is correspondingly concave in its length and is flattened in the transverse direction. At its upper part there is a smooth shallow groove, which concurs with the ulna in the formation of the =interosseous space= of the forearm; the nutrient foramen is in the lower part of this groove. Below this there is in the young subject a narrow, rough, triangular area to which the ulna is attached by an interosseous ligament; in the adult the two bones are fused here. A variable rough elevation below the middle of the surface and close to the internal border gives attachment to the superior check ligament. The =internal border= (Margo medialis) is slightly concave in its length and is largely subcutaneous; at its proximal end there is a smooth area on which the tendon of insertion of the brachialis muscle lies, and a small rough area just below gives attachment to that muscle and the long internal lateral ligament of the elbow joint. The =external border= (Margo lateralis) is more strongly curved, but presents no special features.

The =proximal extremity= or =head= (Capitulum radii) is flattened from before backward and wide transversely. It presents an articular surface (Fovea capituli) which corresponds to that on the distal end of the humerus; it is crossed by a central sagittal ridge, which has a synovial fossa on its posterior part, and ends in front at a prominent lip, the =coronoid process= (Processus coronoideus). Just below the posterior border there are two concave facets for articulation with the ulna, and between these and the interosseous space is a quadrilateral rough area at which the two bones are united by an interosseous ligament. At the inner side of the anterior surface is the =bicipital tuberosity= (Tuberositas radii), into which the biceps tendon is inserted. The =internal tuberosity= is continuous with the preceding eminence, and furnishes attachment to the short part of the internal lateral ligament. The =external tuberosity= is more salient; it gives attachment to the external lateral ligament and to the anterior and lateral extensor muscles of the digit.

[Illustration:

FIG. 48.—LEFT RADIUS AND ULNA OF HORSE, EXTERNAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 49.—LEFT RADIUS AND ULNA OF HORSE, POSTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =distal extremity= is also compressed from before backward. It presents the =carpal articular surface= (Facies articularis carpea) which consists of three parts. The inner facet is the largest, is quadrilateral, concavo-convex from before backward, and articulates with the radial carpal bone (or scaphoid); the middle one is somewhat similar in form but smaller, and articulates with the intermediate carpal bone (or semilunar); the outer facet is smaller, is convex, and articulates below with the ulnar carpal (or cuneiform) and behind with the accessory carpal (or pisiform). The anterior surface presents three =grooves=, separated by ridges. The middle one is vertical and gives passage to the tendon of the extensor carpi radialis; the outer one is similar and contains the tendon of the anterior extensor of the digit; the inner one is small and oblique and lodges the tendon of the extensor carpi obliquus. The posterior aspect is crossed by a rough ridge, below which are three depressions. On either side is a tuberosity (Tuberculum ligamenti) to which the lateral ligament is attached. The outer one is marked by a small vertical groove for the passage of the lateral extensor tendon.

=Development.=—The radius ossifies from four centers, viz., one each for the shaft, the two extremities, and the outer part of the distal end; the last is morphologically the distal end of the ulna which has fused with the radius, and the line of fusion is often indicated by a distinct groove on the carpal articular surface. The proximal extremity unites with the shaft at about one and a half years, the distal end at about three and a half years.

[Illustration:

FIG. 50.—UPPER HALF OF RADIUS AND ULNA OF HORSE, INTERNAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE ULNA

The =ulna= of the horse is a reduced long bone situated behind the radius, with which it is partially fused in the adult.

The =shaft= (Corpus ulnæ) is three-sided and tapers to a point below. The =anterior surface= (Facies dorsalis) is applied to the posterior surface of the radius, and below the interosseous space the two bones are fused in the adult. The surface which enters into the formation of the space is smooth and usually presents a small nutrient foramen, directed upward. Above the space it is rough and is attached to the radius by an interosseous ligament which is usually permanent. The =internal surface= (Facies medialis) is smooth and slightly concave. The =external surface= (Facies lateralis) is flattened. The =internal= and =external borders= are thin and sharp, except at the interosseous space. The =posterior border= is slightly concave in its length and is rounded. The lower end is pointed and is usually a little below the middle of the radius. It is commonly continued by a fibrous cord to the distal external tuberosity of the radius, but this band may be replaced in part or entirely by bone.

The =proximal extremity= is the major part of the bone. It projects upward and somewhat backward behind the lower end of the humerus, and forms a lever arm for the extensor muscles of the elbow. The =internal surface= is concave and smooth. The =external surface= is convex and is roughened above. The =anterior border= bears on its middle a pointed projection, the =processus anconæus= or "beak," which overhangs the =semilunar notch= or =sigmoid cavity= (Incisura semilunaris). The latter is triangular in outline, concave from above downward, and articulates with the humerus; in the middle of its lower part is an extensive synovial fossa. Just below the notch are two convex =facets= which articulate with those on the posterior aspect of the proximal end of the radius. The =posterior border= is nearly straight, and is thick and rounded. The free end or summit is a rough tuberosity, the =olecranon=, which gives attachment to the triceps brachii and other muscles.

The primitive =distal extremity= has, as previously stated, fused with the radius.

=Development.=—The ulna ossifies from three centers, of which one is for the main part of the bone, one for the olecranon, and one for the distal end. The cartilaginous embryonic ulna extends the entire length of the forearm. The lower part of the shaft is usually reduced to a small fibrous band or may disappear entirely; in some cases a variable remnant of it ossifies. The distal extremity fuses early with the radius. The olecranon unites with the rest of the bone at three to three and a half years. A medullary canal appears to occur constantly in the adult—contrary to the statements of some authors.

THE CARPUS

The =carpus= of the horse consists of seven or eight bones (Ossa carpi) arranged in two rows, proximal or antibrachial, and distal or metacarpal. The (abbreviated) names and relative positions of the bones of the left carpus as seen from in front are indicated below.

Proximal Row: Radial Intermediate Ulnar Accessory

Distal Row: First Second Third Fourth

THE RADIAL CARPAL BONE

The =radial carpal= bone (Os carpi radiale, scaphoid) is the largest bone of the upper row; it is somewhat compressed laterally, and is clearly six-sided. The =superior= or =proximal surface= is convex in front, concave behind, and articulates with the inner facet on the distal end of the radius. The =inferior= or =distal surface= is also convex in front and concave behind; it articulates with the second and third carpal bones. The =external surface= bears upper and lower facets on its anterior part for articulation with the intermediate; between and behind these it is excavated and rough. The =anterior= or =dorsal surface= is rough and slightly convex. The =internal surface= and the =posterior= or =volar surface= are rough and tuberculate.

[Illustration:

FIG. 51.—SAGITTAL SECTION OF UPPER PART OF RADIUS AND ULNA OF HORSE. _Cm_, Medullary cavity of ulna.]

THE INTERMEDIATE CARPAL BONE

The =intermediate carpal= bone (Os carpi intermedium, semilunar, lunar) is somewhat wedge-shaped, wider in front than behind. The =superior= or =proximal surface= is saddle-shaped, and articulates with the middle facet on the distal end of the radius. The =inferior= or =distal surface= is smaller, convex in front, concave behind, and articulates with the third and fourth carpal bones. The =internal surface= has upper and lower facets for articulation with the radial carpal, and between these it is excavated and rough. The =external surface= is similar to the preceding and articulates with the ulnar carpal. The =anterior= or =dorsal surface= is rough and slightly convex. The =posterior= or =volar surface= bears a tuberosity on its lower part.

THE ULNAR CARPAL BONE

The =ulnar carpal= bone (Os carpi ulnare, cuneiform) is the smallest and most irregular bone of the upper row. The =superior= or =proximal surface= is concave, and fits the lower part of the outer facet on the distal end of the radius. The =inferior= or =distal surface= is oblique and undulating for articulation with the fourth carpal bone. The =internal surface= has upper and lower facets for articulation with the intermediate. The =anterior= or =dorsal= and =external surfaces= are continuous, convex, and rough. The =posterior= or =volar surface= is oblique, and bears a concave facet for articulation with the accessory carpal bone; below this is a tubercle.

[Illustration:

FIG. 52.—LEFT CARPAL BONES OF HORSE, WITH DISTAL END OF RADIUS AND PROXIMAL END OF METACARPUS; INTERNAL VIEW.]

[Illustration:

FIG. 53.—LEFT CARPAL BONES OF HORSE, WITH ADJACENT ENDS OF RADIUS AND METACARPUS; EXTERNAL VIEW.

_Ca_, Accessory carpal bone; _Cr_, radial carpal; _Ci_, intermediate carpal; _Cu_, ulnar carpal; _C1–4_, first to fourth carpals; _Mc. II_, _III_, _IV_, metacarpal bones; _1_, groove for tendon of extensor carpi obliquus; _2_, groove for lateral extensor tendon; _3_, groove for tendon of flexor carpi externus; _4_, metacarpal tuberosity. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE ACCESSORY CARPAL BONE

The =accessory carpal= bone (Os carpi accessorium, pisiform) is situated behind the ulnar carpal bone and the outer part of the distal end of the ulna. It is discoid and presents for description two surfaces and a circumference. The =internal surface= is concave and forms the outer wall of the carpal groove. The =external surface= is convex and rough; a smooth groove for the outer tendon of the flexor carpi externus crosses its anterior part obliquely downward and slightly forward. The =anterior border= bears two facets;

the upper one is concave and articulates with the back of the outer facet on the distal end of the radius; the lower one is convex and articulates with the ulnar carpal bone. The remainder of the circumference is rounded and rough.

The accessory does not directly bear weight, and may be regarded as a sesamoid bone interposed in the course of the tendons of the middle and external flexors of the carpus, which it enables to act at a mechanical advantage. The posterior border furnishes attachment to the transverse carpal ligament, which completes the carpal canal for the flexors of the digit.

THE FIRST CARPAL BONE

The =first carpal= bone (Os carpale primum, trapezium) is a small inconstant bone, commonly about the size and shape of a pea, which is situated in the lower part of the internal lateral ligament behind the second carpal bone.

This bone appears to be absent on both sides in about half of the cases; in a good many subjects it is present on one side only. In size it varies from a minute nodule to a discoid mass 10 to 12 mm. in length. In exceptional cases it articulates with both the second carpal and the second (inner) metacarpal bone, in other cases with the former only, but in the majority of specimens no articular facet is present.

THE SECOND CARPAL BONE

The =second carpal= bone (Os carpale secundum, trapezoid) is the smallest constant bone of the lower row, and is irregularly hemispherical in shape. The =superior= or =proximal surface= is a convex facet which is continued upon the =posterior= or =volar surface= and articulates with the posterior part of the radial carpal. The =external surface= faces obliquely outward and forward, and bears three facets for articulation with the third carpal bone. The =anterior= or =dorsal= and the =internal surface= bear a tuberosity to which the lateral ligament is attached. The =inferior= or =distal surface= is articular and consists of a large flattened facet for the inner (second) metacarpal bone, and a small one for the large (third) metacarpal bone. Some specimens have a small facet on the lower part of the posterior surface which articulates with the first carpal bone.

[Illustration:

FIG. 54.—CARPAL BONES OF HORSE, WITH ADJACENT ENDS OF RADIUS AND METACARPUS; ANTERIOR VIEW. THE ACCESSORY AND FIRST CARPAL BONES ARE NOT SHOWN.]

[Illustration:

FIG. 55.—CARPAL ARTICULAR SURFACE OF RADIUS AND PROXIMAL ARTICULAR SURFACES OF CARPAL AND METACARPAL BONES, LEFT SIDE. THE ACCESSORY AND FIRST CARPAL BONES ARE NOT SHOWN.

_Cr_, Radial carpal; _Ci_, intermediate carpal; _Cu_, ulnar carpal; _C2_, _C3_, _C4_, second, third, and fourth carpals; _Mc.II_, second or inner small metacarpal bone; _Mc.III_, third or large metacarpal bone; _Mc.IV_, fourth or outer small metacarpal bone; _1_, _2_, grooves for tendons of anterior extensor and extensor carpi radialis; _3_, metacarpal tuberosity. Arrows indicate relations of facets. Short arrow points to facet on ulnar carpal for articulation with accessory carpal. (After Schmaltz, Atlas. d. Anat. d. Pferdes.)]

THE THIRD CARPAL BONE

The =third carpal= bone (Os carpale tertium, os magnum) is much the largest bone of the lower row, forming more than two-thirds of the width of the latter. It is flattened from above downward, and is twice as wide in front as behind. The =superior= or =proximal surface= consists of two facets separated by an antero-posterior ridge; the inner facet is concave and articulates with the radial carpal; the outer facet—for the intermediate carpal—is concave in front and convex behind, where it encroaches on the posterior surface. The =inferior= or =distal surface= is slightly undulating, and articulates almost entirely with the large (third) metacarpal bone, but it usually bears a small oblique facet at its inner side for the inner (second) metacarpal, and there is commonly a non-articular depression externally. The _internal surface_ faces backward and inward, and bears three facets for articulation with the second carpal, between which it is excavated and rough. The =external surface= has two facets for articulation with the fourth carpal, and is depressed and rough in its middle. The =anterior= or =dorsal surface= is convex and is crossed by a rough transverse ridge. The =posterior= or =volar surface= is relatively small, and is rounded; its upper part is encroached upon by the superior articular surface, below which it is rough.

THE FOURTH CARPAL BONE

The =fourth carpal= bone (Os carpale quartum, unciform) is somewhat wedge-shaped, and is readily distinguished from the second by its greater size and its posterior tubercle. The =superior= or =proximal surface= articulates with the intermediate and ulnar; it is convex and curves outward, backward, and downward, encroaching on the external and posterior surfaces. The =inferior= or =distal surface= bears two inner facets for the large (third) metacarpal and an outer one for the external (fourth) metacarpal bone. The =internal surface= has two or three facets for articulation with the third carpal, between which it is excavated and rough. The =anterior= or =dorsal surface= is convex and rough. The =external surface= is small, being encroached upon by the superior articular surface. The =posterior= or =volar surface= bears a tubercle on its lower part.[21]

THE CARPUS AS A WHOLE

The bones of the carpus, exclusive of the accessory, form an irregular quadrangular mass, the width of which is about twice the height or the antero-posterior diameter. The =anterior= or =dorsal surface= is convex from side to side, depressed along the line of junction of the two rows, and prominent below. The =posterior= or =volar surface= is in general slightly convex, but very irregular. It forms with the accessory the =carpal groove= (Sulcus carpi), which in the recent state is rendered smooth by the posterior ligament; it is converted into the =carpal canal= (Canalis carpi) for the flexor tendons by the transverse carpal ligament, which stretches across from the accessory bone to the inner side. The =proximal surface= is widest internally and is elevated in front, concave behind; it is entirely articular and adapted to the carpal articular surface of the radius. The =distal surface= is also articular and is irregularly faceted in adaptation to the surfaces of the metacarpal bones; each of the lower bones usually articulates with two metacarpal bones, but sometimes the third does not bear on the inner metacarpal bone. The =lateral surfaces= are both irregular and rough, the internal one being the wider. With the exception of the accessory, ulnar, and second, each bone articulates with two bones of the other row.

=Development.=—Each ossifies from a single center.

THE METACARPUS

Three =metacarpal bones= (Ossa metacarpalia) are present in the horse. Of these, only one, the third or large metacarpal bone, is fully developed and carries a digit; the other two, the second and fourth, are much reduced, and are commonly called the internal and external small metacarpal or “splint” bones.

[Illustration:

FIG. 56.—DISTAL ROW OF CARPAL BONES, METACARPUS, FIRST AND SECOND PHALANGES, AND PROXIMAL SESAMOID BONES OF HORSE; POSTERIOR VIEW, LEFT SIDE.

The fourth (external) metacarpal bone is wrongly numbered as I. (After Schmaltz, Atlas. d. Anat. d. Pferdes.)]

[Illustration:

FIG. 57.—LEFT METACARPAL AND DIGITAL BONES OF HORSE, INTERNAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE LARGE METACARPAL BONE

This (Os metacarpale tertium) is a very strong long bone, placed vertically between the carpus above and the first phalanx below. It consists of a shaft and two extremities.

The =shaft= (Corpus) is semicylindrical, and presents two surfaces and two borders. The =anterior= or =dorsal surface= is smooth, convex from side to side, and nearly straight in its length. The =posterior= or =volar surface= is somewhat convex from side to side and, with the small bones, forms a wide groove which lodges the suspensory ligament. On either side of its upper two-thirds it is roughened for the attachment of the small metacarpal bones. The =nutrient foramen= occurs at the junction of the upper and middle thirds. The lower third is wider and flattened. The borders are rounded.

The =proximal extremity= (Basis) bears an undulating articular surface adapted to the lower row of carpal bones. The greater part supports the third carpal bone; the oblique outer part, separated from the preceding by a ridge, articulates with the fourth, and a

small facet for the second is usually found at the postero-internal angle. On either side is a notch separating two small facets which articulate with the proximal ends of the small metacarpal bones. Toward the inner side of the anterior surface is the =metacarpal tuberosity=, into which the extensor carpi radialis is inserted. The posterior surface is roughened for the attachment of the suspensory ligament.

The =distal extremity= (Trochlea s. Capitulum) presents an articular surface for the first phalanx and the proximal sesamoid bones, which is composed of two condyles, separated by a sagittal ridge; the inner condyle is slightly the larger. On either side is a small fossa, surmounted by a tubercle, for the attachment of the lateral ligaments of the fetlock joint.

The large metacarpal is one of the strongest bones in the skeleton. The compact substance is specially thick in front and internally. The medullary canal extends further toward the ends than in most of the long bones of the horse and there is little spongy bone.

THE SMALL METACARPAL BONES

These are situated on either side of the posterior surface of the large metacarpal bone, and form the sides of the metacarpal groove. Each consists of a shaft and two extremities.

The =shaft= (Corpus) is three-sided and tapers to the distal end. It is variably curved, convex toward the middle line of the limb. The anterior surface is flattened and is rough, except in its lower part; it is attached to the large metacarpal bone by an interosseous ligament, except near the distal end. The abaxial surface is smooth and rounded from side to side above, grooved below. The axial surface is smooth and concave from edge to edge, except below, where it forms a rounded edge.

The =proximal extremity= or =head= (Basis) is relatively large. In the case of the inner bone it usually bears two facets above which support the second and third carpal bones, while the outer bone has here a single facet for articulation with the fourth carpal bone. Each has also two facets for articulation with the large metacarpal, and is elsewhere roughened for the attachment of ligaments and muscles. The inner bone may present a small facet behind for the first carpal bone.

The =distal extremity= (Capitulum) is usually a small nodule, which projects to a variable extent in different subjects, and is easily felt in the living animal. It is situated two-thirds to three-fourths of the way down the region.

The small metacarpal bones vary much in length, thickness, and curvature. In the majority of cases the inner bone is the longer; in other subjects the outer one is the longer or there is no material difference. Sometimes the curvature is very pronounced, so that the distal end causes a decided projection. The distal end is very variable in size and may be a mere point.

=Development.=—The large metacarpal bone ossifies from three centers. The proximal extremity unites with the shaft before birth, the distal extremity toward the middle of the second year. The small metacarpal bones ossify from two centers, one of which is for the proximal extremity. Their distal ends are cartilaginous at birth. Fusion of the middle part of the shaft with the large metacarpal bone is common.

THE PHALANGES

THE FIRST PHALANX

The _first phalanx_ (Phalanx prima)[22] is a long bone, situated between the large metacarpal bone above and the second phalanx below. It is directed obliquely downward and forward, forming an angle of 50 to 55 degrees with the horizontal plane in well-formed limbs. It consists of a shaft and two extremities.

The =shaft= (Corpus) is wider and much thicker above than below, and presents two surfaces and two borders. The =anterior= or =dorsal surface= is convex from side to side and smooth. The =posterior= or =volar surface= is flattened, and bears a triangular rough area, bounded laterally by ridges which begin at the tuberosities above and converge below; this area furnishes attachment to the inferior sesamoidean ligaments. The =borders=, =internal= and =external=, are rounded and have a rough area or a tubercle on their middle parts.

The =proximal extremity= (Basis) is relatively large. It bears an articular surface adapted to the distal end of the large metacarpal bone, consisting of two glenoid cavities separated by a sagittal groove; the inner cavity is a little larger than the outer one. The posterior angles are formed by buttress-like tuberosities for ligamentous attachment. The anterior surface has a slight elevation for

the attachment of the lateral extensor tendon.

The =distal extremity= is smaller, especially in its antero-posterior diameter. It presents a trochlea for articulation with the second phalanx, consisting of a shallow central groove and two lateral convex areas or condyles; the inner area is a little the larger. On either side, just above the margin of the articular surface, is a depression surmounted by a tubercle, to both of which the lateral ligament is attached. Behind the tubercle is a distinct facet to which the superficial flexor tendon is attached.

=Development.= The first phalanx ossifies from three centers. The distal end unites with the shaft before birth, the proximal end early in the first year.

The first phalanx contains a small medullary canal in the middle of the shaft. It may be remarked that the bone is twisted slightly; when placed volar surface down on the table, it touches the latter by three points only, the proximal tuberosities and the internal condyle.

THE SECOND PHALANX

The =second phalanx= (Phalanx secunda)[23] is situated between the first and third phalanges, its direction corresponding to that of the first phalanx. It is flattened from before backward, and its width is greater than its height. It may be described as possessing four surfaces.

The =upper= or =proximal surface= presents two glenoid cavities separated by a low ridge, and articulates with the first phalanx. The middle of the anterior border is elevated and roughened in front for the attachment of the anterior or common extensor tendon. The posterior border is thick and overhanging; in the fresh state its middle part is covered with cartilage, over which the deep flexor tendon passes. On either side there is an eminence, to which the lateral ligament and the superficial flexor tendon are attached.

The =inferior= or =distal surface= is trochlear, and articulates with the third phalanx and third sesamoid bone. It resembles somewhat the trochlea of the first phalanx, but is more extensive and encroaches more on the anterior and posterior surfaces.

The =anterior= or =dorsal surface= is convex from side to side and smooth in its middle; on its lower part are lateral rough depressions, surmounted by tuberosities, to both of which ligaments are attached.

The =posterior= or =volar= surface is smooth, flattened, and slopes obliquely downward and forward. The borders which separate the anterior and posterior surfaces are concave from above downward, rounded from before backward.

=Development.=—The second phalanx ossifies like the first, but the proximal end unites with the shaft two or three months earlier.

[Illustration:

FIG. 58.—PHALANGES AND THIRD SESAMOID OF HORSE, DORSAL ASPECT.]

THE THIRD PHALANX

The =third= or =ungual phalanx= (Phalanx tertia)[24] is entirely inclosed by the hoof, to which it conforms in a general way. It presents for examination three surfaces, three borders, and two angles or wings.

The =articular surface= (Facies articularis) faces upward and backward, and is chiefly adapted to the distal surface of the second phalanx, but a narrow flattened area along the posterior border articulates with the third sesamoid. The =anterior= or =coronary border= forms a central eminence, the =extensor= (or pyramidal) =process= (Processus extensorius), to the front of which the anterior extensor tendon is attached. On either side is a depression for the attachment of the lateral ligament.

The =dorsal= or =wall surface= (Facies dorsalis) slopes downward and forward. The angle of inclination on the ground plane is about 45 to 50 degrees in front. Laterally the height diminishes, and the slope becomes steeper, especially on the inner side. From side to side the curvature is almost semicircular. The surface is rough and porous, resembling pumice stone somewhat. It is perforated by numerous foramina of various sizes; a series of larger ones is situated on or near the lower border. On either side the =dorsal= (or preplantar) =groove= (Sulcus dorsalis) passes forward from the wing and ends at one of the larger foramina. In the fresh state this surface is covered by the matrix of the wall of the hoof. The =inferior= or =distal border= is thin, sharp, and irregularly notched; there is commonly a wider notch in front.

The =volar= or =inferior surface= (Facies volaris) is arched, and divided into two unequal parts by a curved rough line, the =semilunar crest= (Crista semilunaris). The larger anterior area is crescent-shaped, concave, and comparatively smooth; it corresponds to the sole of the hoof, and may be termed the =sole surface=. The posterior part is much smaller, and is semilunar; it is related to the deep flexor tendon, and is hence called the =flexor= or =tendon surface= (Facies flexoria). It presents a central prominent rough area, on either side of which is the =volar= (or plantar) =foramen= (Foramen volare), to which the =volar= (or plantar) =groove= (Sulcus volaris) conducts from the wing. The foramina lead into the =semilunar canal= within the bone, from which small canals lead to some of the foramina of the wall surface. The deep flexor tendon is inserted into the semilunar crest and the central rough area behind it.

The volar grooves and foramina transmit the terminations of the digital arteries into the semilunar canal, where they meet and form a terminal arch, from which branches pass through canals in the bone and emerge through the foramina on the wall surface.

The =angles= or =wings= (Anguli) are prismatic masses which project backward on either side; the inner one is usually the shorter. Each is divided into upper and lower parts by a notch, or is perforated by a foramen which leads to the vascular groove on the side of the wall surface.[25] The upper border carries the lateral cartilage.

The =lateral cartilages= (Cartilagines ungulæ) are rhomboid curved plates, which surmount the wings on either side. They are relatively large and extend above the margin of the hoof sufficiently to be distinctly palpable. The abaxial surface is convex, the axial concave. The upper border is convex and thin; the lower is thicker and is in part attached to the wing. The anterior end is attached by ligament to the side of the second phalanx. The posterior end curves toward its fellow at the heel, and is perforated by numerous foramina for the passage of veins. The central part is mainly hyaline, the periphery mainly fibrous.

It will be noted that the size and form of the wings vary much in different specimens. In the new-born foal the wing is a small, pointed projection. Later the process of ossification invades the lower part of the cartilage to a varying extent. In some cases the greater part of the cartilage is ossified—a condition commonly termed “sidebone.”

=Development.=—The ossification of the terminal phalanx is peculiar. While the proximal articular part is still cartilaginous, a perichondrial cap of bone is formed in relation to the hoof. Later the process extends into the upper part.

=Structure.=—The interior of this bone is channeled by numerous canals for vessels, most of which radiate from the semilunar canal to the wall surface; these are not canals for nutrient vessels of the bone, but transmit arteries to the matrix of the hoof. Thick layers of compact substance are found at the articular and flexor surfaces and the extensor process, _i. e._, at the points of greatest pressure and traction.

THE SESAMOID BONES

The two =proximal= or =great sesamoids= (Ossa sesamoidea phalangis primæ) are situated behind the distal end of the large metacarpal bone, and are closely attached to the first phalanx by strong ligaments. Each has the form of a three-sided pyramid. The =anterior= or =articular surface= conforms to the corresponding part of the distal end of the large metacarpal bone. The =posterior= or =flexor surface= is flattened and oblique; in the fresh state it is covered by a layer of cartilage which also fills the interval between the opposed borders of the two bones, and forms a smooth groove for the deep flexor tendon. The =abaxial surface= is concave, and gives attachment to part of the suspensory ligament; it is separated from the posterior surface by a rough everted border. The =base= faces downward, and furnishes attachment to the inferior sesamoidean ligaments. The =apex= is directed upward and is rounded.

The =third sesamoid= or =navicular= bone (Os sesamoideum phalangis tertiæ) is shuttle-shaped, and is situated behind the junction of the second and third phalanges. Its long axis is transverse, and it possesses two surfaces, two borders, and two extremities. The =articular surface= (Facies articularis) faces upward and forward; it consists of a central eminence, flanked by concave areas, and articulates with the distal end of the second phalanx. The =flexor= or =tendon surface= (Facies flexoria) is directed downward and backward. It resembles the articular surface in form, but is more extensive and not so smooth. In the fresh state it is coated with cartilage and the deep flexor tendon plays over it. The =proximal border= (Margo liber) is wide and grooved in its middle, narrower and rounded on either side. The =distal border= (Margo ligamenti) bears in front a narrow facet for articulation with the third phalanx. Behind this is a groove, which contains a number of relatively large foramina, and is bounded behind by a prominent edge. The =extremities= are blunt-pointed.

[Illustration:

FIG. 59.—THIRD SESAMOID OR NAVICULAR BONE OF HORSE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

=Development.=—It ossifies from a single center.

THE BONES OF THE PELVIC LIMB

The =pelvic girdle= consists of the ossa coxæ, which unite ventrally at the symphysis pelvis, and articulate with the sacrum dorsally.

OS COXÆ

The =os coxæ= (or os innominatum) forms the skeleton of the hip or haunch, and is the largest of the flat bones. It consists primarily of three parts, the =ilium=, =ischium=, and =pubis=, which meet to form the =acetabulum=, a large cotyloid cavity for articulation with the head of the femur. These parts are fused at about one year of age, but it is convenient to describe them separately.

THE ILIUM

The =ilium= (Os ilium) is the largest of the three parts. It is irregularly triangular and presents two surfaces, three borders, and three angles.

The =gluteal surface= (Facies glutæa) faces upward, backward, and outward. It is wide and concave in front, narrower and convex behind. The wide part is crossed by the curved =gluteal line= (Linea glutæa), which extends from the middle of the inner border toward the external angle. This surface gives attachment to the middle and deep gluteal muscles.

[Illustration:

FIG. 60.—OSSA COXARUM OF MARE, DORSAL VIEW.

_O.il._, Ilium; _O.p._, pubis; _O.is._, ischium; _A.o.i._, wing of ilium; _C.o.i._, shaft of ilium; _Cr.o.i._, anterior border (crest) of ilium; _1_, obturator foramen; _2_, acetabulum; _3_, internal angle of ilium; _4_, external angle of ilium; _5_, gluteal line; _6_, psoas tubercle; _7_, _8_, acetabular and symphyseal branches of pubis; _9_, _10_, acetabular and symphyseal branches of ischium; _12_, lesser sciatic notch; _13_, ischial arch; _14_, great sciatic notch; _15_, symphysis pelvis; _17_, ilio-pectineal eminence; _18_, anterior borders of pubic bones; _19_, posterior gluteal line. (Struska, Anat. d. Haustiere.)]

The =pelvic surface= (Facies pelvina) faces in the opposite direction; it is convex, and consists of two distinct parts. The inner triangular part (Pars articularis) is roughened for ligamentous attachment, and bears an irregular facet, the =auricular surface= (Facies auricularis), for articulation with the sacrum. The outer quadrilateral part (Pars iliaca) is in general smooth. It is crossed by the =ilio-pectineal line= (Crista iliopectinea), which begins below the auricular surface and is continued on the shaft of the bone to join the anterior border of the pubis. The line is interrupted by furrows for the iliaco-femoral vessels, and below these it bears the =psoas tubercle= (Tuberculum psoadicum), which gives attachment to the psoas minor muscle. The iliacus muscle is attached to the surface external to the ilio-pectineal line.

The =anterior border= or =crest= (Crista iliaca) is concave, thick, and rough.

The =internal border= is deeply concave; its middle part forms the lower boundary of the =great sciatic foramen=, and it is continuous behind with the =superior ischiatic spine=.

The =external border= is concave and in great part rough. Its fore part is crossed by grooves for the ilio-lumbar vessels, which are continued on the pelvic surface. The =nutrient foramen= is usually situated on or near the posterior part of this border.

[Illustration:

FIG. 61.—OSSA COXARUM OF MARE, VENTRAL VIEW.

_D_, Ilium; _Sch._, pubis; _S_, ischium; _a_, anterior border (crest) of ilium; _b_, internal angle of ilium; _c′_, external angle of ilium; _d_, great sciatic notch; _e_, external border of ilium; _f_, iliac surface; _g_, linea arcuata; _h_, rough ligamentous area; _i_,

auricular surface; _k_, ilio-pectineal line; _l_, psoas tubercle; _m_, transverse branch, and _n_, symphyseal branch of pubis; _o_, _o′_, symphysis pelvis; _p_, anterior border of pubis (pecten); _q_, tuberculum pubicum; _r_, ilio-pectineal eminence; _s_, tuber ischii; _t_, ischial arch; _u_, lesser sciatic notch; _v_, acetabular branch, and _w_, symphyseal branch of ischium; _x_, obturator foramen; _y_, articular surface of acetabulum; _z_, fossa acetabuli; _1_, groove for ilio-lumbar artery; _2_, groove for iliaco-femoral artery; _3_, subpubic groove; _4_, depression for inner tendon of origin of rectus femoris; _5_, rough area for attachment of adductor muscles. (Ellenberger-Baum, Anat. d. Haustiere.)]

The =internal= or =sacral angle= (Tuber sacrale) curves upward and a little backward close to the first sacral spine, and forms here the highest point of the skeleton. It is somewhat thickened and rough.

The =external= or =coxal angle= (Tuber coxæ) forms the basis of the point of the hip. It is a large quadrangular mass, narrow in its middle, and enlarged at either end, where it bears a pair of tuberosities. It is roughened for muscular attachment.

The =posterior= or =acetabular angle= meets the other two bones at the acetabulum, of which it forms about two-fifths. Its prominent upper border forms part of the =superior ischiatic spine=, which is roughened externally, smooth internally. Two depressions above and in front of the acetabulum give attachment to the tendons of origin of the rectus femoris muscle. This angle is connected with the ala or wide part of the bone by a constricted part, often termed the =shaft=. The latter is of three-sided prismatic form. Its external surface is convex and rough, and gives attachment to the deep gluteus muscle. Its pelvic surface is smooth and is grooved for the obturator vessels and nerves. Its ventral surface is crossed by vascular grooves, below which is a rough area, bounded internally by the psoas tubercle.

THE ISCHIUM

The =ischium= (Os ischii) forms the posterior part of the ventral wall or floor of the bony pelvis. It slopes a little downward and inward, but is practically horizontal in the longitudinal direction. It is irregularly quadrilateral, and may be described as having two surfaces, four borders, and four angles.

The =superior= or =pelvic surface= (Facies pelvina) is smooth and slightly concave from side to side.

The =inferior surface= (Facies externa) is nearly flat, and is in great part roughened for the attachment of the adductor muscles.

The =anterior border= forms the posterior margin of the obturator foramen.

The =posterior border= is thick and rough. It slopes obliquely inward and forward to meet the border of the other side, forming with it the =ischial arch= (Arcus ischiadicus).

The =internal border= meets the opposite bone at the symphysis.

The =external border= is thick and rounded, but concave in =its length=; it forms the =lesser sciatic notch=, the lower boundary of the lesser sciatic foramen.

The =antero-internal angle= or =symphyseal branch= (Ramus symphyseos) meets the pubis, with which it forms the inner boundary of the obturator foramen.

The =antero-external angle= or =acetabular branch= joins the other two bones at the acetabulum, of which it forms more than half. Superiorly it bears part of the =superior ischiatic spine= (Spina ischiadica), and internally it is grooved for the obturator vessels.

The =postero-external angle= is a thick three-sided mass, the =tuber ischii= (Tuber ischiadicum); its lower border is the =inferior ischiatic spine=, to which the biceps femoris and semitendinosus muscles are attached.

THE PUBIS

The =pubis= (Os pubis) is the smallest of the three parts of the os coxæ. It forms the anterior part of the pelvic floor, and may be described as having two surfaces, three borders, and three angles.

The =superior= or =pelvic surface= (Facies pelvina) is convex in the young subject and the stallion, concave and smooth in the mare and usually in the gelding also. The urinary bladder rests on it.

The =inferior= or =ventral surface= (Facies externa) is convex, and in great part rough for muscular attachment. Near the anterior border it is crossed by the =subpubic groove=, the inner part of which is occupied by a large vein, the outer part by the pubo-femoral ligament.

The =anterior border= is thin in its inner part (except in the young subject and the stallion), forming the pecten ossis pubis. Externally it bears the rough =ilio-pectineal eminence= (Eminentia iliopectinea), beyond which it is continuous with the ilio-pectineal line.

The =internal border= joins the opposite bone at the symphysis pubis.

The =posterior border= forms the anterior margin of the obturator foramen, and is marked externally by the obturator groove.

The =internal angle= meets its fellow at the anterior end of the symphysis. This part is very thick in the young subject and the stallion, but in the mare, and usually in the gelding also, it becomes thin with advancing age.

The =external= or =acetabular angle= joins the ilium and ischium at the acetabulum.

The =posterior angle= joins the ischium, with which it forms the inner boundary of the obturator foramen.

The =pubis= may conveniently be regarded as consisting of two branches which meet at a right angle; these are termed the =transverse= or =acetabular branch= (Ramus acetabularis) and the =longitudinal= or =symphyseal branch= (Ramus symphysecs).

The =acetabulum= is a cotyloid cavity which lodges the head of the femur. It faces downward and outward, and consists of an articular and a non-articular part. The =articular part= (Facies lunata) is crescentic, and is cut into internally by the non-articular part, which lies at a lower level, and is termed the =acetabular fossa= (Fossa acetabuli). The inner part of the rim is correspondingly cut into by the =acetabular notch= (Incisura acetabuli), which is converted into a foramen by the transverse ligament in the fresh state, and transmits the pubo-femoral and round ligaments to the head of the femur.

The =obturator foramen= (Foramen obturatum) is situated between the pubis and ischium. It is oval in outline, the longer axis being directed forward and outward. Its margin is grooved antero-externally for the obturator nerve and vessels.

[Illustration:

FIG. 62.—OSSA COXARUM OF STALLION, DORSAL VIEW. (After Ellenberger-Baum, Anat. für Künstler.)]

=Development.=—Each division of the os coxæ ossifies from one chief center. The center for the ilium appears first near the acetabulum, followed quickly by one for the ischium, and a little later by the pubic center. Secondary centers appear for the crest and external angle of the ilium, the tuber and posterior border of the ischium, and the acetabular part of the pubis. The pubis and ischium are united at birth or soon after, but are not fused with the ilium until the second year. The epiphyseal parts fuse with the main mass at four and a half to five years of age.

The acetabular part of the pubis ossifies from a separate center. It is most distinct in the embryo at three months, and is often called the os acetabuli. Martin says that the ilium has a center for the acetabular part, one for the shaft and wing, and a third for the crest. He also states that there is a special center for the acetabular part of the ischium, and a transitory nucleus in the symphyseal part of the pubis.

THE PELVIS

The =bony pelvis= is composed of the ossa coxarum, the sacrum, and the first three coccygeal vertebræ. The =dorsal wall= or =roof= is formed by the sacrum and first three coccygeal vertebræ, and the =ventral wall= or =floor= by the pubic and ischial bones. The =lateral walls= are formed by the ilia and the acetabular part of the ischia. The defect in the skeleton here is supplied in the fresh state by the sacro-sciatic ligaments and semimembranosus muscles.

The =anterior aperture= or =inlet= (Apertura pelvis cranialis) is bounded by the =terminal line= (Linea terminalis) or brim, composed of the base of the sacrum dorsally, the ilio-pectineal lines laterally, and the anterior border of the pubis ventrally. It is almost circular in the mare, semi-elliptical in the stallion, and faces obliquely downward and forward. It has two principal diameters. Of these, the =conjugate= or =sacro-pubic diameter= (Conjugata) is measured from the sacral promontory to the anterior end of the symphysis. The =transverse diameter= (Diameter transversa) is measured at the greatest width, _i. e._, just above the psoas tubercle.

The =posterior aperture= or =outlet= (Apertura pelvis caudalis) is much smaller and is very incomplete in the skeleton. It is bounded above by the third coccygeal vertebra and below by the ischial arch; in the fresh state it is completed laterally by the sacro-sciatic ligament and the semimembranosus muscle.

The =axis= of the pelvis is an imaginary line drawn through the centers of the inlet, cavity, and outlet.

=Sexual Differences.=—Marked differences exist in the size and form of the pelvis in the two sexes. The average =conjugate diameter= is about 9½ inches (ca. 23 to 24 cm.) in the mare, 7½ inches (ca. 18 to 20 cm.) in the stallion. The =transverse diameter= of the inlet averages about 9 inches (ca. 22 to 23 cm.) in the mare, and 8 inches (ca. 20 cm.) in the stallion. The =obliquity= of the inlet is greater in the female; the difference is indicated by the fact that a vertical plane from the pecten cuts the fourth sacral segment in the female, the second in the male. The =outlet= is also larger in the mare, the =ischial arch= being about one-third wider than in the stallion. The =cavity= is much more roomy in the female; the transverse diameter between the middles of the superior ischiatic spines is about 8 inches (20 cm.) in the mare, 6 inches (15 cm.) in the stallion. The pubic part of the =floor= in the female is concave and lies considerably lower than the ischiatic part, which is wide and relatively flat. In the stallion the pubis is very thick centrally, and this part of the floor is convex, while the ischial part is relatively narrow, and is concave from side to side. The =obturator foramina= are correspondingly larger in the female. The ilium is shorter, and the greater sciatic notch deeper and narrower in the male. The pelvis of the gelding, when castration has been performed early, resembles that of the mare; otherwise the male characters appear to be retained to a large degree.

THE FEMUR

The =femur= or thigh bone (Os femoris) is the largest and most massive of the long bones. It extends obliquely downward and forward, articulating with the acetabulum above and the tibia and patella below. It presents for examination a shaft and two extremities.

The =shaft= or =body= (Corpus femoris) is in general cylindrical, but flattened behind, and larger above than below. The =anterior= and =lateral surfaces= are continuous and strongly convex from side to side; there is often a central vertical rough line on the proximal part, but otherwise these surfaces are smooth. They are covered by the quadriceps femoris muscle. The =posterior surface= is wide, flat, and smooth in its proximal fourth. Below this part there is a rough elevation externally for the attachment of the femoral tendon of the biceps femoris, and a rough line internally to which the quadratus femoris is attached. The middle third is narrower, and is rough for the attachment of the adductor muscle. Just below this area an oblique groove crosses the surface, indicating the position of the femoral vessels. The =internal border= bears on its proximal part the =internal trochanter= or =trochanter minor=, a thick rough ridge, to which the ilio-psoas muscle is attached. From this a rough line curves up to the front of the neck and indicates the limit of the attachment of the vastus internus muscle. A narrow rough area about the middle gives attachment to the pectineus muscle, and the =nutrient foramen= is usually found just in front of this mark. The =supracondyloid crest= is situated below the groove for the femoral vessels, and gives origin to the inner head of the gastrocnemius. The =external border= is prominent in its upper part, and bears at the junction of its proximal and middle thirds the =external= or =third trochanter= (Trochanter tertius); this process is curved forward, and furnishes insertion to the tendon of the superficial gluteus muscle. At the lower part is found the =supracondyloid= or =plantar fossa= (Fossa plantaris), in which the superficial flexor arises; it is bounded externally by a thick rough margin, to which the outer head of the gastrocnemius muscle is attached.

[Illustration:

FIG. 63.—RIGHT FEMUR OF HORSE, EXTERNAL VIEW.]

[Illustration:

FIG. 64.—RIGHT FEMUR OF HORSE, POSTERIOR VIEW.]

[Illustration:

FIG. 65.—RIGHT FEMUR OF HORSE, INTERNAL VIEW.

_1_, Anterior part, _1′_, posterior part of trochanter major; _2_, neck; _3_, fovea capitis; _4_, crest; _5_, trochanteric fossa; _6_, external or third trochanter; _7_, trochanter minor; _8_, eminence for attachment of biceps femoris; _9_, internal border; _10_, nutrient foramen; _11_, groove for femoral vessels; _12_, supracondyloid crest; _13_, supracondyloid fossa; _14_, trochlea; _15_, external epicondyle; _16_, external condyle; _17_, extensor fossa; _18_, internal condyle; _19_, internal epicondyle; _20_,

intercondyloid fossa. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =proximal extremity= (Extremitas proximalis) is large and consists of the head, neck, and great trochanter. The =head= (Caput femoris) is placed at the inner side and is directed inward, upward, and somewhat forward. It is approximately hemispherical and articulates with the acetabulum. It is cut into internally by a deep notch, the =fovea capitis=, in which the pubo-femoral and round ligaments are attached. The articular surface is surrounded by a distinct margin. The =neck= (Collum femoris) is most distinct in front and internally. The =great trochanter= (Trochanter major) is situated externally; it presents three features. The =anterior part= or =convexity= is situated opposite to the head and rises little above the level of the latter; it gives attachment to the deep gluteus muscle, and in the fresh state its outer surface is coated with cartilage, over which a tendon of the middle gluteus passes, to be inserted into the =crest=, which is placed below and behind the convexity. The =posterior part= or =summit= is separated from the convexity by a notch; it is situated behind the plane of the head and rises to a much greater height. It furnishes insertion to part of the middle gluteus muscle. Its posterior border is continued downward as the =trochanteric ridge=, which forms the outer wall of the =trochanteric fossa=. A number of foramina are found in the concave area internal to the convexity.

[Illustration:

FIG. 66.—FRONTAL SECTION OF LEFT FEMUR OF HORSE, ANTERIOR VIEW.

The figure shows that the medullary cavity is traversed for the most part by fine bony trabeculæ.]

The =distal extremity= (Extremitas distalis) is large in both directions and comprises the trochlea in front and two condyles behind. The =trochlea= consists of two ridges separated by a groove, and forms an extensive surface (Facies patellaris) for articulation with the patella. It is very unsymmetrical; the inner ridge or lip is much wider, more prominent, and extends up higher than the external one, and the two converge below. The =condyles=, =internal= and =external= (Condylus medialis, lateralis), are separated by the deep =intercondyloid fossa= (Fossa intercondyloidea), and articulate with the condyles of the tibia and the semilunar cartilages of the stifle joint. A ridge connects each condyle with the lower part of the corresponding lip of the trochlea. The intercondyloid fossa lodges the spine of the tibia and the crucial ligaments of the stifle joint, which are attached here.

The condyles are obliquely placed, with their long axes directed downward, forward, and inward. The articular surface of the external condyle is more strongly convex from side to side than that of the inner one, and the ridge which connects it with the trochlea is much narrower.

The =internal epicondyle= (Epicondylus medialis) is a rounded prominence on the internal surface of the internal condyle, to which the internal lateral ligament and the adductor muscle are attached. The corresponding =external epicondyle= (Epicondylus lateralis) is less distinct; it presents a mark where the lateral ligament is attached, below and behind which there is a depression (Fossa musculi poplitei) in which the popliteus muscle arises. Between the external condyle and trochlea is the =extensor fossa= (Fossa extensoria), in which the tendon of origin of the anterior extensor and peroneus tertius is attached.

=Development.=—The shaft and the distal end each ossify from one center, but the proximal end has two centers, one of which is for the great trochanter. The edge of the external trochanter also has a separate center. The proximal end fuses with the shaft at three to three and a half years, the distal at about three and a half years.

[Illustration:

FIG. 67.—DISTAL EXTREMITY OF RIGHT FEMUR OF HORSE, END VIEW.]

THE TIBIA

The =tibia= is a long bone which extends obliquely downward and backward from the stifle to the hock. It articulates above with the femur, below with the tarsus, and externally with the fibula. It possesses a shaft and two extremities.

The =shaft= or =body= (Corpus tibiæ), large and three-sided above, becomes smaller and flattened in the sagittal direction below, but widens a little at the distal end. It presents for notice three surfaces and three borders. The =internal surface= (Facies medialis) is broad above, where it furnishes insertion to the internal lateral ligament and the sartorius and gracilis muscles; below this it is convex and subcutaneous. The =external surface= (Facies lateralis) is smooth and somewhat spiral. It is wide and concave in its upper part, below which it becomes narrower and slightly convex, and winds gradually to the front of the bone; near the distal end it widens a little, becomes flat, and faces forward. The =posterior surface= (Facies posterior) is flattened, and is divided into two parts

by the rough =popliteal line=, which runs obliquely from the upper part of the external border to the middle of the internal border. The triangular area above the line is occupied by the popliteus muscle, while the area below is marked by rough lines (Lineæ musculares) to which the deep flexor muscle of the digit is attached; the lines fade out below, where the surface is smooth and flat. The =nutrient foramen= is situated on or near the popliteal line. The =anterior border= is very prominent in its upper third, forming the =tibial crest= (Crista tibiæ); below it is reduced to a rough line, which ends at a small elevation near the distal end of the bone. The =internal border= (Margo medialis) is rounded in its upper half, to which the popliteus muscle is attached, and a tubercle is found on this part. The lower part is a rough line on well-marked bones. The =external border= (Crista interossea) is concave in its upper part and concurs with the fibula in the formation of the interosseous space of the leg; a smooth impression indicates the course of the anterior tibial vessels through the space to the front of the leg. Lower down the border divides and incloses a narrow triangular surface.

[Illustration:

FIG. 68.—RIGHT TIBIA AND FIBULA OF HORSE, EXTERNAL VIEW.]

The =proximal extremity= (Extremitas proximalis) is large and three-sided. It bears two lateral eminences, the =internal= and =external condyles= (Condylus medialis, lateralis). Each presents a somewhat saddle-shaped surface for articulation with the condyle of the femur and the semilunar cartilage. The =spine= or =intercondyloid eminence= (Eminentia intercondyloidea) is the central prominence, upon which the articular surfaces are continued; it consists of a high inner part and a lower outer part (Tuberculum intercondyloideum mediale, laterale). On, before, and behind the spine are the =anterior= and =posterior intercondyloid fossæ=, in which the anterior crucial ligament and the semilunar cartilages are attached. The condyles are separated behind by the deep =popliteal notch= (Incisura poplitea), on the inner side of which is a tubercle for the attachment of the posterior crucial ligament. The external condyle has an overhanging outer margin, below which is a =facet= for articulation with the fibula. The =large anterior= eminence is the =tuberosity= of the tibia (Tuberositas tibiæ). It is marked in front by a =groove=, the lower part of which gives attachment to the middle patellar ligament, and the groove is flanked by rough areas for the attachment of the internal and external patellar ligaments. A semicircular smooth =notch= (Sulcus muscularis) separates the tuberosity from the external condyle, and gives passage to the tendon of origin of the anterior extensor and the peroneus tertius.

[Illustration:

FIG. 69.—RIGHT TIBIA AND FIBULA OF HORSE, POSTERIOR VIEW.]

The =distal extremity= (Extremitas distalis) is much smaller than the proximal; it is quadrangular in form and larger internally than externally. It presents an =articular surface= (Cochlea tibiæ), which is adapted to the trochlea of the tibial tarsal bone (astragalus), and consists of two grooves separated by a ridge. The ridge and grooves are directed obliquely forward and outward, and are bounded laterally by the =malleoli=, to which the lateral ligaments of the hock joint are attached. The =internal malleolus= (Malleolus tibialis) is the more prominent of the two, and forms the anterior boundary of a groove for the tendon of the inner head of the flexor perforans. The =external malleolus= (Malleolus fibularis) is broader, and is marked by a vertical groove for the passage of the lateral extensor tendon.

[Illustration:

FIG. 70.—RIGHT TIBIA AND FIBULA OF HORSE, ANTERIOR VIEW.]

=Development.=—The tibia has the usual three chief centers of ossification and supplementary ones for the tuberosity and the external malleolus. The latter is really the distal end of the fibula; it is a separate piece at birth, and the line of union is commonly quite evident in the adult in the external articular groove. The proximal end unites with the shaft at about three and a half years, and the distal end at about two years of age.

THE FIBULA

The =fibula= of the horse is a much reduced long bone, situated along the outer side of the tibia.

The =shaft= or =body= (Corpus fibulæ) is a slender rod which forms the outer boundary of the interosseous space; it usually terminates below in a pointed end about one-half to two-thirds of the way down the external border of the tibia.

The =proximal extremity= or =head= (Capitulum fibulæ) is relatively large, and is flattened transversely. Its internal surface presents a narrow area along the upper border for articulation with the tibia. The external surface is rough and gives attachment to the external lateral ligament of the stifle joint. It has rounded anterior and posterior borders.

[Illustration:

FIG. 71.—PROXIMAL EXTREMITY OF RIGHT TIBIA OF HORSE, END VIEW.

_l.c.a._, _l.c.p._, Depressions for attachment of anterior and posterior crucial ligaments; _l_, _m_, _m_, depressions for attachment of semilunar cartilages.]

The =distal extremity= is fused with the tibia, constituting the external malleolus.

=Development.=—This resembles that of the ulna. The embryonic cartilaginous fibula extends the entire length of the leg, but does not articulate with the femur. The lower part of the shaft is usually reduced to a fibrous band. Three centers of ossification appear, one each for the shaft and the extremities. The distal end unites early with the tibia, forming the external malleolus.

It is interesting to note that in some cases the entire shaft of the fibula develops, a reversion to the condition in the Miocene ancestors of the present horse.

THE PATELLA

The =patella= is a large sesamoid bone which articulates with the trochlea of the femur. It presents for description two surfaces, two borders, a base, and an apex.

The =anterior= or =free surface= (Facies libera) is irregularly quadrilateral, convex, and rough for muscular and ligamentous attachment.

The =posterior= or =articular surface= is smaller and is triangular in outline. It presents a vertical rounded ridge, which corresponds to the groove on the trochlea of the femur, and separates two concave areas. Of the latter, the inner cavity is much the larger, and is not very well adapted to the inner lip of the trochlea; in the fresh state, however, it is completed and rendered more congruent by the curved =accessory fibro-cartilage=.

[Illustration:

FIG. 72.—FRONTAL SECTION OF RIGHT TIBIA OF HORSE, ANTERIOR VIEW.]

The =lateral borders= converge to the apex below, and each forms a prominence or angle at the base. The inner angle and the adjacent part of the border give attachment to the fibro-cartilage of the patella, which increases the articular surface. The external border is rounded and its angle is less prominent.

The =base= (Basis patellæ) faces upward and backward, and is convex transversely, concave from before backward.

The =apex= forms a blunt point directed downward.

=Development.=—The patella develops as a sesamoid bone from a single center in a cartilaginous deposit in the tendon of the quadriceps femoris muscle.

THE TARSUS

The =tarsus= or =hock= of the horse usually comprises six short bones (Ossa tarsi), but exceptionally seven are present.

THE TIBIAL TARSAL BONE

The =tibial tarsal= bone (Os tarsi tibiale, astragalus, or talus) is the inner bone of the proximal row. It is extremely irregular in form, but may be considered as offering six surfaces for description.

[Illustration:

FIG. 73.—RIGHT PATELLA OF HORSE, ANTERIOR VIEW.]

[Illustration:

FIG. 74.—RIGHT PATELLA OF HORSE, POSTERIOR VIEW.]

The =superior= and the =anterior= or =dorsal surface= are continuous, and form a =trochlea= for articulation with the distal end of the tibia. The trochlea consists of two oblique ridges with a deep groove between them, which curve spirally forward, downward, and outward. There is usually a shallow =synovial fossa= in the groove. The =inferior surface= is convex from before backward, and most of it articulates with the central tarsal; externally it has an oblique facet for the fourth tarsal, and a non-articular groove cuts into the surface to its middle. The =posterior= or =plantar surface= is oblique and extremely irregular; it presents four facets for articulation with the fibular tarsal bone; the facets are separated by rough excavated areas, and the largest fossa (Sulcus tali) forms with a corresponding one on the fibular tarsal a cavity termed the =sinus tarsi=. The =internal surface= bears on its lower part a large tuberosity, and on its upper part a small one for the attachment of the internal lateral ligament. The =external surface= is smaller than the internal, and is marked by a wide rough fossa in which the external ligament is attached.

THE FIBULAR TARSAL BONE

[Illustration:

FIG. 75.—RIGHT TARSUS AND UPPER PART OF METATARSUS OF HORSE, INTERNAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 76.—RIGHT TARSUS AND UPPER PART OF METATARSUS OF HORSE, POSTERIOR (PLANTAR) VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =fibular tarsal= bone (Os tarsi fibulare, calcaneum, os calcis) is the largest bone of the hock. It is elongated, flattened from side to side, and forms a lever for the muscles which extend the hock joint. It consists of a body and an inner process, the sustentaculum tali.

[Illustration:

FIG. 77.—RIGHT TIBIAL TARSAL BONE OF HORSE, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 78.—RIGHT TIBIAL TARSAL BONE OF HORSE, EXTERNAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =body= (Corpus calcanei) is enlarged at its proximal end to form the =tuber calcis= or “point of the hock.” The posterior part of this eminence gives attachment to the tendon of the gastrocnemius, while in front and laterally it furnishes insertion to tendons of the flexor perforatus, biceps, and semitendinosus muscles. The =inferior extremity= bears a concave facet for articulation with the fourth tarsal bone. The =internal surface= has on its lower part a strong process, the =sustentaculum tali=, which projects inward. The process has a large, oval, slightly concave facet in front for articulation with the tibial tarsal, and sometimes a small articular surface below for the central tarsal bone. Its plantar surface forms with the smooth inner surface of the body a groove for the deep flexor tendon (Sulcus musculi flexoris hallucis longi). Its inner surface has a prominence on the lower part for the attachment of the lateral ligament. The =external surface= of the body is flattened, except below, where there is a rough prominence for the attachment of the lateral ligament. The =anterior= or =dorsal border= is concave in its length, smooth and rounded in its upper part. About its middle is a blunt-pointed projection (Processus cochlearis) which bears facets on its inner and lower surfaces for articulation with the tibial tarsal bone, and is roughened outwardly for ligamentous attachment. Below this are two facets for the tibial tarsal, and an extensive rough fossa which concurs in the formation of the sinus tarsi. The =posterior= or =plantar border= is straight and thick, and widens a little at either end; it is rough, and gives attachment to the long plantar ligament.

[Illustration:

FIG. 79.—RIGHT FIBULAR TARSAL BONE OF HORSE, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 80.—RIGHT FOURTH TARSAL BONE OF HORSE, UPPER SURFACE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 81.—RIGHT CENTRAL TARSAL BONE OF HORSE, UPPER SURFACE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 82.—RIGHT FIRST, SECOND, AND THIRD TARSAL BONES OF HORSE, UPPER SURFACE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

[Illustration:

FIG. 83.—PROXIMAL ARTICULAR SURFACES OF LEFT METATARSAL BONES OF HORSE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE CENTRAL TARSAL BONE

The =central tarsal= bone (Os tarsi centrale, scaphoid, or navicular) is irregularly quadrilateral, and is situated between the tibial tarsal above and the third tarsal below. It is flattened from above downward, and may be described as having two surfaces and four borders. The =superior surface= is concave from before backward, and almost all of it articulates with the tibial tarsal; a non-articular depression cuts into its outer part, and sometimes there is a facet for the fibular tarsal bone on the posterior angle. The =inferior surface= is convex, and is crossed by a non-articular groove, which separates facets for articulation with the third and the first and second (fused) tarsals. The =anterior= or =dorsal border= and the =internal border= are continuous, convex, and rough. The =posterior= or =plantar border= bears two prominences, separated by a notch. The =external border= is oblique, and bears anterior and posterior facets for articulation with the fourth tarsal, between which it is excavated and rough.

[Illustration:

FIG. 84.—RIGHT TARSAL AND METATARSAL BONES OF HORSE. EXTERNAL VIEW. (After Schmaltz, Atlas d. d. Anat. d. Pferdes.)]

FIRST AND SECOND TARSAL BONES

The =first= and =second tarsal= bones (Os tarsale primum et secundum, cuneiform parvum) are usually fused in the horse, forming a bone of very irregular shape, situated in the inner and posterior part of the lower row, below the central and behind the third tarsal. It is the smallest of the tarsal bones, and may be described as having two surfaces, two borders, and two extremities. The =internal surface= faces backward and inward, and is convex. Its anterior part is ridged, and gives attachment to the internal lateral ligament, and its posterior part bears an imprint where the inner tendon of the tibialis anterior is inserted. The =external surface= is marked by a deep notch which indicates the division between the first and second tarsal elements; it bears on its anterior part a large concave facet for the central tarsal. The =superior border= is convex. The =inferior border= is broad in front, where it articulates with the large and inner small metatarsal bones. The =anterior extremity= has a small facet for articulation with the third tarsal, and bears internally a ridge or tubercle. The =posterior extremity= is a blunt point.

In some cases the first and second tarsal bones remain separate—a remarkable reversion to the condition in the early ancestors of the horse. In such specimens the first tarsal is a discoid bone, articulating above with the central, below with the small metacarpal bone. The second tarsal is quadrangular, equivalent to the thick anterior part of the bone as described above, and overlapped by the anterior part of the first tarsal.

THE THIRD TARSAL BONE

The =third tarsal= bone (Os tarsale tertium, third or great cuneiform) resembles the central, but is smaller and triangular in outline. It is situated between the central above and the large metatarsal bone below. It possesses two surfaces and three borders.

The =superior surface= is concave, and is crossed by a non-articular depression which divides it into two unequal facets; it articulates with the central tarsal. The =inferior surface= is slightly convex, and rests on the large metatarsal bone; it has an extensive central rough excavation. The =anterior= or =dorsal border= is convex and bears a rounded ridge on its inner part. The =internal border= is deeply notched and has a small facet for the second tarsal on its anterior part. The =external border= is also divided by a notch into two parts, and bears two diagonally opposite facets for articulation with the fourth tarsal. In some cases

there is a facet for the inner small metatarsal bone.

[Illustration:

FIG. 85.—CROSS-SECTIONS OF METACARPAL AND METATARSAL BONES OF HORSE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

THE FOURTH TARSAL BONE

The =fourth tarsal= bone (Os tarsale quartum, cuboid) is the outer bone of the lower row, and is equal in height to the central and third together. It is cuboid in shape and presents six surfaces.

The =superior surface= is convex from side to side, and articulates chiefly with the fibular tarsal, but to a small extent with the tibial tarsal also. The =inferior surface= rests on the large and external small metatarsal bones. The =internal surface= bears four facets for articulation with the central and third tarsal bones. It is crossed from before backward by a smooth groove, which by apposition with the adjacent bones forms the =canal of the tarsus= (Canalis tarsi) for the passage of the perforating tarsal vessels. The =anterior= or =dorsal=, =external=, and =posterior= or =plantar surfaces= are continuous and rough. A tuberosity behind gives attachment to the plantar ligament.

=Development.=—The fibular tarsal bone has two centers of ossification, one for the main mass and the other for the tuber calcis; the latter fuses with the rest of the bone at about three years of age. The first and second tarsals have separate centers, but fusion usually occurs before birth. Each of the other bones ossifies from a single center.

[Illustration:

FIG. 86.—DIGITAL BONES OF FORE LIMB OF HORSE, VOLAR ASPECT.]

[Illustration:

FIG. 87.—DIGITAL BONES OF HIND LIMB OF HORSE, VOLAR ASPECT.]

THE METATARSUS

The =metatarsal= bones (Ossa metatarsalia), three in number, have the same general arrangement as the metacarpal bones, but present some important differences. Their direction is slightly oblique, downward and a little forward.

The =large= or =third metatarsal= bone is about one-sixth longer than the corresponding metacarpal; in an animal of medium size the difference is about two inches. The shaft is more cylindrical, and is almost circular on cross-section, except in its lower part. At the upper part of its external surface there is a groove, which is directed obliquely downward and backward, and is continued by the furrow formed by the apposition of the external metatarsal bone; it indicates the course of the great metatarsal artery. A faint impression in a similar place on the inner side marks the position of the corresponding vein. The nutrient foramen is relatively higher than on the metacarpal bone. The proximal extremity is much wider from before backward than that of the metacarpal bone. Its articular surface is slightly concave, and is marked by a large central non-articular depression, continued outward by a deep notch. The greater part of the surface articulates with the third tarsal, but there is an outer facet for the fourth, and usually a small facet posterointernally for the second tarsal bone. Posteriorly there are two pairs of facets for articulation with the small metatarsal bones. The front is crossed by a rough ridge for insertion, which becomes larger and turns downward on the outer side behind the vascular groove. The distal extremity closely resembles that of the corresponding metacarpal bone.

In some cases the lower part of the shaft is bent backward somewhat. The articular surface extends a little higher behind than in the case of the metacarpal bone. The large metatarsal bone is even more strongly constructed than the metacarpal. The shell of compact substance is very thick in the middle of the shaft, especially in front and internally.

The =small metatarsal= bones are a little longer than the corresponding metacarpals. The =external= (fourth) =metatarsal= is relatively massive, especially in its upper part. The head is large and outstanding, and bears two facets above for the fourth tarsal, and two in front and internally for articulation with the large metatarsal; elsewhere it is roughened for attachment. The =internal= (second) =metatarsal= is much more slender than the outer one, especially in its upper part. The head bears two facets above for the first and second tarsals, and sometimes one for the third tarsal.

THE PHALANGES AND SESAMOIDS

The axis of the phalanges of the hind limb is about five degrees less oblique than that of the fore limb, and the chief differences in the form and size of the bones are as follows:

The =first phalanx= is a little shorter, wider above, and narrower below.

The =second phalanx= is narrower and slightly longer.

The =third phalanx= is narrower, the angle of inclination of the wall surface is a little (ca. 5 degrees) greater, the sole surface is more concave, and the wings are less prominent and closer together.

The =proximal sesamoids= are a little smaller, except in thickness. The =third sesamoid= or =navicular bone= is narrower and shorter.

SKELETON OF THE OX

VERTEBRAL COLUMN

The vertebral formula is C_{7}T_{13}L_{6}S_{5}Cy_{18–20}.

The =cervical vertebræ= are much shorter than those of the horse and are smaller in their other dimensions. The =articular processes= are smaller than in the horse, and a plate of bone connects each two of the same side. The transverse processes of the third, fourth, and fifth are double; the upper part projects backward, and is short and stout; the lower part is directed downward and forward, and is longer and more plate-like. The lower part of the sixth transverse process is a large, thick, quadrilateral and almost sagittal plate, directed downward. The seventh transverse process is single, short, and thick, and presents no foramen transversarium; it is in series with the upper part of the preceding processes. The =spinous processes= are well developed, and increase in height from before backward. They are directed upward and forward, with the exception of the last, which is nearly vertical and is about four or five inches (ca. 10 to 12 cm.) in height. The summit of that of the third bone is usually bifid. The =ventral spines= are prominent and thick in their posterior part; they are absent on the last two.

The =atlas= has a large rough =tuberosity= on its dorsal arch. The =ventral arch= is very thick. The =wings= are less curved than in the horse, and the foramen transversarium (posterior foramen) is absent. The cavities for the occipital condyles are divided into upper and lower parts by a non-articular area, and are separated by a narrow interval below. The =posterior articular surfaces= are flattened behind and are continued into the vertebral canal, forming an extensive area for the odontoid process of the axis.

The =axis= is short. The =spine= projects a little in front, and increases in height and thickness behind; its posterior border descends abruptly. The =odontoid process= (dens) is wide, and its upper surface is deeply concave from side to side. The =intervertebral foramen= is circular and not so close to the anterior border of the arch as in the horse. The =posterior notches= are not so deep. The =transverse processes= are stouter, but the =foramen transversarium= is small and sometimes absent.

The =thoracic vertebræ=, thirteen in number, are larger than those of the horse. The =bodies= are longer and are distinctly constricted in the middle. They bear a thin-edged ventral crest. The =arches=—in addition to the usual notches, which are shallow—are perforated in the posterior part by a foramen. The =transverse processes= are thick and strong, and bear rounded mammillary processes (except at the posterior end of the series); the last two, although prominent, do not always articulate with the ribs. The =spinous processes= are long. The first is much higher than in the horse, the next two are usually the most prominent, and behind this there is a very gradual diminution in height. The backward slope, slight at first, increases to the tenth; the last is vertical and lumbar in character. The summit is usually pointed on the first, and the thickening on those further back is less than in the horse. The width diminishes from the fifth to the eleventh usually. Both borders of the spines are in general thin and sharp, but the last three or four sometimes have thick posterior margins.

[Illustration:

FIG. 88.—SKELETON OF COW.

_1.H._, Atlas; _7.H._, seventh cervical vertebra; _1.R._, first thoracic vetrebra; _6.R._, sixth rib; _12.R._, twelfth thoracic vertebra; _13.R._, last rib; _1.L._, first, _6.L._, last lumbar vertebra; _K_, sacrum; _1.S._, first coccygeal vertebra; _6.K._, sixth costal

cartilage; _x_, wing of atlas; _1_, scapula; _1′_, cartilage of scapula; _2_, spine of scapula; _3_, acromion; _4_, humerus; _4′_, external condyle of humerus; _5_, external tuberosity of humerus; _6_, deltoid tuberosity; _7_, ulna; _8_, olecranon; _9_, radius; _10_, carpus; _11_, accessory carpal bone; _12_, metacarpus; _13_, phalanges; _14_, sternum; _14′_, manubrium; _14″_, xiphoid cartilage; _15_, ilium; _16_, external angle of ilium; _16′_, internal angle of ilium; _17_, tuber ischii; _18_, femur; _19_, trochanter major; _20_, patella; _21_, tibia; _21′_, external condyle of tibia; _22_, tarsus; _23_, distal end of fibula; _24_, tuber calcis; _25_, metatarsus; _26_, phalanges. (After Ellenberger-Baum, Anat. für Künstler.)]

The =lumbar vertebræ=, six in number, are much longer than in the horse. The =bodies= are much constricted in the middle, expanded at either end, and bear rudimentary ventral crests. The fourth and fifth are usually the longest. The =intervertebral foramina= are often double in the anterior part of the series, and are very large further back. The =articular processes= are large, and their facets are more strongly curved than in the horse. The =transverse processes= all curve forward. They are separated by considerable intervals, and form no articulations with each other or with the sacrum. Their borders are thin and irregular, and often bear projections of variable size and form. The first is the shortest and the length increases to the fifth, the last being considerably shorter. The =spinous processes= are relatively low and wide, the last being the smallest; their summits are moderately thickened.

The =sacrum= is longer than that of the horse. It consists originally of five segments, but fusion is more complete and involves the spinous processes, which are united to form a =median sacral crest=, with a convex thick and rough margin. =A lateral crest= is formed by the fusion of the articular processes. The =pelvic surface= is concave in both directions, and is marked by a central =groove=, which indicates the course of the middle sacral artery. The =inferior sacral foramina= are large. The =wings= are quadrangular, short, compressed from before backward, and high dorso-ventrally. They have an extensive anterior surface, which is concave from side to side, and non-articular. The posterior surface is rough, and bears a triangular area below for articulation with the ilium. The body of the first segment is very wide, and the entrance to the sacral canal correspondingly wide and low. The =anterior articular processes= are large, and are concave and semicylindrical in curvature internally. The =lateral borders= are thin, sharp, and irregular. The =apex= is wider than in the horse, and the posterior end of the crest forms a pointed projection over the opening of the sacral canal.

The =coccygeal vertebræ= are longer and better developed than in the horse. The first five or six have complete arches and spinous processes. The transverse processes are relatively large in the anterior part of the series, in which there are also anterior articular processes (which do not articulate), and a pair of ventral spines which form a hæmal groove for the middle coccygeal artery.

Vertebral curves: The cervical curve is very slight and is concave dorsally. The thoracic and lumbar regions form a gentle curve, concave ventrally. The promontory is more pronounced than in the horse, especially in subjects in which the sacrum is inclined upward behind. Another promontory occurs at the junction of the sacrum and first coccygeal vertebræ.

Length: The following table gives the lengths of the regions of a shorthorn cow of medium size:

Cervical 47 cm. Thoracic 75 cm. Lumbar 40 cm. Sacral 24 cm. Coccygeal 75 cm. ———————— 261 cm.

Variations: Sometimes fourteen thoracic vertebræ and fourteen pairs of ribs are present; reduction to twelve with the normal number of lumbar vertebræ is very rare. According to Franck, there are sometimes seven lumbar vertebræ with the normal number in the thoracic region. The number of coccygeal vertebræ may vary from sixteen to twenty-one.

THE RIBS

Thirteen pairs of ribs are normally present, of which eight are sternal and five asternal. They are in general longer, wider, flatter, less curved, and less regular in form than in the horse. The eighth, ninth, and tenth are the longest and widest. The width of most of the ribs increases considerably in the middle, and the breadth of the intercostal spaces is correspondingly diminished. The neck is long, and forms (except in the posterior part of the series) a smaller angle with the shaft than in the horse. The articular surface of the tubercle is concave transversely, except on the last two or three, where the facet is small and flat or absent. The lower ends of the second to the tenth or eleventh inclusive form diarthrodial joints with the costal cartilages. The first costal cartilages are very short; they articulate by their internal surfaces with the sternum, but not with each other.

The presence of a fourteenth rib is not very rare. It is usually floating and may correspond to an additional thoracic vertebra or to the first lumbar. Reduction of the thirteenth is more common. The eighth cartilage often does not reach the sternum, but articulates

with the seventh.

The =sternum= consists of seven sternebræ, most of which are developed from two lateral centers. It is wider, flatter, and relatively longer than in the horse, and the ventral crest or "keel" is absent. The manubrium is somewhat wedge-shaped and laterally compressed. Its base forms a diarthrodial joint with the body of the bone, and laterally it bears extensive facets for articulation with the first pair of costal cartilages. The body widens from before backward, but behind the last pair of costal facets it becomes much narrower. The ventral surface is prominent on the second and third segments, concave further back. The lateral borders are notched for the passage of vessels. The cariniform cartilage is absent. The xiphoid cartilage is like that of the horse but is smaller.

THE THORAX

The bony thorax is shorter than in the horse. The inlet is higher. The roof is short, and the floor wider and relatively longer. The transverse diameter is wider in the posterior part. The summits of the spinous processes are almost in a straight line from the second thoracic to the middle of the lumbar region.

BONES OF THE SKULL

BONES OF THE CRANIUM

The =occipital bone= is situated in the lower part only of the posterior surface of the skull, and is separated from the highest part (the frontal eminence) by the parietal and interparietal bones. The supraoccipital, interparietals, and parietals fuse before birth or soon after, and the mass so formed is separated from the lateral parts of the occipital bone by a transverse suture in the skull of the calf. Above this suture is a central tuberosity, to which the ligamentum nuchæ is attached, and the surface on either side is depressed and rough for muscular attachment. Below the suture the bone is much wider than that of the horse. The foramen magnum is wide, so that the condyles are further apart except below. The paramastoid processes are short and wide and are bent inward. Two constant foramina are found in the condyloid fossa; the anterior one is the hypoglossal, the other (sometimes double) conducts a vein from the =condyloid canal=. The latter passes upward from a foramen on the inner side of the condyle and opens into the parieto-temporal canal. The cranial surface of the supraoccipital presents a central depression, and above this is a variable but never very pronounced eminence, which corresponds to the tentorium osseum of the horse. On either side is a groove leading to the parieto-temporal canal. The basilar process is short and wide; its cranial surface is deeply concave, and the internal spheno-occipital crest is prominent. Two large tubercles below mark the junction with the sphenoid. The foramen lacerum is short and very narrow. In the adult animal the bone is excavated to contain an air-cavity which is regarded as a part of the frontal sinus.

The =sphenoid bone= is short. The cranial surface of the body presents a deep sella turcica, in front of which it rises abruptly. The high anterior part bears a central ridge (Rostrum sphenoidale), which joins the crista galli of the ethmoid. Two foramina occur on either side. Of these, the large anterior one is equivalent to the foramen rotundum, lacerum orbitale, and patheticum of the horse. The posterior one is the =foramen ovale=, which transmits the inferior maxillary nerve. The orbital wing is thick and is overlapped by the frontal in such manner as to appear externally to divide into two branches; the anterior part joins the ethmoid close to the sphenopalatine foramen, and contains a small sinus which communicates with an ethmoidal meatus. The temporal wing is small, but forms a prominent thick pterygoid crest. The pterygoid process is wide, and the pterygoid or alar foramen is absent. The sphenoidal sinus is absent in the calf and small in the adult; it communicates by one or two small openings with an ethmoidal meatus, and so with the nasal cavity.

[Illustration:

FIG. 89.—SKULL AND ATLAS OF OX, LATERAL VIEW.

_9_, Zygomatic arch; _11_, coronoid process; _12_, supraorbital process; _13″_, paramastoid or styloid process; _13■_, occipital condyle; _14_, parietal bone; _15_, frontal bone; _16_, squamous temporal bone; _17_, external auditory meatus; _18_, temporal condyle; _19_, orbital surface of lacrimal bone; _20_, malar bone; _21_, facial surface of lacrimal bone; _22_, nasal bone; _23_, nasal process of premaxilla; _24′_, incisor teeth; _26_, maxilla; _27_, facial tuberosity; infraorbital foramen in front of _27_; _28′_, molar part of ramus of mandible; _30_, broad vertical part of ramus; _30′_, angle of jaw; _31_, condyle of mandible; _32_, atlas; _x_, wing of atlas. (After Ellenberger-Baum, Anat. für Künstler.)]

The =ethmoid bone= has an extensive perpendicular plate. The lateral mass consists of five endoturbinals and eighteen ectoturbinals (Paulli). The largest ethmoturbinal is so extensive as to be termed a third or middle turbinal bone; it projects forward between the upper and lower turbinals. The lamina papyracea appears to a small extent externally in the pterygo-palatine fossa, forming part of the upper margin of the sphenopalatine foramen.

The =interparietals= are primitively paired, but unite before birth. As already mentioned, fusion occurs before or shortly after birth with the parietals and supraoccipital. No distinct tentorium osseum is present.

[Illustration:

FIG. 90.—SKULL OF OX, BASAL VIEW, WITHOUT MANDIBLE.

_F_, Pterygoid bone; _G_, horizontal and _G′_, perpendicular part of palate bone; _H_, occipital bone; _J_, malar bone; _K_, sphenoid bone; _O_, maxilla; _P_, vomer; _Sch._, squamous temporal; _St._, frontal bone; _Z_, premaxilla; _1_, for. magnum; _2_, occipital condyle; _3_, paramastoid (styloid) process of occipital; _4_, hypoglossal and condyloid foramina; _5_, for. lacerum; _6_, pharyngeal tubercles; _7_, bulla ossea; _8_, muscular process (left one is removed to expose for. ovale); _9_, hyoid process; _10_, ext. auditory meatus; _11_, zygomatic process; _12_, external opening of parieto-temporal canal; _13_, postglenoid process; _14_, temporal condyle; _15_, for. ovale; _16_, for. lac. orbitale + for. rotundum; _17_, optic foramen; _18_, ethmoidal foramen; _19_, orbital opening of supraorbital canal; _20_, pterygoid crest; _21_, hamulus of pterygoid bone; _22_, lacrimal bulla; _23_, temporal process of malar; _24_, pterygoid process of maxilla; _25_, sphenopalatine foramen; _26_, maxillary foramen; _27_, posterior palatine foramen; _28_, anterior palatine foramen; _29_, accessory palatine foramina; _30_, palate process of maxilla; _31_, interalveolar border; _32_, palatine cleft; _33_, palate process of premaxilla; _34_, fissura incisiva; _35_, facial tuberosity; _36_, posterior nares. (Ellenberger-Baum, Anat. d. Haustiere.)]

The =parietal bones= do not enter into the formation of the roof of the cranium. They constitute the upper part of the posterior wall, and bend sharply forward along the lateral wall, forming part of the wall of the temporal fossa. The line of inflection is marked by the prominent =parietal crest=, which is continuous with the temporal crest below. The parietals are excavated to form part of the frontal sinuses in the adult animal.

The condition in the young subject is as follows: The two parietals are united with each other and also with the interparietal and supraoccipital. The resulting mass is somewhat horseshoe-shaped. Its occipital part (Planum occipitale) forms the greater part of the posterior wall of the cranium and bears about its center the tuberosity for the attachment of the ligamentum nuchæ. From either side of this a line curves outward, and divides the surface into an upper smooth area and a lower area which is rough for muscular attachment. The upper border joins the frontal bone and concurs in the formation of the frontal eminence. The temporal parts (Plana temporalia) are much smaller and are concave externally; they join the frontal above and the squamous temporal below.

[Illustration:

FIG. 91.—SKULL OF OX, DORSAL VIEW (WITH MANDIBLE).

_12_, Supraorbital process; _14_, parietal bone; _15_, frontal bone; _16_, squamous temporal bone; _19_, orbit; _20_, malar bone; _21_, lacrimal bone; _22_, nasal bone; _23_, premaxilla; _26_, maxilla; _27_, facial tuberosity; _24_, incisor teeth. (After Ellenberger-Baum, Anat. f. Künstler.)]

[Illustration:

FIG. 92.—SKULL AND ATLAS OF OX, VENTRAL VIEW.

_13_, Basi-occipital; _13″_, paramastoid or styloid process; _13■_, occipital condyle; _24′_, incisor teeth; _28_, body of mandible; _31_, condyle of mandible; _32_, ventral tubercle of atlas. (After Ellenberger-Baum, Anat. für Künstler.)]

The =frontal bones= are very extensive, forming about one-half of the entire length of the skull, and all of the roof of the cranium. The posterior borders form with the parietals a large central =frontal eminence= (Torus frontalis), the highest point of the skull. At the junction of the posterior and the lateral borders are the =processus cornu= or “horn-cores,” for the support of the horns. These processes are of elongated conical form, and vary greatly in size, length, curvature, and direction. The external surface is rough and porous, marked by numerous grooves and foramina; in the fresh state they are covered by the matrix of the horns. The base has a constriction, the neck. The interior is excavated to form a number of irregular intercommunicating spaces, divided by bony

septa, and communicating with the frontal sinus. In the polled breeds these processes are absent, the skull is narrower in this region, and the frontal eminence more pronounced. The supraorbital process is situated about half-way between the anterior and posterior margins; it is short and joins the frontal process of the malar bone. The supraorbital foramen (often double) is situated about an inch inward from the root of the process; it is the external orifice of the =supraorbital canal= (Canalis supraorbitalis), which passes downward and forward into the orbit. The foramen is in the course of the =supraorbital groove= (Sulcus supraorbitalis), which marks the course of the frontal vein. The anterior ends of the naso-frontal parts form a notch which receives the nasal bones, and sutural or Wormian bones are often found at this junction (naso-frontal suture). The orbital part is extensive; it is perforated behind by the orbital opening of the supraorbital canal, and below by the ethmoidal or internal orbital foramen. It does not articulate with the palatine, from which it is separated by the orbital wing of the sphenoid. The temporal part is also more extensive than in the horse. The frontal sinus is very extensive, being continued into the parietals and occipital, and the horn processes when present.

The =squamous= and =petrous parts= of the =temporal bone= fuse early—in fact, union is nearly complete at birth. The squamous part is relatively small. Its external surface is divided into two parts by the prominent temporal crest, which is continuous with the parietal crest above and turns forward below, ending at a tubercle above the external auditory meatus. The part behind the crest faces backward, and is partly free, partly united with the occipital. The area in front of the crest is concave and enters into the formation of the temporal fossa; it is perforated by foramina which communicate with the parieto-temporal canal. The zygomatic process is much shorter and weaker than in the horse, and articulates with the malar only. The condyle is convex in both directions. The postglenoid process is less prominent, and behind it is the chief external opening of the parieto-temporal canal. The internal surface is almost completely overlapped by the parietal and sphenoid. The petrous part proper is small, but the tympanic part is extensive. The external auditory meatus is smaller than in the horse and is directed outward. From it a plate projects downward and helps to inclose the deep depression in which the hyoid process is placed. Behind this plate is the stylo-mastoid foramen. The muscular process is large and often bifid at its free end. The bulla ossea is large and laterally compressed. It is separated from the occipital bone by a narrow opening which is equivalent to part of the foramen lacerum basis cranii of the horse. The parieto-temporal canal is formed entirely in the temporal bone. The facial canal, on the other hand, is bounded partly by the occipital bone.

BONES OF THE FACE

The =maxilla= is shorter but broader and relatively higher than in the horse. Its external surface bears instead of the facial crest a rough =facial tuberosity= (Tuber malare), placed above the third cheek tooth; a rough curved line often extends from it to the upper part of the malar bone. The infraorbital foramen—often double—is situated above the first cheek tooth. The tuber maxillare is small, laterally compressed, and usually bears a small pointed process (Processus pterygoideus). The zygomatic process is very small. The interalveolar border is concave, and there is no alveolus for a canine tooth. The palatine process is wider, but somewhat shorter than in the horse. It incloses a large air-space, which is continuous behind with a like cavity in the horizontal part of the palate bone, forming the =palatine sinus=. This communicates externally (over the infraorbital canal) with the maxillary sinus; in the macerated skull it communicates with the nasal cavity by a large oval opening, which is closed by mucous membrane in the fresh state. A median septum separates the two palatine sinuses. The alveoli for the cheek teeth increase in size from before backward. The maxillary sinus proper is small and is undivided. The maxillary foramen is a narrow fissure, deeply placed at the inner side of the lacrimal bulla. The maxilla takes no part in the formation of the palatine canal. Sutural (or Wormian) bones may be found at its junction with the lacrimal and malar bones.

The body of the =premaxilla= is thin and flattened, and has no alveoli, since the canine and upper incisor teeth are absent. A deep notch takes the place of the foramen incisivum. The nasal process is short, convex externally, and is not closely attached to the nasal bone; the space between the two processes is greater than in the horse. The palatine process is narrow and is grooved on its nasal surface for the septal cartilage and the vomer. The palatine cleft is very wide.

The =palatine bone= is very extensive. The =horizontal part= forms one-fourth or more of the hard palate. The anterior palatine foramen opens near the junction with the maxilla, about half an inch from the median palatine suture and crest. =Accessory palatine foramina= are also present. The palatine groove is usually not very distinct. The palatine canal is formed entirely in this part, and there is no articulation with the vomer. A rounded ridge occurs on the nasal side of the median suture. The interior is hollow, forming part of the palatine sinus. The =perpendicular part= is an extensive, quadrilateral, thin plate, which forms the posterior part of the lateral wall of the nasal cavity and in part bounds the narrow posterior nares. Its internal surface is nearly flat, and is smooth and free, except behind, where it is overlapped by the pterygoid bone. The external surface is attached to a small

extent to the pterygoid process behind, and is free elsewhere. The sphenopalatine foramen is a long elliptical opening, formed by a deep notch in the upper edge of the palate bone and completed by the ethmoid and sphenoid. The edge behind this foramen articulates with the orbital wing of the sphenoid, not the frontal as in the horse.

[Illustration:

FIG. 93.—MEDIAN SECTION OF SKULL OF OX, WITHOUT THE MANDIBLE.

The mucous membrane is retained. The septum nasi is removed. _a_, Superior meatus; _b_, middle meatus, with _b′_ and _b″_, its upper and lower divisions; _c_, inferior meatus; _d_, superior turbinal; _e_, superior turbinal fold; _f_, inferior turbinal; _g_, alar fold; _h_, inferior turbinal fold; _i_, lateral mass of ethmoid (ethmoturbinals); _i′_, large ethmoturbinal or middle turbinal; _k_, frontal sinus; _l_, sphenoidal sinus; _m_, cranial cavity; _n_, palatine sinus; _o_, nasal bone; _o′_, parietal cartilage; _p_, palate process of maxilla; _q_, palate bone (horizontal part); _1_, sphenoid bone; _2_, _3_, inner and outer plates of frontal bone; _4_, _4′_, outer and inner plates of parietal bone; _5_, _5′_, occipital bone; _5″_, condyloid and hypoglossal foramina; _6_, paramastoid or styloid process; _6′_, occipital condyle; _7_, petrous temporal bone; _7′_, internal auditory meatus; _8_, squamous temporal bone; _9_, muscular process; _10_, pterygoid bone (hamulus). (After Ellenberger, in Leisering's Atlas.)]

The =pterygoid bone= is wider than in the horse, and forms the greater part of the lateral boundary of the posterior nares. Its outer surface is almost entirely united to the palate bone and the pterygoid process, but a small part is free in the pterygo-palatine fossa. The hamulus is distinctly hook-like, thin, and sharp.

The =nasal bone= is little more than half the length of that of the horse. It is straight in its length, but strongly curved from side to side. It does not fuse laterally with the adjacent bones, even in old age. The posterior extremity is pointed and fits into the notch between the frontal bones. The anterior end is broader, and is divided into two parts by a deep notch. In old animals there is a small extension of the frontal sinus into this bone.

The =lacrimal bone= is very large. The extensive facial part is concave in its length, and bears no lacrimal tubercle. The orbital margin is marked by several notches. The orbital part forms below the remarkable =lacrimal bulla=; this is a large and very thin-walled protuberance, which bulges backward into the lower part of the orbit, and contains an extension of the maxillary sinus. The lacrimal fossa is small, and is just behind the orbital margin.

The =malar bone= is relatively long. The facial surface is extensive; it bears a curved crest (Crista facialis) just below the orbital margin, and below this it is concave from above downward. The zygomatic process divides into two branches; of these, the frontal process turns upward and backward and joins the supraorbital process of the frontal bone; the temporal process continues backward, and is overlapped by the zygomatic process of the temporal bone, completing the zygomatic arch.

The =superior turbinal bone= is less cribriform and fragile than in the horse, and is thickest in its middle, small at either end. It is attached to the turbinal crest of the nasal bone, and curves downward, outward, and upward to be applied outwardly to the frontal and lacrimal bones. It thus incloses a cavity which communicates with the middle meatus nasi. (In the macerated skull it opens into the frontal sinus, but this communication is closed by mucous membrane in the fresh state.)

The =inferior turbinal bone= is shorter but much broader than in the horse. It is attached to the maxilla by a basal lamella about an inch (ca. 2 to 3 cm.) wide, which slopes downward and inward. At the inner edge of this it splits into two plates which are rolled in opposite directions, and inclose two separate cavities, subdivided by several septa. The upper one opens into the middle meatus, the lower one into the inferior meatus nasi.

The =vomer= forms a wider and deeper groove than in the horse. Its anterior end rests in a groove formed by the ends of the palatine processes of the premaxillæ. The anterior third of its thin lower edge fits into the nasal crest of the maxilla; behind this it is free and separated by a considerable interval from the nasal floor.

[Illustration:

FIG. 94.—HYOID BONE OF OX.

_a_, Body; _b_, lingual process; _c_, thyroid cornu and cartilage, _c′_; _d_, small cornu; _e_, middle cornu; _f_, great cornu; _g_, muscular angle of _f_. (Ellenberger-Baum, Anat. d Haustiere.)]

The two halves of the =mandible= do not fuse completely even in advanced age. The symphyseal surfaces are extremely rough and are marked by reciprocal projections and cavities. The body is shorter, wider, and flatter than in the horse, and has eight round and relatively shallow alveoli for the lower incisors. The interalveolar border is long, curved, thin and sharp. There are no alveoli for the canine teeth, which are absent. The anterior part of the ramus constitutes a long narrow neck. The mental foramen is further forward than in the horse, and is in the posterior end of a fossa. The rami diverge more, so that the submaxillary space is wider than in the horse. They are also more strongly curved, and the angle is more pronounced. The molar part is not so high, especially in its anterior part. Its lower border is convex in its length. Its upper border bears six alveoli for the lower cheek teeth; the first is quite small, and they increase in size from before backward. The vertical part is much smaller than in the horse and its posterior border is relatively thin below, concave and wider above. The mandibular foramen is about in the middle of its inner surface, and a groove for the lingual nerve curves downward and forward from it. The condyle projects inward further than in the horse, and is concave from side to side. The coronoid process is extensive and curves backward.

The =hyoid bone= has a short tuberous lingual process. The middle cornua are almost, as large as the small cornua. The great cornua are narrow, except at the ends. The upper end divides into two branches, which correspond to the two angles of that of the horse. The thyroid cornua do not fuse with the body.

SKULL OF THE OX AS A WHOLE

The skull of the ox is more clearly pyramidal than that of the horse, and is shorter and relatively wider. The cranium is quadrangular and larger externally than in the horse; its large size is due mainly to the great extent of the frontal sinus, and does not affect the cranial cavity, which is smaller than in the horse.

The =superior= or =frontal surface= is formed by the frontals, nasals, and premaxillæ. The frontal part is quadrilateral and very extensive, the greatest width being at the orbits. It presents a central depression on its anterior part, and on either side are the supraorbital grooves and foramina. Behind is the median frontal eminence, and at the lateral angles the "horn-cores" project in horned cattle. The nasal part is very short. The osseous nasal aperture is wide. The premaxillæ do not bend downward as in the horse; they are relatively thin and weak, and are separated by an interval which has a wide anterior part in place of the foramen incisivum.

The =lateral surface= is more triangular than in the horse. The temporal fossa is confined to this surface. It is deep and narrow, and its boundaries are more complete. It is limited above by a crest which extends from the postero-external angle of the frontal to the supraorbital process, and is analogous to the sagittal crest of the horse. Behind it is bounded by the temporal crest. It is clearly marked off from the orbit by the rounded posterior orbital ridge and the pterygoid crest. The zygomatic process is short, weak, and flattened, and is formed by the temporal and malar only. Its condyle is convex and is wide from before backward. The glenoid cavity and postglenoid process are small. The orbit is encroached upon below by the lacrimal bulla, and presents the orifice of the supraorbital canal behind. The margin is completed behind by the frontal process of the malar; its lower part is prominent and rough, not smooth and rounded as in the horse. The pterygo-palatine fossa is much larger, deeper, and more clearly defined. It has a long narrow forward extension (maxillary hiatus) between the vertical plate of the palate bone internally and the maxilla and lacrimal bulla externally; thus the sphenopalatine and maxillary foramina are deeply placed. The preorbital region is short but relatively high. A tuberosity and curved line take the place of the facial crest. The infraorbital foramen is situated above the first cheek tooth and is often double.

The =basal surface= is short and wide, especially in its cranial part. The occipital condyles are limited in front by transverse ridges. The tubercles at the junction of the occipital and sphenoid are large. The condyloid fossæ contain two foramina, the hypoglossal below and in front, and the condyloid above and behind; other inconstant ones occur. The paramastoid processes are short and convergent. The foramen lacerum is slit-like. The bulla ossea is a large, laterally compressed prominence. The muscular processes are usually long and narrow triangular plates, with one or two sharp points. The external auditory process is directed almost straight outward. A curved plate extends downward from it and joins the bulla ossea internally, completing the deep cavity which receives the articular angle of the hyoid bone. The chief external opening of the temporal canal is in front of this plate, and an accessory one lies behind it. The infratemporal fossa is small, and presents the foramen ovale. The posterior nares are very narrow, and the vomer does not reach to the level of their margin. The hard palate is wide, and forms about three-fifths of the entire length of the skull. A small central part only of its posterior border enters into the formation of the posterior nares; the lateral parts are notched and just above them are the posterior palatine foramina. The anterior palatine foramina are an inch or more from the posterior margin, and about the same distance apart. The palatine grooves are distinct for a short distance only. Just beyond the cheek teeth

the palate narrows and becomes concave; beyond this it widens and flattens.

The =posterior= or =nuchal surface= is extensive and somewhat pentagonal in outline in the adult. About its center is the eminence for the attachment of the ligamentum nuchæ. From this a median crest extends toward the foramen magnum, and laterally two lines (Lineæ nuchæ superiores) curve outward, marking the upper limit of the area which is roughened for muscular attachment. The surface above the lines is relatively smooth, and is covered only by the skin and the thin auricular muscles in the living animal. It is separated from the cranial roof by a thick border, which forms centrally the frontal eminence, and bears at its extremities the processus cornu—except in the polled breeds. The condyles are further apart, and the articular surfaces are more clearly divided into upper and lower parts than in the horse.

[Illustration:

FIG. 95.—CROSS-SECTION OF SKULL OF OX. SECTION PASSES THROUGH FIFTH CHEEK TOOTH.]

[Illustration:

FIG. 96.—CROSS-SECTION OF SKULL OF OX. SECTION PASSES THROUGH SECOND CHEEK TOOTH.

_a_, _b_, _c_, Superior, middle, inferior meatus; _b′_, communication between middle meatus and cavity of upper part of inferior turbinal; _c′_, communication between inferior meatus and lower part of inferior turbinal; _d_, cavity of superior turbinal; _e_, _f_, outer and inner walls of _d_; _g_, _h_, upper and lower cavities of inferior turbinal bone; _i_, basal lamella of inferior turbinal; _i′_, _i″_, upper and lower divisions of inferior turbinal bone; _k_, floor of nasal cavity; _m_, lacrimal sinus; _n_, maxillary sinus; _p_, palatine sinus; _q_, septum between maxillary and palatine sinuses; _r_, infraorbital canal; _s_, septum between palatine sinuses; _t_, common meatus; _u_, naso-lacrimal canal; _v_, floor of nasal cavity and roof of palatine sinus; _1_, septum nasi; _2_, posterior part of second cheek tooth; _3_, posterior part of fifth cheek tooth; _4_, hard palate. (After Ellenberger, in Leisering's Atlas.)]

The =cranial cavity= is shorter and its long axis is more oblique than in the horse, but it is relatively high and wide. The anterior fossa lies at a much higher level than the rest of the floor. The olfactory fossæ are smaller, and the sella turcica is much deeper than in the horse. A deep groove leads from the petrous temporal forward over the foramen ovale to the foramen rotundum. Behind the sella there is often a distinct prominence (Dorsum sellæ). The internal sagittal crest is prominent anteriorly, but absent further back. A faintly marked elevation takes the place of the tentorium osseum. The small petrous temporal bone projects into the cavity laterally. The ridges and digital impressions are very pronounced. The parieto-temporal canal is formed entirely in the temporal bone, and opens at the apex of the petrous, where it is joined by the condyloid canal. The foramen lacerum is divided into two parts (For. lacerum anterius et posterius).

The =nasal cavity= is incompletely divided by the septum, which does not reach the floor posteriorly. The floor is relatively long, and is more concave from side to side than in the horse. In the dry skull it has a large oval opening into the palatine sinus, which is closed during life by mucous membrane. The middle meatus is divided behind into upper and lower branches by the great ethmoturbinal. The posterior nares are narrow and oblique.

[Illustration:

FIG. 97.—SKULL OF OX, DORSAL VIEW.

The outer plate of bone has been removed to show the sinuses. _a_, Frontal sinus; _a′_, cranial plate of frontal bone; _a″_, anterior part of frontal sinus, which is separated from remainder by a septum (_b_); _c_, _c′_, communications between frontal sinus and nasal cavity; _d_, supraorbital foramen; _e_, supraorbital canal; _f_, cavity of superior turbinal bone, and _g_, its opening into the nasal cavity; _h_, lacrimal sinus, _i_, its communication with the maxillary sinus; _k_, maxillary sinus; _l_, orbit; _1_, frontal bone; _1′_, processus cornu; _2_, nasal bone; _3_, premaxilla (nasal process); _4_, maxilla; _5_, lacrimal bone; _6_, malar bone; _7_, dotted line indicating course of naso-lacrimal duct. (After Ellenberger, in Leisering's Atlas.)]

The =frontal sinus= is very large. It involves almost all of the frontal bone and a large part of the posterior wall of the cranium. It also extends for a variable distance into the horn processes when these are present. A complete median septum separates the right and left sinuses. The anterior limit is indicated by a transverse plane through the middle of the orbits. It extends externally to the crest which limits the temporal fossa above, and into the root of the supraorbital process. At the highest part of the cranial cavity and at the tuberosity on the posterior surface the two plates of the bone come together. The cavity is very irregular and is subdivided into

numerous spaces by ridges and partial septa. This multilocular character is most marked in the anterior part, and here several small spaces appear to be cut off from the main cavity (Baum). The supraorbital canal passes through the sinus. Several small openings lead from the sinus to the ethmoidal meatuses, and thus indirectly to the upper division of the middle meatus nasi. The communications with the cavity of the superior turbinal and with the lacrimal part of the maxillary sinus which are seen in the macerated skull are closed in the fresh state by mucous membrane.

[Illustration:

FIG. 98.—SKULL OF OX, LATERAL VIEW WITHOUT MANDIBLE.

The maxillary, lacrimal, and turbinal sinuses have been opened, and a portion of the orbit removed, _a_, Cavity of superior turbinal bone; _b_, lacrimal sinus; _c_, maxillary sinus; _d_, communication between maxillary and palatine sinuses; _e_, opening between maxillary and lacrimal sinuses; _f_, thin osseous bulla; _g_, lacrimal bulla; _h_, orbit; _1–6_, cheek teeth; _7_, nasal bone; _8_, premaxilla (nasal process); _9_, maxilla; _9′_, infraorbital foramen; _10_, frontal bone; _11_, lacrimal bone; _12_, malar bone; _13_, fissure between nasal bone and maxilla; _14_, temporal bone (squamous); _15_, external auditory meatus; _16_, styloid or paramastoid process; _17_, occipital condyle; _18_, palate bone (perpendicular part); _19_, pterygoid bone (hamulus); _20_, tympanic part of temporal; _20′_, muscular process of petrous temporal. (After Ellenberger, in Leisering's Atlas.)]

The =maxillary sinus= is excavated chiefly in the maxilla, lacrimal, and malar, and is not divided by a septum as in the horse. It extends forward as far as the facial tuberosity, or a little further in old animals. Its upper limit is indicated approximately by a line drawn from the infraorbital foramen to the upper margin of the orbit. It is continued directly backward into the lacrimal bulla to a point nearly opposite to the bifurcation of the zygomatic process of the malar. It also extends upward and backward through a large opening into a cavity formed by the lacrimal, frontal, ethmoid, and turbinal bones, at the inner side of the orbit.[26] The floor of the cavity is irregular and the roots of the last three or four cheek teeth project up into it, covered by a plate of bone. The sinus communicates with the palatine sinus freely over the infraorbital canal through an oval opening about two to three inches (ca. 5 to 7.5 cm.) long. Above this it communicates by a shorter and much narrower opening with the middle meatus nasi.

The =palatine sinus= is excavated in the hard palate, and is separated from that of the opposite side by a median septum. It extends from the posterior border of the palate to a plane an inch or more (2.5 to 3 cm.) in front of the first cheek tooth. As mentioned above, there is a large communication with the maxillary sinus over the infraorbital canal, so that the cavity is sometimes regarded as a part of that sinus. The large defect in the bony roof of the sinus is closed by two layers of mucous membrane in the fresh state. The palatine canal passes obliquely through the posterior part of the sinus.

The =sphenoidal sinus= is almost entirely in the sphenoid bone and does not communicate with the palatine and maxillary sinus. It has one or two openings into the ventral ethmoidal meatuses. There is no cavity in the perpendicular part of the palate bone.

There are several small air-cavities between the lateral mass of the ethmoid and the anterior part of the frontal sinus, which communicate separately with ethmoidal meatuses.

BONES OF THE THORACIC LIMB

The =scapula= is more regularly triangular than in the horse, relatively wider at the vertebral end and narrower at the lower end. The scapular index is about 1 ■ 0.6. The spine is more prominent and is placed further forward, so that the supraspinous fossa is narrow and does not extend to the lower part of the bone. The spine is sinuous, bent backward in its middle, forward below. Its free border is somewhat thickened in its middle, but bears no distinct tubercle. Instead of subsiding below as in the horse the spine becomes a little more prominent, and is prolonged by a pointed projection, the =acromion=, from which part of the deltoid muscle arises. The subscapular fossa is shallow. The areas for the attachment of the serratus muscle are not very distinct. The nutrient foramen is usually in the lower third of the posterior border. The glenoid cavity is almost circular and without any distinct notch. The tuberosity is small and close to the glenoid cavity. The coracoid process is short and rounded. The cartilage resembles that of the horse.

The =humerus= has a shallow musculo-spiral groove. The deltoid tuberosity is less prominent than in the horse, and the curved line running from it to the neck bears a well-marked tubercle on its upper part. The nutrient foramen is usually in the lower third of the posterior surface. The external tuberosity is very large, and rises an inch or more (ca. 3 cm.) above the level of the head. Its anterior part curves inward over the bicipital groove, and below it externally there is a prominent circular rough area for the insertion of the tendon of the supraspinatus. The anterior part of the internal tuberosity has a small projection which curves over the groove.

The groove is undivided. The distal articular surface is decidedly oblique, and the grooves and ridge are very well marked. The coronoid and olecranon fossæ are deep and wide. The external condyloid crest is represented by a rough raised area. The proximal end unites with the shaft at three and one-half to four years, and the distal at about one and one-half years.

The =radius= is short and relatively broad. It is somewhat oblique, the lower end being nearer the median plane than the upper. The curvature is more pronounced below than above. The shaft is prismatic in its middle part and has anterior, external, and posterior faces. There is a marked increase in width and thickness below. The proximal articular surface presents a synovial fossa which extends inward from the deep groove between the two glenoid cavities. The bicipital tuberosity is represented by a slightly elevated rough area. The posterior facets for the ulna are larger than in the horse. The two bones commonly fuse above the proximal interosseous space and always fuse below it, except near the distal end, where there is a small distal interosseous space. A groove connects the two spaces externally. The distal extremity is large, and is thickest internally. Its articular surface is oblique in two directions, _i. e._, from within upward and backward. The grooves for the extensor tendons are shallow. The proximal end unites with the shaft at one to one and one-half years, and the distal at three and one-half to four years.

The approximation of the lower ends of the forearms and the carpi gives the "knock-kneed" appearance in cattle. The obliquity of the joint surfaces produces lateral deviation of the lower part of the limb in flexion. The facets for the radial and intermediate carpals are narrower than in the horse and run obliquely forward and outward. The surface for the ulnar carpal is extensive and saddle-shaped; its outer part is furnished by the ulna.

[Illustration:

FIG. 99.—SKELETON OF LEFT FORE LIMB OF OX, FROM SHOULDER DOWNWARD, ANTERIOR VIEW. (After Ellenberger-Baum, Anat. für Künstler.)]

The =ulna= is more fully developed than in the horse. The shaft is complete, three-sided, and strongly curved. It is fused with the radius in the adult, except at the two interosseous spaces mentioned above. Its upper part contains a medullary canal which extends somewhat into the proximal end. The olecranon is large and bears a rounded tuberosity above. The distal end is fused with the radius; it projects below the level of the latter, forming the =styloid process= (Processus styloideus ulnæ), which furnishes part of the facet for the ulnar carpal. The proximal and distal ends unite with the shaft at three and one-half to four years.

[Illustration:

FIG. 100.—SKELETON OF LEFT FORE LIMB OF OX, FROM ELBOW DOWNWARD, EXTERNAL VIEW. (After Ellenberger-Baum, Anat. für Künstler.)]

The =carpus= consists of six bones, four in the upper row, and two in the lower. The upper row is oblique in conformity with the carpal articular surface of the radius. The radial and intermediate resemble in general those of the horse, but are less regular in shape, and their long axes are directed obliquely backward and inward. The radial is narrower than in the horse and curves upward behind. The intermediate is constricted in its middle, and wider behind than in front. The ulnar is large and very irregular. Its proximal surface is extensive and sinuous and articulates with both radius and ulna. Behind is a large oval facet for articulation with the accessory carpal. The accessory is short, thick, and rounded; it articulates with the ulnar carpal only. The first carpal is absent. The second and third carpals are fused to form a large quadrilateral bone. The fourth carpal is a smaller quadrilateral bone.

The =metacarpus= consists of a large metacarpal and an external small metacarpal bone. The large metacarpal bone (Mc. 3 + 4) results from the fusion of the third and fourth bones of the fœtus, and bears evidences of its double origin even in the adult state. The shaft is shorter than in the horse, and is relatively wider and flatter. The anterior surface is rounded, and is marked by a vertical vascular groove connecting two canals which traverse the ends of the shaft from before backward. The posterior surface is flat and presents a similar but much fainter groove. The borders are rough in the upper third. The proximal end bears two slightly concave facets for articulation with the bones of the lower row of the carpus; the inner area is the larger, and they are separated by a ridge in front and a notch behind. The outer angle has a facet behind for the small metacarpal bone. The inner part of the extremity has anterior and posterior tuberosities. The distal end is divided into two parts by a sagittal notch. Each division bears an articular surface similar to that in the horse, but much smaller. The =medullary canal= is divided into two parts by a =vertical septum= which is usually incomplete in the adult.

The =small metacarpal= bone (Mc. 5) is a rounded rod about an inch and a half (ca. 3.5 to 4 cm.) in length, which lies against the upper part of the outer border of the large bone. Its upper end articulates with the latter, but not with the carpus. The lower end is pointed.

Four cartilaginous metacarpals are present in the early fœtal state, viz., the second, third, fourth, and fifth. The second commonly either disappears or unites with the third; sometimes it develops as a small rod of bone. The third and fourth gradually unite, but can be cut apart at birth. Each has three centers of ossification; the proximal epiphysis fuses with the shaft before birth, the distal at two to two and one-half years.

Four =digits= are present in the ox. Of these, two—the third and fourth—are fully developed and have three phalanges and three sesamoids each. The second and fifth are vestiges and are placed behind the fetlock; each contains one or two small bones which do not articulate with the rest of the skeleton.

The =first phalanges= are shorter and narrower than in the horse and are three-sided. The interdigital surface is flattened and its posterior part bears a prominence for the attachment of the interdigital ligaments. The proximal extremity is relatively large, and is somewhat compressed from side to side. The articular surface is concave from before backward and is divided by a sagittal groove into two areas, of which the abaxial one is the larger and higher. Behind these are two facets for articulation with the sesamoid bones. The posterior surface bears two tuberosities separated by a deep depression. The distal extremity is smaller than the proximal, especially in the antero-posterior direction. Its articular surface is divided by a sagittal groove into two convex facets, of which the abaxial one is decidedly the larger. There are depressions on either side for ligamentous attachment. The bone consists at birth of two pieces—the distal end and the fused shaft and upper extremity. Union occurs at one and one-half to two years.

The =second phalanges= are about two-thirds of the length of the first and are distinctly three-sided. The proximal articular surface is divided by a sagittal ridge into two glenoid cavities, of which the abaxial one is much the larger. There is a central prominence in front and two lateral tubercles behind. The distal extremity is smaller than the proximal. Its articular surface encroaches considerably on the anterior and posterior surfaces, and is divided into two lateral parts by a groove. There is a deep depression for ligamentous attachment on the interdigital side. The bone contains a small medullary canal. The distal end unites with the rest of the bone about the middle of the second year.

The =third phalanges= resemble in a general way one-half of the bone of the horse. Each has four surfaces. The dorsal or wall surface is marked in its lower part by a shallow groove, along which there are several foramina of considerable size; the posterior one of the series is the largest, and conducts to a canal in the interior of the bone. Below the groove the surface is prominent, rough, and porous. Near and on the extensor process are several relatively large foramina. The slope of the surface is very steep posteriorly, but in front it forms an angle of 25 to 30 degrees with the ground plane. The articular surface is narrow from side to side, and slopes downward and backward. It is also oblique transversely, the interdigital side being the lower. It is adapted to the distal surface of the second phalanx, with the exception of a facet behind for the distal sesamoid. The extensor process is very rough. The volar or sole surface is narrow and slightly concave, and presents two or three foramina of considerable size. It is separated from the wall surface by a border which is sharp in front, rounded behind. There is no semilunar crest, since the deep flexor tendon is attached to the thick posterior border of the sole surface. The interdigital surface is smooth and grooved below, rough and porous above. At the upper angle it is perforated by a large foramen, which is equivalent to the volar foramen of the horse and leads to a cavity in the middle of the bone. The surface is separated by a rounded border from the wall surface, and by a sharp edge from the sole surface. The wing or angle is very short and blunt, and there is no lateral cartilage.

Four =proximal sesamoids= are present, two for each digit. They are much smaller than in the horse. The bones of each pair articulate with the corresponding part of the distal end of the large metacarpal bone by their anterior surfaces, with each other and with the first phalanx by small facets.

The two =distal sesamoids= are short and their ends are but little narrower than the middle.

BONES OF THE PELVIC LIMB

The =ilia= are almost parallel to each other and are also less oblique with regard to the horizontal plane than in the horse. They are relatively small. The gluteal line is prominent and is nearly parallel to the external border; it joins the superior ischiatic spine. A rounded ridge separates the two parts of the ventral surface. The surface for articulation with the sacrum is triangular. The internal angle is truncated, does not extend as high as the vertebral spines, and is separated from the opposite angle by a wider interval

than in the horse. The external angle is relatively large and prominent; it is not so oblique as in the horse, and is wide in the middle, smaller at either end. The shaft is short and compressed from side to side.

The =ischium= is large. Its long axis is directed obliquely upward and backward, forming an angle of about 45 to 50 degrees with the horizontal plane. The transverse axis is oblique downward and inward at a similar angle, so that this part of the pelvic floor is deeply concave from side to side. The middle of the ventral surface bears a rough ridge or imprint for muscular attachment. The superior ischiatic spine is high and thin, and bears a series of almost vertical rough lines externally. The tuber ischii is large and three-sided, bearing upper, lower, and external tuberosities. The ischial arch is narrow and deep. The symphysis bears a ventral ridge, which fades out near the ischial arch.

The acetabular branch of the =pubis= is narrow, and is directed outward and a little forward. The anterior border is marked by a transverse groove which ends below the rough ilio-pectineal eminence. The longitudinal branch is wide and thin.

The =acetabulum= is smaller than in the horse. The rim is rounded and is usually marked by two notches. One of these is postero-internal and is narrow and deep; it leads to the deep acetabular fossa and is commonly almost converted into a foramen by a bar of bone. The other notch is antero-internal, small, and sometimes replaced by a foramen or absent.

The =obturator foramen= is large and elliptical. Its inner border is thin and sharp.

[Illustration:

FIG. 101.—SKELETON OF LEFT HIND LIMB OF OX, FROM MIDDLE OF THIGH DOWNWARD, POSTERIOR VIEW. _21_, Tibia; _24_, tuber calcis; _25_, large metatarsal bone. (After Ellenberger-Baum, Anat. für Künstler.)]

The =pelvic inlet= is elliptical and is more oblique than in the horse. In a cow of medium size the =conjugate diameter= is about nine and a half inches (ca. 23 to 24 cm.), and the transverse about seven inches (ca. 18 cm.). The anterior end of the symphysis lies in a transverse plane through the junction of the third and fourth sacral segments. The roof is concave in both directions. The =floor= is deeply concave, particularly in the transverse direction. The =cavity= is narrower and its =axis= is inclined strongly upward in the posterior part. The distance between the acetabulum and the external angle of the ilium is only a little (ca. 3 to 4 cm.) more than the distance between the former and the tuber ischii.

[Illustration:

FIG. 102.—FRONTAL SECTION OF LEFT FEMUR OF OX, FRONT VIEW.]

[Illustration:

FIG. 103.—FRONTAL SECTION OF LEFT TIBIA OF OX, ANTERIOR VIEW.

These figures show the internal architecture of these bones, and especially the great extent of the medullary cavity as compared with those of the horse (Figs. 67 and 72).]

The =femur= has a relatively small shaft, which is cylindrical in its middle, prismatic below. The trochanter minor has the form of a rough tuberosity, and is situated higher up than in the horse and encroaches on the posterior surface. The trochanteric ridge (Crista intertrochanterica posterior) connects it with the trochanter major. The third trochanter is absent. The supracondyloid (plantar) fossa is shallow. The proximal extremity is very wide. The head is smaller than in the horse and the articular surface extends considerably on the upper surface of the neck. Instead of the notch there is a small depression on the middle of the head for the attachment of the round ligament. The neck is well defined except above. The trochanter major is very massive and is undivided; its external surface is very rough. The trochanteric fossa is deep, but does not extend so far downward as in the horse. The distal end presents no very striking differential features, but the lips of the trochlea are less oblique than in the horse, and converge very slightly below. The proximal extremity unites with the shaft at about three and one-half years, the distal at three and one-half to four years.

The =tibia= resembles that of the horse rather closely, but is somewhat shorter. The shaft is distinctly curved, so that the inner side is convex. The posterior surface is not divided into two areas, and the lineæ musculares are fewer and extend up higher than in the horse. The articular grooves and ridge of the distal end are almost sagittal in direction, and present an extensive but shallow synovial fossa. The external groove is separated by a sharp ridge from an outer area which is for articulation with the external malleolus. The anterior part of the internal malleolus is prolonged downward and has a pointed end. The groove behind it is broad

and well defined. Externally there is a deep narrow groove which separates two prominences. The proximal extremity fuses with the shaft at three and one-half to four years, the distal at two to two and one-half years.

The =fibula= usually consists of the two extremities only. The head is fused with the external condyle of the tibia and bears a small blunt-pointed prolongation below. The distal end remains separate and forms the external malleolus (sometimes called the os malleolare). It is quadrilateral in outline and compressed from side to side. The proximal surface articulates with the distal end of the tibia, and bears a small spine which fits into the groove on that bone. The distal surface rests on the fibular tarsal, and the inner articulates with the external ridge of the tibial tarsal bone. The outer surface is rough and irregular.

The early cartilaginous fibula is complete, but later the shaft is reduced and is usually represented by a fibrous cord which connects the two ends. In some cases, however, the upper part undergoes partial ossification, forming a slender rod which is usually united with the outer border of the tibia and is joined to the head by fibrous tissue.

The =patella= is long, narrow, and very thick. The anterior surface is strongly convex and very rough and irregular. The articular surface is convex from side to side and nearly straight in the vertical direction. The large prominence on the inner side for the attachment of the accessory cartilage allows prompt determination of the side to which the bone belongs. The apex is more pointed than in the horse.

The =tarsus= consists of five pieces; the central and fourth, and the second and third tarsal bones are fused.

The =tibial tarsal= bone is relatively long and narrow, and is somewhat flattened from before backward. It bears a trochlea at either end. The groove and ridges of the proximal trochlea are not spiral, but almost sagittal; the outer ridge is the wider, and articulates with both tibia and fibula. The distal trochlea consists of two condyles divided by a groove, and articulates with the combined central and fourth tarsals. The posterior surface bears a large oval facet for articulation with the fibular tarsal; this occupies most of the surface, and is convex and grooved from above downward. The outer surface presents two facets for articulation with the fibular tarsal, and is excavated and rough elsewhere. The inner surface bears a tuberosity at its upper part, and is flattened below.

The =fibular tarsal= bone is longer and more slender than in the horse. The distal part of the body is compressed laterally, and bears a projection in front which articulates with the external malleolus. The tuber calcis is marked posteriorly by a wide shallow groove, which is coated with cartilage in the fresh state.

The =central= and =fourth tarsals= are fused to form a large bone (Os centrotarsale quartum, scapho-cuboid), which extends across the entire width of the tarsus and articulates with all of the other bones. The greater part of the upper surface is molded on the distal trochlea of the tibial tarsal, and its inner part rises high above the rest posteriorly. Externally there is a narrow undulating surface for articulation with the distal end of the fibular tarsal bone. The posterior surface bears two tuberosities, of which the outer one is rounded, the inner more prominent and narrower.

The =first tarsal= bone is quadrilateral and small. It articulates with the central above, the metatarsus below, and the second tarsal in front.

The =second= and =third tarsals= are fused to form a rhomboid piece. The proximal surface is concavo-convex, and articulates with the central component. The distal surface is undulating and rests on the metatarsus. The external surface bears a small facet in front for the fourth tarsal component, and the posterior surface a very small one for the first tarsal bone.

The =large metatarsal= bone is about one-seventh (ca. 3 cm.) longer than the corresponding metacarpal. Its shaft is compressed laterally and is distinctly four-sided. The groove on the anterior surface is deep and wide. The posterior surface is marked by variable grooves. The upper foramen on this surface does not perforate the shaft, but passes obliquely through the extremity, opening on the posterior part of its proximal surface. The postero-internal angle of the proximal end bears a facet for articulation with the small metatarsal bone.

[Illustration:

FIG. 104.—SKELETON OF DISTAL PART OF LEFT HIND LIMB OF OX, INTERNAL VIEW. _24_, Tuber calcis; _25_, large metatarsal bone; _30_, first phalanx; _31_, second phalanx; _32_, third phalanx. (After Ellenberger-Baum, Anat. für Künstler.)]

The =small metatarsal= bone is a quadrilateral disc a little less than an inch in width and height. Its anterior face bears a facet for articulation with the large metatarsal bone.

The large metatarsal bone is usually regarded as consisting of the fused third and fourth metatarsal bones. The medullary cavity is subdivided like that of the large metacarpal bone. Some anatomists, however, consider that the ridges at the upper end of each border represent the second and fifth metatarsals (Rosenberg and Retterer). On this basis the small bone would be the first metatarsal.

The =phalanges= and =sesamoids= resemble those of the thoracic limb so closely as to render separate description unnecessary.

SKELETON OF THE PIG

VERTEBRAL COLUMN

The =vertebral formula= is C_{7}T_{14–15}L_{6–7}S_{4}Cy_{20–23}.

[Illustration:

FIG. 105.—SKELETON OF PIG, LATERAL VIEW.

_a_, Cranium; _b_, upper jaw; _c_, lower jaw; _1H.-7H._, cervical vertebræ; _1R.w._, first thoracic vertebra; _13 R.w._, thirteenth thoracic vertebra (next to last); _1L._, first lumbar vertebra; _6L._, sixth lumbar vertebra (next to last usually); _K._, sacrum; _S._, coccygeal vertebra; _1R._, first rib; _14R._, last rib; _R.kn._, costal cartilages; _St._, sternum; _d_, supraspinous fossa of scapula; _d′_, infraspinous fossa; _1_, spine of scapula; _2_, neck of scapula; _e_, humerus; _3_, head of humerus; _4_, tuberosities of humerus; _5_, deltoid tuberosity; _6_, external epicondyle of humerus; _f_, radius; _g_, ulna; _7_, olecranon; _h_, carpus; _18–25_, carpal bones; _i-i■_, metacarpus; _k-k■_, proximal phalanges; _l-l■_, middle phalanges; _m-m■_, distal phalanges; _n_, _o_, sesamoids; _p_, ilium; _8_, external angle of ilium (tuber coxæ); _9_, internal angle of ilium (tuber sacrale); _10_, superior ischiatic spine; _q_, ischium; _11_, tuber ischii; _r_, pubis; _12_, acetabulum; _s_, femur; _13_, trochanter major; _14_, trochanter minor; _15_, external epicondyle; _t_, patella; _u_, tibia; _16_, crest of tibia; _17_, external condyle of tibia; _v_, fibula; _w_, tarsus; _26–31_, tarsal bones; _26′_, tuber calcis. (After Ellenberger, in Leisering's Atlas.)]

The =cervical vertebræ= are short and wide. The bodies are elliptical in cross-section, the long diameter being transverse. The anterior articular surfaces are slightly convex from side to side and concave dorso-ventrally; the posterior ones are slightly concave. A ventral crest is not present. The arches are wide from side to side, but the laminæ are narrow, so that a considerable interval (Spatium interarcuale) separates adjacent arches dorsally. The pedicles are perforated by a foramen on either side in addition to the usual intervertebral foramina. The transverse processes divide into two branches, both of which increase in size from the third to the sixth. The upper branch projects outward and backward; it is short and is thickened at its free end. The lower branch is a quadrilateral plate directed ventrally; each overlaps the succeeding one to a small extent, and the series forms the lateral boundary of a deep and wide groove beneath the bodies. The spines increase in height from the third to the last; the anterior ones are inclined backward, the posterior ones forward. The last cervical is recognized by the great length of its spine (ca. 10 cm. in the adult), the absence of the ventral plate of the transverse process, and the flatness of the body, which bears a pair of small facets on its posterior margin for the heads of the first ribs. It has foramina transversaria, and usually two foramina in either side of the arch.

The dorsal arch of the =atlas= bears a large tuberosity. The ventral tubercle is long, compressed laterally, and projects back under the axis. The wing is flattened and bears a posterior tuberosity. The foramen transversarium passes through the posterior border of the wing to the fossa under the latter, and is not visible dorsally; it is sometimes very small or absent. The sides of the vertebral foramen bear two lateral projections which partially divide it into a ventral narrow part, which receives the odontoid process, and a dorsal larger part for the spinal cord. In the fresh state the division is completed by the transverse ligament, which is attached to the projections.

The =axis= has a large spinous process, which is directed upward and backward. The odontoid process is a thick cylindrical rod. The transverse process is very small and the foramen transversarium is often incomplete.

[Illustration:

FIG. 106.—ATLAS OF PIG, DORSAL VIEW.

_a_, Wing; _b_, ventral tubercle; _c_, foramen transversarium; _d_, alar foramen; _e_, intervertebral foramen; _f_, dorsal tuberosity; _g_, articular surface corresponding to that of posterior articular process of typical vertebra; _h_, facet on ventral arch

for odontoid process. (Ellenberger-Baum, Anat. d. Haustiere.)]

[Illustration:

FIG. 107.—AXIS OF PIG, LEFT LATERAL VIEW.

_a_, Odontoid process (dens); _b_, spinous process; _c_, anterior articular process; _d_, posterior articular processes; _e_, transverse process; _f_, foramen transversarium; _g_, bar of bone which bounds _h_, intervertebral foramen; _i_, vertebral foramen. (Ellenberger-Baum, Anat. d. Haustiere.)]

The =thoracic vertebræ= are often fifteen in number. Their bodies are relatively long, constricted in the middle, and without ventral crests. Their extremities are elliptical, depressed in the middle and prominent at the periphery. The arch is perforated by a foramen on either side, and in most of the series there is also a foramen in the posterior part of the root of the transverse process which communicates with the former or with the posterior intervertebral foramen. Sometimes there is a foramen in the anterior part of the process also. There are mammillary processes except on the first two; in the posterior five or six vertebræ they project from the anterior articular processes. The facet for the tubercle of the rib is absent or fused with that for the head in the last five or six. The last transverse process is lumbar in character, plate-like, and about an inch (2 cm.) long. Small accessory processes occur in the posterior part of the region. The first spinous process is broad, very high, and inclined a little forward. The others diminish very gradually in length to the tenth, beyond which they are about equal. The second to the ninth are inclined backward, the tenth is vertical (anticlinal), and the rest incline forward. The width decreases decidedly from the fourth to the tenth, beyond which there is a gradual increase. The summits are slightly enlarged and lie almost in a straight line.

The occurrence of fifteen thoracic vertebræ appears to be quite common, and some observers have recorded the existence of sixteen and even seventeen; a reduction to thirteen is rare.

The =lumbar vertebræ= are six or seven in number. The bodies are longer than in the thoracic region and bear a ventral crest. They become wider and flatter in the posterior part of the series. The arches are deeply notched, and are separated by an increasing space dorsally. The mammillary processes project outward and backward. The transverse processes are bent downward and incline a little forward. Their length increases to the fifth and is much diminished in the last. They form no articulation with each other or with the sacrum. The posterior edge of the root of the process is marked by a notch in the anterior part of the series, a foramen in the posterior part. The spines are broad and incline forward, with the exception of the last, which is narrow and vertical.

Lesbre states that six and seven lumbar vertebræ occur with almost equal frequency. The number may be reduced to five, and the number of presacral vertebræ varies from twenty-six to twenty-nine.

The =sacrum= consists usually of four vertebræ, which fuse later and less completely than in the other domesticated animals. It is less curved than in the ox. The spines are absent, excepting small rudiments on the last two segments. The middle of the dorsal surface is flattened and smooth, and presents openings into the sacral canal between adjacent arches (Spatia interarcualia). On either side are the superior sacral foramina, and tubercles which indicate the fused articular processes. The wings resemble those of the ox. The anterior articular processes are very large. The pelvic surface resembles that of the ox, but is not so strongly curved, and the transverse lines are very distinct.

[Illustration:

FIG. 108.—SACRUM OF PIG, DORSAL VIEW.

_a_, Wing; _b_, dorsal sacral foramina; _c_, articular process; _1–4_, segments or sacral vertebræ. (Ellenberger-Baum, Anat. d. Haustiere.)]

The =coccygeal vertebræ= are specially characterized by the presence of functional articular processes on the first four or five, beyond which these processes become non-articular and smaller. The arches of the first five or six are complete. The transverse processes are broad and plate-like in the anterior part of the series and diminish very gradually.

The numerical variation here is twenty to twenty-six according to the observation of several anatomists. Lesbre states that he has found twenty-three most frequently.

=Curves.=—The cervical region is practically straight. The thoracic and lumbar regions form a gentle curve, concave ventrally, the highest point of which is at the junction of the two regions. The sacral promontory is not so pronounced as in the ox, and the sacral curve is flatter.

THE RIBS

The =ribs= number fourteen or fifteen pairs, of which seven are sternal and seven or eight asternal usually. They are in general strongly curved in the improved breeds, so that there is a fairly distinct angle, except toward the end of the series. The backward slope of the posterior ribs is slight. The first rib is prismatic, has a large sternal end, and a very short cartilage. The width is greatest in the third to the sixth, and the length in the sixth and seventh usually. The tuberosity fuses with the head on the last five or six. The second to the fifth form diarthrodial joints with their cartilages, which are wide and plate-like.

THE STERNUM

The =sternum= consists of six segments and resembles that of the ox in general form. The first segment (Manubrium) is long, flattened laterally, and bears a blunt-pointed cartilage on its anterior end; its posterior end forms a diarthrodial joint with the body. The latter is flattened, wide in its middle, narrow at either end. The widest segments are formed of two lateral parts, which are not completely fused in the adult. The last segment has a long narrow part which bears the xiphoid cartilage.

The =thorax= is long and is more barrel-shaped than in the horse or ox, since the ribs are more strongly curved and differ less in relative length.

[Illustration:

FIG. 109.—SKULL OF PIG, LATERAL VIEW WITHOUT MANDIBLE.

_1_, Occipital condyle; _2_, paramastoid or styloid process; _3_, bulla ossea; _4_, external auditory meatus, _5_, zygomatic process of temporal bone; _6_, sphenoid bone; _7_, orbital opening of supraorbital canal; _8_, malar bone; _9_, pterygoid bone; _10_, pterygoid process of sphenoid; _11_, pterygoid process of palate bone; _I1–3_, incisor teeth; _C_, canine tooth; _P1–4_, premolars; _M1–3_, molars.]

BONES OF THE SKULL

CRANIUM

The =occipital bone= has an extensive squamous part or supraoccipital, which forms a very broad and prominent crest. The latter is concave, and is thick and rough above, where it forms the highest part of the skull; laterally it becomes thinner, turns downward, and is continuous with the temporal crest. Two divergent ridges pass upward from the foramen magnum, and the surface between them is concave and smooth. The greater part of the inner (or anterior) surface of the supraoccipital is united with the parietal bones, but a lower concave area faces into the cranial cavity. The foramen magnum is almost triangular, and is narrow above, where it is flanked by two small tuberosities. The paramastoid processes are extremely long and project almost straight downward. The hypoglossal foramen is at the inner side of the root of the process. The basilar part is short and wide; its lower surface bears a thin median ridge and two lateral imprints or tubercles which converge at the junction with the sphenoid bone.

[Illustration:

FIG. 110.—SKULL OF PIG, DORSAL VIEW.]

The =interparietal= fuses before birth with the occipital. The tentorium osseum is absent.

The =parietal= is overlapped by the occipital bone behind and concurs in the formation of the occipital crest. Its external surface is divided by the parietal crest into two parts. The inner part (Planum parietale) faces upward and forward, and is flattened and smooth. Its inner border is short and straight and unites early with the opposite bone. Its anterior border is concave and joins the frontal bone. The outer part (Planum temporale) faces outward and is more extensive; it is concave, forms a large part of the temporal fossa, and is overlapped below by the squamous temporal. The parietal crest extends in a curve from the occipital crest forward and outward to the supraorbital process. The internal surface is concave and is marked by digital impressions. The lower border projects into the cranial cavity and forms a crest which separates the cerebral and cerebellar compartments laterally. The

interior forms part of the frontal sinus in the adult. There is no parieto-temporal canal.

The =frontal bone= is long. The frontal surface slopes downward and forward, the inclination varying in different subjects. The anterior part is concave and is marked by the supraorbital foramen and the groove leading forward from the foramen to the nasal bone. The supraorbital canal opens into the orbit at the upper part of the inner wall of the latter. The supraorbital process is short and blunt-pointed, and is not connected with the zygomatic arch. The gap in the orbital margin is closed by the orbital ligament in the fresh state. The orbital part is extensive and forms the greater part of the inner wall of the orbit. Its upper part is perforated by the orbital orifice of the supraorbital canal, in front of which is the distinct fovea trochlearis. The ethmoidal or internal orbital foramen is situated in the lower part near the junction with the orbital wing of the sphenoid. The temporal part is very narrow and is separated from the orbital plate by a ridge which joins the pterygoid crest below. The interior of the bone is excavated by the frontal sinus in practically its entire extent in the adult. In the young subject the cavity is confined to the anterior part and the rest of the bone is thick.

The =temporal bone= has a general resemblance to that of the ox. The zygomatic process is short and stout and is bent at a right angle. The upper border of the process is thin; traced from before backward it curves sharply upward and forms a high prominence in front of the external auditory meatus; beyond this it drops rather abruptly and is then continued upward to the occipital crest. The anterior part of the lower border joins the zygomatic process of the malar, which is deeply notched. The condyle is concave in the transverse direction. The postglenoid process is absent, but the articular surface is bounded behind and internally by a crest. There is no parieto-temporal canal. The external auditory canal is very long and is directed upward and outward. The bulla ossea is large, compressed laterally, and bears a pointed muscular process in front. A narrow space intervenes between the bulla and the basilar part of the occipital bone, so that the foramen lacerum resembles that of the horse. The small hyoid process is situated in a deep depression in front of the root of the paramastoid process, and the stylo-mastoid foramen is immediately external to it. The petrous part presents no important differential features. The squamous part (including the root of the zygomatic process) contains an air-cavity, which is continuous with the sphenoidal sinus.

[Illustration:

FIG. 111.—BASAL SURFACE OF SKULL OF YOUNG PIG, WITHOUT THE MANDIBLE.

_Sq.o._, Supraoccipital; _E.o._, exoccipital; _B.o._, basioccipital; _B.s._, body of sphenoid; _Sq._, squamous temporal bone; _V_, vomer; _Mx._, maxilla; _Pa._, horizontal part of palate bone; _P.p._, palate process of maxilla; _Z_, malar bone; _J_, premaxilla; _D.c._, canine tooth; _J1–3_, incisor teeth; _O_, temporal fossa; _1_, occipital crest; _2_, for. magnum; _3_, occipital condyle; _4_, paramastoid (styloid) process; _5_, bulla ossea; _6_, for. lacerum basis cranii; _7_, pterygoid process of sphenoid; _8_, posterior nares; _9_, anterior palatine foramen; _10_, palatine cleft. (Struska, Anat. d. Haustiere.)]

The =sphenoid bone= is short and resembles that of the ox in general. The body is narrow. The pituitary fossa is very deep, and is limited behind by a prominent dorsum sellæ; the dorsum bears lateral projections, the =posterior clinoid processes=. The foramen ovale is absent, being included in the foramen lacerum anterius. The other foramina are like those of the ox. The pterygoid process is broad and twisted. Its base is not perforated and its free edge is thin and sharp. It concurs with the pterygoid and palate bones in the formation of the pterygoid fossa, which opens backward and is not present in the horse or ox. The sphenoidal sinus is very large and occupies the body, the temporal wings, and a great part of the pterygoid processes in the adult; it is continued into the temporal bone as mentioned above.

The =ethmoid bone= has a relatively long perpendicular plate, which is marked by ridges corresponding to the ethmoidal meatuses. The cribriform plate is extensive and very oblique, so that it and the crista galli are almost in line with the basi-cranial axis. A linear series of relatively large foramina is found on either side of the crista. The lateral mass consists of five endoturbinals and eighteen ectoturbinals (Paulli). The lamina papyracea concurs in the formation of the pterygo-palatine fossa.

FACE

The =maxilla= is extensive. Its external surface forms a longitudinal groove, which is continued upon the premaxilla in front and the facial parts of the lacrimal and malar behind. The infraorbital foramen—sometimes double—is large and is situated above the third or fourth cheek tooth. The alveolus for the canine tooth produces a ridge at the anterior end which is very pronounced in the boar. The facial crest extends forward from the root of the zygomatic process and fades out behind the infraorbital foramen; in some specimens it is prominent and thin-edged, in others it is rounded and projects little. The zygomatic process is short but stout and

buttress-like; it is overlapped externally by the malar. The maxillary tuberosity forms in the young subject a long bulla, which occupies most of the pterygo-palatine fossa and contains the developing permanent molars; after the eruption of the teeth the tuberosity flattens and joins the vertical part of the palate bone. The palatine process is very long and is marked in its anterior part by transverse ridges corresponding with those of the mucous membrane of the palate. The anterior palatine foramen is near the junction with the palate bone; from it the palatine groove can be traced distinctly along the entire length of the process. The alveolar border presents a large alveolus for the canine tooth at its anterior end; behind this are seven alveoli for the cheek teeth, which increase in size from first to last. The maxillary foramen and infraorbital canal are very large. The maxillary sinus is small.

The body of the =premaxilla= is narrow and prismatic. It presents three alveoli for the incisor teeth, which are separated by short intervals and diminish in size from before backward. As in the ox, a narrow space separates the right and left bones and takes the place of the foramen incisivum. The palatine process is long and narrow. The nasal process is very extensive and is somewhat rhomboid in outline. Its upper border forms a very long suture with the nasal bone, and the lower articulates to about the same extent with the maxilla. The palatine fissure is relatively wide.

The horizontal part of the =palate bone= forms a fourth to a fifth of the length of the palate; its palatine surface is triangular, the apex being anterior; its nasal surface is deeply grooved and smooth. A pterygoid process (processus pyramidalis of man) projects backward and downward, and its thick rounded end is received between the pterygoid process of the sphenoid and the pterygoid bone. The perpendicular part is largely overlapped externally by the maxilla and concurs in forming part of the palatine canal. Superiorly the two plates separate and inclose an air-cavity which opens into an ethmoidal meatus. The inner plate curves inward and unites with the vomer and ethmoid to form a horizontal plate (Lamina transversalis), which divides the posterior part of the nasal cavity into an upper olfactory part and a lower respiratory part.

The =pterygoid bone= is nearly vertical in direction, and is narrow in its middle, wide at each end. The external surface is free below and forms the inner wall of the pterygoid fossa. The lower end is notched and forms a distinct hamulus.

The =nasal bone= is very long and its width is almost uniform, except at the anterior end, which is pointed and reaches almost as far forward as the premaxilla. The facial surface is flattened from side to side. In profile it is nearly straight in some subjects, variably concave in others. The external border is free to a small extent in front only; otherwise it is firmly connected with the premaxilla and maxilla. In the adult the frontal sinus extends into the posterior part of the bone.

The =lacrimal bone= is very sharply bent. Its facial surface presents a deep depression, surmounted by a ridge or tubercle. On or close to the orbital margin are two lacrimal foramina which lead to the lacrimal canals. The orbital surface presents a fossa in which the inferior oblique muscle of the eyeball arises, and its lower part bears a crest, which is crossed obliquely by a vascular furrow. The upper border articulates with the frontal only. The bone concurs in the formation of the maxillary sinus.

The =malar bone= is strongly compressed from side to side. Its facial surface is small and presents a fossa which is continuous with the depressions of the maxilla and lacrimal. The orbital surface is still smaller and is smooth and deeply grooved. The zygomatic process is very extensive, especially in the vertical direction. Its external surface is convex and free, and bears a rough eminence in its middle. Its internal surface is concave; it is overlapped in front by the maxilla, and in the remainder of its extent is free and smooth. The upper border is thick and rounded in front, where it forms the lower part of the orbital margin; behind this it forms an extensive notch which receives the zygomatic process of the temporal. (It might be regarded as dividing into frontal and temporal branches.) The lower border is convex and becomes thinner behind.

The =turbinal bones= resemble those of the ox. The superior turbinal is, however, relatively longer, less fragile, and more firmly attached to the nasal bone. There is no middle turbinal.

The =vomer= is very long. The anterior extremity reaches to the body of the premaxilla or very close to it. The lower border is received into a groove formed by the nasal crest of the maxillæ and palate bones and in front by the palatine processes of the premaxillæ. The posterior border is concave, thin, and sharp.

The =os rostri= (or prenasal bone) is situated in the snout between the nostrils. It has the form of a short three-sided prism. The upper surface is convex and is notched at each end. The lateral surfaces are concave, smooth, and converge below, forming a grooved lower border. The posterior surface is triangular, notched centrally, and rough laterally. The anterior surface is deeply pitted and is surrounded by an irregular sharp border.

The =mandible= is very strong, and differs very much from that of the horse or ox. The body narrows decidedly in front; the lingual surface is deeply concave; the mental surface is strongly convex, slopes downward and backward, and forms a distinct prominence at the point of divergence of the rami. Above this prominence is a pair of foramina. The alveolar border presents six alveoli for the incisor teeth, and a little further back two large cavities for the canine teeth. There are two pairs of mental foramina of considerable size and a variable number of smaller ones. The rami diverge more than in the horse or ox, and the upper part is somewhat incurved. The horizontal part is very thick and strong. Its outer surface is strongly convex from above downward. The inner surface is prominent over the roots of the molar teeth and overhangs the concave lower part. The alveolar border is thin in front and widens behind; it does not follow the axis of the ramus, but runs nearly straight and produces the marked overhang noted above. There are seven alveoli for the lower cheek teeth, which increase in size from before backward. The first is small, not always present in the adult, and is separated by short spaces from the second and the canine alveolus. The vertical part is relatively wide above. The condyle is convex in both directions, wide in front, narrow and declivitous behind. The very small and thin-edged coronoid process is not quite so high as the condyle, from which it is separated by a very wide notch. The mandibular foramen is large. The two halves of the bone unite soon after birth in the improved breeds.

The body of the =hyoid bone= is broad from before backward, short transversely, and bears on its ventral aspect a very short pointed lingual process. The thyroid cornua are wide and curved, concave and grooved dorsally; their ends are attached to the thyroid cartilage of the larynx by rather long bars of cartilage. The small cornua are short, wide, and flattened dorso-ventrally; they are attached to short bars which project from the junction of the body and thyroid cornua. The middle cornu is a little longer than the small cornu, but is relatively slender; it is largely cartilaginous in the young subject and does not ossify at either end. The great cornu is a very slender rod, slightly enlarged at either end; the upper extremity is attached to the hyoid process of the temporal by a rather long and wide bar of cartilage.

[Illustration:

FIG. 112.—MANDIBLE OF PIG.

_a_, Body of mandible; _b_, horizontal part of ramus; _f_, vertical part of ramus; _c_, interalveolar border; _c′_, interval between canine and corner incisor; _c″_, interval between first and second premolars; _d_, mental foramina; _e_, vascular impression; _g_, coronoid process; _h_, condyle; _i_, sigmoid notch; _k_, mandibular foramen; _1–7_, cheek teeth, _8_, canine tooth; _9_, _10_, _11_, incisors. (Ellenberger-Baum, Anat d. Haustiere.)]

THE SKULL AS A WHOLE

The =length= and the =profile= contour vary greatly in different subjects. Primitively the skull is long—especially in its facial part—and the frontal profile is almost straight. The condition is very pronounced in wild or semi-feral pigs, and exists also in the improved breeds during extreme youth. Most of the latter are decidedly brachycephalic when fully developed; the face is “dished” in a pronounced fashion. The frontal region slopes sharply upward, and the nasal region is shortened, and in some specimens even distinctly concave in profile. The supraorbital foramina are about midway between the orbital margin and the frontal suture. The supraorbital grooves extend forward from the foramina to the nasal region and turn outward and downward toward the infraorbital foramina over the ridges which separate the nasal and lateral regions.

The =lateral surface= is triangular when the mandible is included. The temporal fossa is entirely lateral and its long axis is almost vertical. It is bounded above by the occipital crest, behind by the temporal crest, in front by the parietal crest, and is marked off from the orbital cavity by the supraorbital process and a curved crest which extends from it to the root of the pterygoid process. The zygomatic arch is strong, high, and flattened from side to side. Its root is notched above and bears a projection below. It curves sharply upward behind and forms a pointed recurved projection above and in front of the external auditory meatus. The orbit is small. Its margin is deficient behind in the dry skull, thick and rounded in front and below. The cavity is limited below by a ridge on the frontal and lacrimal bones, and is separated by a crest from the temporal fossa. The inner wall is perforated above by the orbital opening of the supraorbital canal, and below by the optic and ethmoidal foramina; on its antero-inferior part is the fossa in which the inferior oblique muscle of the eye takes origin. Two lacrimal foramina are found on or close to the anterior margin. The pterygo-palatine fossa is well defined; its upper part forms a deep groove which leads from the large foramen in the sphenoid (like that of the ox) to the very large maxillary foramen. The preorbital region is deeply grooved in its length and is clearly marked off by a ridge from the nasal and frontal regions. The facial crest is short, usually thin-edged, and lies above the fifth and sixth cheek teeth. A little (ca. 2 cm.) in front of it is the infraorbital foramen. There is a ridged prominence over the canine alveolus. In some

skulls the anterior part of the upper jaw is inclined upward.

The most striking features of the =basal surface= are as follows: The paramastoid processes are extremely long, less flattened than in the horse and ox, and nearly vertical. At the inner side of the root of each is the hypoglossal foramen, and in front of it are the stylo-mastoid foramen and a deep cavity in which the hyoid process is concealed. The bulla ossea is long, compressed laterally, and bears a sharp, short, muscular process. The basioccipital is wide and flattened; it bears a median crest and two lateral tubercles. The posterior nares are small and are wider below than above. On either side of them is the tuberosity of the palate bone, and above this is the pterygoid fossa. The palate is remarkably long and is relatively narrow. It constitutes about two-thirds of the entire length of the skull. It is widest between the canines and premolars and narrow at each end. It is marked by a crest medially and by the palatine foramen and groove laterally. The anterior part bears transverse ridges. It is moderately arched from side to side. In some specimens it is nearly straight or slightly concave in its length; in others it curves upward to a variable degree in front. The posterior end always slopes upward more or less.

The =posterior= or =nuchal surface= is remarkable for its height and the breadth of the occipital crest. The central part above the foramen magnum is smooth and concave from side to side, and is bounded laterally by ridges, which converge below and end on two tubercles at the upper margin of the foramen magnum. The surface is separated from the temporal fossæ by the temporal crests, which curve downward and outward and blend with the external auditory canals. The mastoid process has the form of a plate which overlaps the root of the paramastoid process and bears a crest on its anterior part.

The =cranial cavity= is small, in spite of the great size of the cranium; the discrepancy is due to the enormous development of the frontal sinuses in the adult. It is relatively longer, but much lower than that of the ox. Its width is greatly diminished between the orbits. The olfactory fossæ are extensive and very oblique. The floor resembles that of the ox, but the foramen ovale is absent, the dorsum sellæ is more developed, and the foramen lacerum basis cranii is like that of the horse. Two oblique lateral crests clearly mark the limit between the cerebral and cerebellar compartments. The tentorium osseum and the parieto-temporal canals are absent.

The =nasal cavity= is very long. Its posterior part is divided by a horizontal plate into olfactory and respiratory parts. The olfactory part or fundus is above, and contains the ethmoturbinals and ethmoidal meatuses. The lower part is continuous with the inferior meatus and leads to the pharyngeal orifice; hence it is sometimes called the naso-pharyngeal meatus. The bony roof is almost complete in front on account of the great length of the nasal bones.

The =frontal sinus= is a vast excavation in the adult animal. It involves all of the roof and almost all of the sides of the cranium, and extends forward into the roof of the nasal cavity a variable distance—sometimes as far as a transverse plane through the infraorbital foramina. The septum between the right and left sinuses is usually deflected in an irregular manner in its middle part, but is practically median at either end. Each sinus is subdivided by numerous septa, some of which are complete. Thus the sinus is divided into compartments, each of which communicates with an ethmoidal meatus.

In the young pig the sinus is small and is confined to the anterior part of the frontal bone. Later it extends backward, outward, and to a less extent forward. In the old subject it penetrates laterally into the supraorbital process and the root of the zygomatic process of the temporal bone, and behind almost down to the foramen magnum and the occipital condyles. It then consists of six to eight compartments usually.

The =maxillary sinus= is relatively small. Its anterior end is a little less than an inch (ca. 2 cm.) behind the infraorbital foramen, and it extends upward into the lacrimal and backward into the malar bone. The infraorbital canal passes along its floor, and the roots of the molar teeth do not project up into it. It does not communicate with the frontal and sphenoidal sinuses, but with the posterior part of the middle meatus by means of a considerable orifice.

The =sphenoidal sinus= is very large. It involves the body, pterygoid processes, and temporal wings of the sphenoid bone, and extends into the squamous temporal. It communicates with the ventral ethmoidal meatus.

There is a small sinus in the perpendicular part of the palate bone which communicates with an ethmoidal meatus.

BONES OF THE THORACIC LIMB

The =scapula= is very wide, the index being about 1 ■ 0.7. The spine is triangular and is very wide in its middle, which curves backward over the infraspinous fossa and bears a large tuberosity. Its lower part bears a small projection (rudimentary acromion).

The anterior border is strongly convex in profile, sinuous when viewed from the front, and thick and rough in its middle. The posterior border is wide, slightly concave, and bears an outer rough lip. The vertebral border is convex, and the cartilage is not so extensive as in the horse and ox. The cervical angle is thin and bent inward a little. The dorsal angle is thick and is about a right angle. The neck is well defined. The rim of the glenoid cavity is rounded and not notched. The tuberosity is just above the antero-internal part of the glenoid cavity and bears no distinct coracoid process.

The =humerus= has an appearance in profile somewhat like an italic _f_ minus the cross-bar; this is due to the marked backward and forward inclination of the proximal and distal ends respectively. The shaft is decidedly compressed from side to side. The internal surface is extensive and flattened; it is separated from the anterior surface by a distinct border, and bears no teres tubercle. The musculo-spiral groove is shallow. The deltoid tuberosity is small, and there is a larger rounded eminence midway between it and the external tuberosity. The nutrient foramen is on the posterior surface below its middle. The head is more strongly curved and the neck better marked than in the horse or ox. The external tuberosity is very large and extends upon the front of the extremity. It is divided into two high prominences by a wide deep groove. There is a third eminence below and externally for the attachment of the supraspinatus muscle. The bicipital groove is at the front of the inner side; it is undivided and is almost converted into a canal. The outer groove on the distal articular surface is so shallow as to give the appearance of two condyles of similar size. The olecranon fossa is very deep, and the plate of bone which separates it from the coronoid fossa is thin and sometimes perforated. The proximal end unites with the shaft at three and a half years, the distal at one year.

The =radius= is short and narrow, but thick. The shaft increases in size from above downward. The greater part of the posterior surface is in apposition with the ulna; this part is marked by a vascular furrow which runs downward from the upper interosseous space, and has the nutrient foramen at its proximal end. The bicipital tuberosity is represented by a rough area. The distal end is relatively large. Its carpal surface consists of concavo-convex facets for the radial and intermediate carpal bones. There is a wide shallow groove on the middle of the front. The proximal end fuses with the shaft at one year, the distal at three and a half years.

The =ulna= is massive. It is much longer and considerably heavier than the radius. The shaft is curved. The anterior surface is convex and most of it is rough and attached to the radius by the interosseous ligament. There is a smooth area on the upper third, which concurs with the radius in forming the upper interosseous space, and is marked in its upper part by the nutrient foramen. From this space a vascular furrow passes downward to the lower part of the shaft, where there is often a distal interosseous space for the passage of vessels. The internal surface is extensive, concave, and smooth. The external surface is slightly convex, and its upper part is marked by an oblique rough line or ridge. The proximal extremity is large and is bent inward somewhat; its length is more than one-third of that of the entire bone. The distal extremity is relatively small; it articulates with the ulnar and accessory carpal bones, and is notched in front to accommodate the ridge on the radius. The bone contains a considerable medullary canal. The bone is consolidated at three to three and a half years.

The =carpus= comprises eight bones, four in each row. The bones of the proximal row resemble those of the ox, with the exception of the accessory, which is more like that of the horse, but has no external groove. The first carpal is small, elongated from before backward, rounded, and articulates in front with the second carpal. The latter is high and narrow, and articulates with the second and third metacarpal bones below. The third carpal articulates with the radial and intermediate above, the third metacarpal bone below. The fourth is the largest bone of the row; it articulates with the intermediate and ulnar above, the fourth and fifth metacarpals below, and bears a tuberosity on its volar aspect.

[Illustration:

FIG. 113.—SKELETON OF FOREARM AND MANUS OF PIG, ANTERO-EXTERNAL VIEW.

_a_, Radius; _b_, ulna; _c_, radial carpal; _d_, intermediate carpal; _e_, ulnar carpal; _f_, accessory carpal; _g_, first carpal; _h_, second carpal; _i_, third carpal; _k_, fourth carpal; _l-o_, second to fifth metacarpal bones; _p-s_, second to fifth digits; _1_, olecranon; _2_, beak of ulna (proc. anconeus); _3_, semilunar notch; _4_, styloid process of ulna; _5_, styloid process of radius; _6_, distal epiphyseal lines; _7_, first phalanx; _8_, second phalanx; _9_, third phalanx. (Ellenberger-Baum, Anat. d. Haustiere.)]

Four =metacarpal bones= are present. The first is absent, the third and fourth are large and carry the chief digits, while the second and fifth are much smaller and bear the accessory digits. Their proximal ends articulate with each other and with the carpus as indicated above. The bones are consolidated at about two years of age.

The third and fourth metacarpals are flattened from before backward, three-sided, and placed close together. The distal end of each bears a trochlea for articulation with the first phalanx and the sesamoids. The third is the wider of the two, and articulates with all of the lower row of the carpus except the first. The fourth articulates with the fourth carpal chiefly, but has a small facet for the third. The second and fifth metacarpals are placed further back than the chief bones. The fifth is considerably the thicker of the two. The proximal ends are small and articulate with the corresponding carpal and metacarpal bones. The distal end is relatively large; its articular surface is condyloid in front, trochlear behind.

Each chief digit comprises three =phalanges= and three =sesamoids=. The bones of the chief digits resemble those of the ox in form, but there is no foramen on the interdigital side of the extensor process and the proximal sesamoids are narrow and ridged behind. The phalanges of the accessory digits (which do not reach the ground ordinarily) are similar in form but much smaller.

BONES OF THE PELVIC LIMB

The =os coxæ= is long and narrow. The ilium and ischium are almost in line with each other and sagittal in direction. The wing of the =ilium= bends outward much less than in the horse or ox. The gluteal surface is divided into two fossæ by a ridge, which is continuous with the superior ischiatic spine behind. The inner surface presents an extensive rough area behind, which is in apposition with the wing of the sacrum. The smooth iliac area is narrow, and is bounded above by a ridge. The crest or anterior border is convex, and is thick, rough, and prominent in its middle, which forms the highest point of the bone. The internal angle is lower than the crest, is directed backward, and articulates internally with the sacrum. The external angle is lower still and is very little thickened. The =ischia= in the female are somewhat divergent and flattened behind. The tubera are everted and bear three prominences. There is a crest or tuberosity on the ventral surface. The superior ischiatic spine is like that of the cow, but is slightly incurved and the muscular ridges on its outer face are more pronounced. The symphyseal part of the =pubis= is thick and the two bones are almost in a horizontal plane. The ilio-pectineal eminence is prominent and the psoas tubercle is well marked.

The =acetabulum= is placed a little further back than in the ox. The rim is thick and is cut into posteriorly by a narrow fissure, which leads into the deep fossa acetabuli. The three pieces of the os coxæ are fused by the end of the first year, but the crest and the ischial tubera are partially separate till the sixth or seventh year. The symphysis does not usually undergo complete anchylosis. Interischial bones are present.

The =inlet= of the =pelvis= is elliptical and very oblique. In a sow of full size the conjugate diameter is about five to six inches (10 to 12 cm.) and the transverse about three and a half to four inches (ca. 8.75 to 10 cm.). In the female the floor is relatively wide and flattened, especially at the outlet, where the tubera are everted; it also has a decided downward inclination behind. The pelvic axis is therefore correspondingly oblique. The ischial arch is wide. In the boar the pubis is much thicker and the ischia are not everted posteriorly. The inlet is smaller. The floor is concave from side to side and slopes decidedly less than in the sow. The superior ischiatic spines are more incurved, and the ischial arch is much narrower and deeper.

The =femur= has a relatively wide and massive shaft, on which four surfaces might be recognized. The principal nutrient foramen is situated in the proximal third of the anterior surface. The posterior surface is wide, and is limited outwardly by a ridge which extends from the trochanter major to the large external supracondyloid crest. There is no supracondyloid (plantar) fossa. The head is strongly curved, and is marked toward the inner side by a rather large depression for the attachment of the round ligament. The neck is distinct. The trochanter major, although massive, does not extend up as high as the head. The trochanteric ridge and fossa resemble those of the ox. The external (third) trochanter is absent. The ridges of the trochlea are similar and almost sagittal.

The shaft of the =tibia= is slightly curved, convex internally. The tuberosity is grooved in front, and a narrow sulcus separates it from the external condyle. The facet for the fibula is on the posterior border of the latter, and is bounded internally by an eminence. The upper part of the crest is very prominent and curves outward. The distal end resembles in general that of the ox, but is relatively narrower transversely and thicker from before backward.

The =fibula= extends the entire length of the region, and is separated from the tibia by a wide interosseous space. The shaft is flattened from side to side; the proximal part is wide and deeply grooved externally; the lower part is narrower and thicker. The proximal end is flattened, grooved externally, and articulates internally with the external condyle of the tibia. The distal end forms the external malleolus. It is grooved externally, and articulates with the tibia and tibial tarsal internally, with the fibular tarsal bone distally.

The =patella= is very much compressed laterally and presents three surfaces.

[Illustration:

FIG. 114.—COXAL BONES OF PIG, LEFT POSTERIOR VIEW.

_a_, Wing, _b_, shaft, _c_, external angle, _d_, anterior border, _e_, internal angle, _f_, gluteal line of ilium; _g_, great sciatic notch; _h_, smooth, _i_, rough part of ventral surface of ilium; _k_, psoas tubercle; _l_, ilio-pectineal eminence; _m_, acetabular branch, _n_, symphyseal branch of pubis; _o_, obturator foramen; _p_, _p′_, ischium; _q_, _q′_, tuber ischii; _r_, symphysis; _s_, ischial arch; _t_, _t′_, superior ischiatic spine; _u_, acetabulum; _v_, epiphyseal line. (Ellenberger-Baum, Anat. d. Haustiere.)]

The =tarsus= comprises seven bones. The tibial and the fibular tarsal resemble in general those of the ox. The axis of the tibial is, however, slightly oblique downward and inward, and its distal end bears a double trochlea for articulation with the central and fourth tarsals. The tuber calcis is deeply grooved posteriorly. The central tarsal is narrow transversely and thick. Its proximal surface is deeply concave, and the posterior bears a large tubercle. The first tarsal is high and narrow; it articulates with the central and second tarsals and the second metatarsal bone. The second tarsal is small and somewhat prismatic; it articulates with the central above, the third in front, the first behind, and the second and third metatarsals below. The third tarsal is much larger, and is compressed from above downward, wide in front, narrow behind. It articulates with the central tarsal above, the third metatarsal below, the second tarsal internally, and the fourth tarsal externally. The fourth tarsal is large. Its external face is crossed by an oblique groove for the tendon of the peroneus longus. The internal surface articulates with the central and third tarsals. The proximal surface supports the tibial and fibular tarsal bones, and the distal surface rests on the fourth and fifth metatarsals. It ossifies from two centers.

The four =metatarsal bones= resemble the corresponding bones of the fore limb, but are somewhat longer. The proximal ends of the third and fourth each have a considerable projection behind; the process on the third has a facet for articulation with a discoid sesamoid bone. The second and fifth are placed more on the posterior aspect of the large bones than is the case in the fore limb.

The first and second =phalanges= are a little longer and narrower than those of the fore limb.

SKELETON OF THE DOG

VERTEBRAL COLUMN

The vertebral formula is C_{7}T_{13}L_{7(6)}S_{3}Cy_{20–23}.

The =cervical vertebræ= are relatively longer than in the ox and the pig. The bodies of the typical vertebræ diminish in length from first to last and are compressed dorso-ventrally. The anterior extremity is moderately convex and the posterior slightly concave; both are oblique. The median ridge and lateral grooves on the upper surface of the body are very well marked. The second, third, and fourth have distinct ventral spines. The spinous process of the third has the form of a long low crest; in the remainder it is higher, blunt-pointed, and inclined forward. The transverse processes of the third, fourth, and fifth project downward and backward, and divide into two branches; of these, the anterior one is thin, and the posterior is thick and tuberculate at its free end. The process of the sixth has two parts; one of these is an extensive quadrilateral plate directed downward and outward and ridged on its inner surface; the other part is short and blunt, and is directed outward and a little backward and upward. The seventh is readily distinguished by its shortness, the length of its spine, and the single transverse process. The posterior articular processes bear tubercles which are large on the third, fourth, and fifth.

The ventral arch of the =atlas= is narrow from before backward, and bears a small tubercle posteriorly. The upper surface of the dorsal arch is strongly convex and rough centrally. The wings are wide, flattened, and almost horizontal. The upper surface is rough. There is an alar notch (Incisura alaris) on the anterior border instead of the anterior foramen. The foramen transversarium is present.

The body of the =axis= is flattened dorso-ventrally, especially in front. The odontoid process is rounded and relatively long, reaching almost to the occipital bone; it is inclined upward a little. The articular surfaces which flank it are condyloid in form and very oblique. The inferior surface is wide, and is divided by a median crest into two fossæ. The transverse processes are single, pointed, directed backward and outward, and perforated by relatively large foramina transversaria. The spinous process is thin and of moderate height, but very long; it is prolonged forward so as to overhang the dorsal arch of the atlas, and is terminated behind by a tuberosity which is connected by two crests with the posterior articular processes. The anterior notches are large and are never converted into foramina.

The bodies of the =thoracic vertebræ= are wide and compressed dorso-ventrally, especially at each end of the region. Their convex anterior surfaces are depressed in the middle. The posterior facets for the heads of the ribs are absent on the last three or four. The transverse processes resemble those of the horse. They bear mammillary processes except at the anterior end of the region. The facets for the tubercles of the ribs are large and concave in the anterior part of the series, and become smaller and slightly convex further back. The last three have accessory processes also. The first three or four spinous processes are about equal in length. Behind this they become gradually shorter to the tenth, and then remain equal. The backward slope is most marked in the ninth and tenth. The eleventh is practically vertical (anticlinal vertebra) and the last two incline slightly forward.

The bodies of the =lumbar vertebræ= are decidedly flattened dorso-ventrally, and increase in width from first to last. The length increases to the sixth. The transverse processes are plate-like and are directed forward and downward. Their length increases to the fifth and sixth. They form no joints with each other or with the sacrum. Their extremities are enlarged, with the exception of the last. The accessory processes project backward over the posterior notches of the first five. The anterior articular processes are large, compressed laterally, and bear mammillary processes. The spinous processes are broad below, narrower above, and with the exception of the last, incline a little forward. Their height diminishes behind the fourth.

[Illustration:

FIG. 115.—SKELETON OF DOG, LATERAL VIEW.

_a_, Cranium; _b_, face; _c_, mandible; _1H-7H_, cervical vertebræ; _13B_, last thoracic vertebra; _1L-7L_, lumbar vertebræ; _K_, sacrum; _S_, coccygeal vertebræ; _1R-13R_, ribs; _R.Kn._, costal cartilages; _St._, sternum; _d_, scapula; _d′_, supraspinous fossa; _d″_, infraspinous fossa; _1_, spine of scapula; _2_, acromion; _3_, tuberosity of scapula; _3′_, articular end of scapula; _e_, humerus; _4_, head of humerus; _5_, external tuberosity of humerus; _5′_, deltoid ridge; _6_, _6′_, epicondyles of humerus; _7_, external condyloid crest; _7′_, coronoid fossa; _f_, radius; _g_, ulna; _8_, olecranon; _9_, "beak" of ulna; _h_, carpus; _i_, metacarpus; _k_, proximal phalanges; _l_, middle phalanges; _m_, distal phalanges; _n_, sesamoid; _p_, ilium; _10_, wing of ilium; _11_, shaft of ilium; _12_, crest of ilium; _13_, external angle of ilium (tuber coxæ); _14_, internal angle of ilium (tuber sacrale); _15_, superior ischiatic spine; _q_, pubis; _r_, ischium; _16_, tuber ischii; _17_, acetabulum; _s_, femur; _18_, head of femur; _19_, trochanter major; _20_, trochanter minor; _21_, trochanter tertius; _22_, _23_, condyles; _24_, _25_, epicondyles; _26_, trochlea; _t_, patella; _u_, tibia; _27_, tuberosity of tibia; _28_, _29_, condyles of tibia; _30_, internal malleolus; _v_, fibula; _31_, external malleolus; _32_, head of fibula; _w_, tarsus; _x_, metatarsus; _y_, phalanges; _33_, occipital bone; _34_, paramastoid (styloid) process; _35_, parietal bone; _36_, frontal bone; _37_, lacrimal bone; _38_, malar bone; _39_, squamous temporal; _40_, maxilla; _40′_, infraorbital foramen; _41_, premaxilla; _42_, nasal bone; _43_, external auditory meatus; _44_, canine tooth; _45_, masseteric fossa; _46_, angular process of mandible. (After Ellenberger, in Leisering's Atlas.)]

The =sacrum= results from the early fusion of three vertebræ. It is short, wide, and quadrangular. The spines are fused to form a median crest, which is notched, however, between the summits of the spines. On either side are two tubercles, vestiges of the fused articular processes. The pelvic surface is deeply concave and presents two pairs of foramina. The wings are prismatic and very high. Their lateral surfaces are extensive, face almost directly outward, and bear an auricular surface on the lower part. The anterior surface of the body of the first vertebra is extensive, depressed in its middle, and bears a prominent lip below. The anterior articular processes are large and have extensive, slightly concave facets which face upward and inward. The posterior articular processes are small. The transverse processes of the last vertebra project backward and may articulate or fuse with those of the first coccygeal. The sacral canal is strongly compressed dorso-ventrally.

[Illustration:

FIG. 116.—ATLAS OF DOG, VIEWED FROM ABOVE AND BEHIND.

_a_, Wing; _b_, dorsal arch and tubercle; _c_, ventral tubercle; _d_, intervertebral foramen; _e_, foramen transversarium; _f_, articular surface for axis. (Ellenberger-Baum, Anat. d. Hundes.)]

[Illustration:

FIG. 117.—AXIS OF DOG, LEFT LATERAL VIEW.

_a_, Odontoid process; _b_, articular surface for atlas; _c_, transverse process; _d_; foramen transversarium; _d′_, posterior opening of _d_; _e_, spine; _f_, posterior articular process. (Ellenberger-Baum, Anat. d. Hundes.)]

The =coccygeal vertebræ= are fully developed in the anterior part of the region. The arch is complete in the first six usually. The first three or four have well developed articular processes at each end. Behind this the posterior pair quickly disappears, and the anterior ones become non-articular and gradually reduced in size. The transverse processes of the first five or six are relatively large; behind this they quickly disappear. =Hæmal arches= (or chevron bones) in the form of a =V= or =Y= occur ventrally at the intercentral junctions of the third, fourth, and fifth usually. They transmit the middle coccygeal artery, which passes between pairs of ventral tubercles further back.

[Illustration:

FIG. 118.—SIXTH CERVICAL VERTEBRA OF DOG, LEFT VIEW.

_a_, Ventral plate, _b_, lateral part of transverse process; _c_, foramen transversarium; _d_, anterior articular process; _f_, accessory process; _g_, spinous process; _h_, articular head of body. (Ellenberger-Baum, Anat. d. Hundes.)]

[Illustration:

FIG. 119.—FOURTH THORACIC VERTEBRA OF DOG, LEFT VIEW.

_a_, Head; _b_, glenoid cavity; _c_, facet for head of rib; _d_, transverse process; _e_, facet for tubercle of rib; _f_, mammillary process; _g_, posterior articular process; _h_, spinous process. (Ellenberger-Baum, Anat. d. Hundes.)]

=Curves.=—A gentle curve, convex ventrally, is formed by the cervical and the anterior part of the thoracic region. The posterior thoracic and the lumbar vertebra form a second curve, concave ventrally. The sacral promontory is well marked. The sacrum and the anterior part of the coccygeal region constitute a third and more pronounced curve, concave ventrally. In long-tailed dogs the sacro-coccygeal region is somewhat =S=-shaped.

=Variations.=—Numerical variations are not common except in the coccygeal region. The number of thoracic vertebræ may be twelve or fourteen, with or without compensatory change in the lumbar region. Girard recorded a case with eight lumbar and the usual number of thoracic vertebra. Six lumbar with fourteen thoracic vertebræ have been met with. The first coccygeal sometimes unites with the sacrum.

THE RIBS

Thirteen pairs of ribs are present, of which nine are sternal and four asternal. They are strongly curved, narrow, and thick. Those in the middle of the series are the longest. The first eight or nine increase in width in their lower part. The last rib is usually floating. The costal cartilages are long and curve forward; the length and curvature of the first pair is a striking special feature.

[Illustration:

FIG. 120.—FOURTH LUMBAR VERTEBRA OF DOG, LEFT VIEW.

_a_, _b_, Articular surfaces of body; _c_, transverse process; _d_, accessory process; _e_, anterior articular process; _e′_, mammillary process; _f_, posterior articular process; _g_, spinous process. (Ellenberger-Baum, Anat. d. Hundes.)]

[Illustration:

FIG. 121.—SACRUM OF DOG, DORSAL VIEW.

_a_, Dorsal sacral foramina; _b_, articular surface of body of first segment; _c_, _d_, anterior articular processes; _e_, wing; _f_, rudiments of articular processes; _g_, lateral part; _h_, spinous processes. (Ellenberger-Baum, Anat. d. Hundes.)]

THE STERNUM

This is long, laterally compressed, and consists of eight sternebræ, which fuse only in exceptional cases and in extreme old age. The first segment is the longest; its anterior end is blunt-pointed and bears a short conical cartilage. It widens at the point of articulation of the first pair of cartilages. The last segment is also long, thinner than its predecessors, wide in front, and narrow behind, where it bears a narrow xiphoid cartilage.

The =thorax= is distinctly barrel-like and is not decidedly compressed anteriorly like that of the horse and ox. The inlet is oval and is relatively wide on account of the marked curvature of the first pair of ribs and cartilages.

BONES OF THE SKULL

In the following descriptions of the separate bones an intermediate type—_e. g._, a fox terrier—is selected, and the most striking differences in the brachycephalic and dolichocephalic breeds will be considered in the section on the skull as a whole.

CRANIUM

[Illustration:

FIG. 122.—BASE OF SKULL OF DOG, WITHOUT MANDIBLE.

_I_, Occipital; _II_, tympanic part of temporal; _IIa_, squamous part of temporal; _IIb_, mastoid part of temporal; _III_, sphenoid; _IV_, pterygoid; _V_, palate bone; _VI_, vomer; _VII_, malar; _VIII_, zygomatic arch; _IX_, inner wall of orbit; _X_, palatine process of maxilla; _XI_, premaxilla; _XII_, orbital cavity; _1_, _1_, tubercles above foramen magnum; _2_, foramen magnum; _3_, occipital condyle; _4_, notch between occipital condyles; _5_, condyloid fossa; _6_, hypoglossal foramen; _7_, paramastoid (styloid, jugular) process; _8_, for. lacerum and posterior opening of carotid canal; _9_, petro-occipital synchondrosis; _10_, petro-tympanic fissure; _11_, tubercle; _12_, bulla ossea; _13_, muscular process of petrous; _14_, carotid foramen; _15_, osseous Eustachian tube; _16_, postglenoid process; _17_, glenoid cavity; _18_, for. ovale; _19_, posterior opening of alar canal; _20_, external opening of parieto-temporal canal; _21_, stylo-mastoid foramen; _22_, external auditory meatus; _23_, temporal crest; _24_, zygomatic process of temporal bone; _25_, body of postsphenoid; _26_, body of presphenoid; _27_, anterior opening of alar canal; _28_, for. lacerum orbitale; _29_, optic foramen; _30_, hamulus of pterygoid; _31_, horizontal part of palate bone; _32_, perpendicular part of palate bone; _33_, median palatine suture; _34_, palato-maxillary suture; _35_, posterior nasal spine; _36_, anterior palatine foramen; _37_, palatine groove; _38_, alveolar border of maxilla; _39_, palatine process of maxilla; _40_, pterygoid process of maxilla; _41_, palatine fissure; _42_, body of premaxilla; _43_, palatine process of premaxilla; _44_, alveolar border of premaxilla; _45_, supraorbital process of frontal bone. (Ellenberger-Baum, Anat. d. Hundes.)]

The =occipital bone= is similar in position to that of the horse. The crest, is prominent, angular, and directed backward. Just below the crest are two rough imprints or tubercles for muscular attachment. The surface below these is convex from side to side and concave from above downward. On either side, at the junction with the squamous, there is a foramen which communicates with the parieto-temporal canal. The condyles are somewhat flattened and are widely separated above; at the inner side of each is a short condyloid canal, which opens into the parieto-temporal canal. The paramastoid processes are very short. The basilar part is wide and joins the bulla ossea on either side; its lower surface is flattened and the tubercles are at the junction with the bulla. The hypoglossal foramen is small and is close to the foramen lacerum posterius; the latter is bounded in front by the bulla ossea, behind and internally by the occipital bone.

The =interparietal bone= fuses with the occipital before birth. It forms the high posterior part of the sagittal crest, and is wedged in between the two parietal bones. The tentorium osseum is thin and curved, concave ventrally. Its base concurs with the occipital and parietal bones in the formation of a transverse canal which is continuous with the parieto-temporal canals.

[Illustration:

FIG. 123.—SKULL OF DOG, DORSAL VIEW.

_I_, Occipital; _II_, parietal; _III_, frontal; _IV_, lacrimal; _V_, malar; _VI_, squamous temporal; _VII_, nasal; _VIII_, maxilla; _IX_, premaxilla; _1_, supraoccipital; _2_, interparietal; _3_, parieto-occipital suture; _4_, occipital crest; _5_, sagittal crest; _6_, parieto-frontal suture; _7_, squamous suture; _8_, parietal eminence; _9_, antero-external angle of parietal bone; _10_, frontal crest; _11_, _14_, orbital margin; _12_, supraorbital process; _13_, frontal fossa; _15_, temporal part of frontal bone; _16_, nasal process of frontal bone; _17_, frontal suture; _18_, lacrimal foramen; _19_, maxillary process of frontal bone; _20_, lacrimo-maxillary suture; _21_, frontal process of malar bone; _22_, lacrimal process of malar; _23_, zygomatic process of malar; _24_, zygomatic process of squamous temporal; _24′_, posterior end of nasal bone; _25_, nasal suture; _26_, anterior end of nasal bone; _27_, infraorbital foramen; _28_, canine tooth; _29_, cheek tooth; _30_, frontal process of maxilla; _31_, body, _32_, nasal process, _33_, palatine process of premaxilla; _34_, palatine fissure; _35_, incisor teeth. (Ellenberger-Baum, Anat. d. Hundes.)]

The =parietal bone= is rhomboid in outline and is strongly curved. It is extensive and forms the greater part of the roof of the cranial cavity. At the junction of the right and left bones there is a prominent sagittal crest which is continued upon the frontal bones. The lower border articulates with the temporal wing of the sphenoid by its anterior part and with the squamous temporal in the remainder of its extent. The external surface enters into the formation of the temporal fossa. The internal surface is marked by digital impressions, and by grooves for the middle meningeal artery and its branches.

The external surface of the =frontal bone= is crossed by a frontal crest, which extends in a curve from the sagittal crest to the supraorbital process, and separates the frontal and temporal parts. The frontal parts of the two bones form a central depression and slope downward and forward. The supraorbital process is very short, so that the orbital margin is incomplete as in the pig. The supraorbital foramen is absent. In front there is a narrow pointed nasal part which fits in between the nasal bone and the maxilla. The orbital and temporal parts are relatively extensive. Two ethmoidal foramina are commonly present. The frontal sinus is confined to the frontal bone.

The parts of the =temporal bone= fuse early. The zygomatic process curves widely outward and forward. Its anterior part is beveled below and articulates extensively with the corresponding process of the malar. The articular surface for the condyle of the mandible consists of a transverse groove which is continued upon the front of the large postglenoid process. Behind the latter is the lower opening of the parieto-temporal canal. There is no condyle. The mastoid part is small, but bears a distinct mastoid process. The external auditory meatus is large and the canal very short, so that one can see into the tympanum in the dry skull. The India ossea is very large and is rounded and smooth; the inner side is united to the basioccipital. Above this junction and roofed in by the union of the petrous part and the basioccipital is the =petro-basilar canal= (Canalis petrobasilaris); this transmits a vein from the floor of the cranium to the foramen lacerum posterius. The latter is in reality a depression and is situated behind the bulla ossea. In its posterior part is a foramen which transmits the ninth, tenth, and eleventh cranial nerves. The =carotid canal= branches off from the petro-basilar, passes forward external to it through the inner part of the bulla ossea, and opens in front at the =carotid foramen=; it transmits the internal carotid artery. The Eustachian opening is immediately external to the carotid foramen. The muscular and hyoid processes are extremely rudimentary. The petrous part projects into the cranial cavity and forms a sharp prominent petrosal crest. The inner surface presents a deep =floccular fossa= above the internal auditory meatus. The anterior surface is also free. The anterior angle is perforated by a =canal= for the fifth cranial nerve (Canalis nervi trigemini).

[Illustration:

FIG. 124.—CRANIAL CAVITY OF DOG, AS SEEN ON SAGITTAL SECTION OF SKULL.

_I_, Roof of cranium; _II_, base of cranium; _III_, posterior wall of cranium; _IV_, anterior wall of cranium; _A_, anterior cranial fossa; _B_, middle cranial fossa; _C_, posterior cranial fossa; _a_, body of presphenoid; _a′_, body of postsphenoid; _c_, palate bone; _d_, vomer; _e_, occipital; _f_, occipital condyle; _g_, sagittal crest; _h_, frontal sinus; _h′_, cranial plate of frontal bone; _i_, cribriform plate of ethmoid bone; _i′_, ethmoidal foramen; _k_, ethmoturbinals; _l_, parietal bone; _l′_, _l″_, squamous temporal bone; _l■_, temporal wing of sphenoid bone; _m_, sella turcica; _m′_, dorsum sellæ; _n_, optic foramen; _o_, foramen lacerum orbitale; _p_, foramen rotundum; _q_, foramen ovale; _r_, _r′_, carotid foramina; _s_, tentorium osseum; _t_, foramen lacerum; _u_, _u′_, orifices of parieto-temporal canal; _v_, condyloid canal; _w_, canal for trigeminal nerve; _x_, internal auditory meatus; _y_, _y′_, orifices of canal for inferior occipital sinus; _z_, floccular fossa. (After Ellenberger, in Leisering's Atlas.)]

The body of the =sphenoid bone= is flattened dorso-ventrally. The sella turcica is shallow, but the dorsum sellæ is well developed and bears =posterior clinoid processes=. A pair of =anterior clinoid processes= project back from the roots of the orbital wings. The latter are relatively small and are crossed externally by a crest, which is continued forward upon the palate bone. The temporal wings are extensive and articulate above with the parietals. Perforating the roots of the wings are the following foramina, named from before backward: The optic passes through the orbital wing. The foramen lacerum orbitale is a little lower and is at the junction of the wings. The foramen rotundum opens into the alar canal, which passes through the root of the short but wide pterygoid process. The foramen ovale is near the posterior border of the temporal wing. There is no sphenoidal sinus.

The =ethmoid bone= is highly developed. The cribriform plate is extensive, and the olfactory fossæ are very deep. The crista galli is little developed, and often incomplete. The perpendicular plate is long. The lateral masses are greatly developed and bulge upward into the frontal sinus. There are four large endoturbinals and six ectoturbinals. The lamina papyracea is extensive and forms the inner wall of the maxillary sinus. Its lower border joins the palatine process of the maxilla and the horizontal part of the palate bone. A shelf-like plate extends inward from its lower part and concurs with the similarly incurved part of the palate bone in forming the

=transverse lamina= (Lamina transversalis), which divides the olfactory fundus of the nasal cavity from the naso-pharyngeal meatus.

FACE

The =maxilla= is short, but very high posteriorly. The facial crest is absent. The infraorbital foramen is over the alveolus for the third premolar. The =frontal process= fits into a deep notch between the nasal and orbital parts of the frontal bone, and the middle part of the posterior border lies along the orbital margin. There are more or less pronounced ridges, juga alveolaria, over the canine and molar teeth. The zygomatic process is short and thin; it is completely overlapped outwardly by the malar, and is perforated by a number of foramina (Foramina alveolaria). A maxillary tuberosity is not present in the adult, but there is a pointed projection, the pterygoid process, behind the last alveolus. The internal surface bears a short turbinal crest on its anterior part, behind which it is deeply concave and forms the outer wall of the maxillary sinus. The palatine process is short, wide behind, and moderately arched from side to side. The anterior palatine foramen is situated at or close to the transverse palatine suture about midway between the median suture and the alveolar border. The palatine groove is distinct. The large alveolus for the canine tooth is completed by the premaxilla. The small alveolus for the first premolar is separated from the preceding one by a small interval. The next two consist of anterior and posterior parts for the roots of the teeth. The fourth and fifth are much larger and are divided into three parts. The last is small and consists of three divisions. The infraorbital canal is short.

The body of the =premaxilla= is compressed dorso-ventrally, and contains three alveoli for the incisor teeth, which increase in size from first to third; it also completes the inner wall of the large alveolus for the canine tooth. The foramen incisivum is very small except in large skulls. The interalveolar border is wide and very short. The nasal process is wide at its origin and tapers to a sharp point behind; the anterior part curves upward, backward, and a little inward, and forms the lateral margin of the osseous nasal aperture; the posterior part extends backward a long distance between the nasal bone and the maxilla. The palatine process turns upward and outward, forming with its fellow a wide groove for the septal cartilage; the posterior end is pointed and fits into a notch between the palatine processes of the maxillæ, and supports the end of the vomer. The palatine fissure is short but wide.

The horizontal part of the =palate bones= is extensive, forming about one-third of the hard palate. It presents a variable number of lesser palatine foramina. There is usually a pointed posterior nasal spine at the end of the median suture. The palatine canal is sometimes formed entirely in this bone. The perpendicular part is even more extensive. Its external surface is chiefly free and forms most of the inner wall of the large pterygo-palatine fossa. The maxillary foramen is situated in a deep recess between this bone and the zygomatic process of the maxilla. Just above it there is commonly another foramen which opens into the nasal cavity. The posterior palatine and sphenopalatine foramina are situated further back and a little lower; the former is immediately below the latter. A horizontal plate extends from the inner surface, meets that of the opposite bone and completes the lamina transversalis spoken of in the description of the ethmoid bone. There is no palatine sinus.

The =pterygoid bones= are very wide and short. They form a considerable part of the lateral boundaries of the posterior nares. The lower and posterior holders are free and at their angle of junction there is a variable hamulus.

The =nasal bones= are (in most breeds) long and wider in front than behind. The external surface is variably concave in its length and is inclined toward the median suture so as to form a central groove. The inner borders turn downward and form an internal nasal crest which becomes very prominent behind. The posterior parts fit into a notch formed by the frontal bones. The anterior ends form an almost semicircular nasal notch.

The =lacrimal bone= is very small. The facial part extends very little or not at all beyond the orbital margin. The orbital surface is small and triangular, and presents the entrance to the lacrimal canal.

[Illustration:

FIG. 125.—MANDIBLE OF DOG, RIGHT-ANTERIOR VIEW.

_a_, Right ramus; _b_, left ramus; _c_, body; _d_, alveolar border; _e_, processus angularis; _f_, condyle; _g_, coronoid process; _h_, masseteric fossa; _i_, _k_, crests which form the upper and lower boundaries of fossa; _l_, mandibular foramen; _m_, mental foramina; _n_, masseteric line; _o_, sigmoid notch. (Ellenberger-Baum, Anat. d. Hundes.)]

The large zygomatic process constitutes the bulk of the =malar bone=. It is very long and is strongly curved. The upper border is convex, free in front, where it forms part of the orbital margin, beveled behind for articulation with the similar process of the

temporal bone. Between these it bears an eminence, the processus frontalis, to which the orbital ligament is attached. The body of the bone may be considered to consist of a =lacrimal process= directed upward and fitting in between the lacrimal and maxilla, and a =maxillary process= directed downward. The facial surface is convex.

The =superior turbinal bone= is in its anterior part a simple plate, attached by one edge to the nasal bone; it curves downward and inward, and its free border is thickened and everted. The posterior part is wider and resembles the ethmoturbinals, with which it is connected.

The =inferior turbinal bone= is short and very complex. It is attached to the nasal surface of the maxilla by a basal lamina, which divides into two secondary lamellæ. The latter detach numerous tertiary lamellæ, which are coiled and have thick free edges (Fig. 373).

The =vomer= is not in contact with the posterior part of the floor of the nasal cavity, and does not divide the posterior nares. The posterior end is narrow and deeply notched. Near the posterior nares the two plates curve outward and join the palate bones and assist in forming the lamina transversalis.

The two halves of the =mandible= do not fuse completely even in old age. The body presents six alveoli for the incisor teeth and two for the canines. The incisor alveoli increase in size from first to third. The canine alveoli extend deeply downward and backward. There are usually two or more foramina on the mental surface. The rami diverge less than in the pig. The inferior border of the horizontal part is convex in its length and is thick and rounded. The alveolar border slightly concave in its length and is a little everted, especially in its middle; it presents seven alveoli for the lower cheek teeth, which resemble those of the upper jaw except that the fourth and sixth are much smaller and the fifth is like the fourth of the upper series. The interalveolar space is very short or even absent. There are two or three mental foramina on either side. The vertical part is relatively small. Its external surface presents a deep =masseteric fossa= which encroaches on the coronoid process and is limited by ridges in front and below. The internal surface is convex and is marked by the usual foramen. At about the same level as the latter is the rough =angular process= (Processus angularis), which projects backward from the posterior border, and is equivalent to the angle of the other animals. The condyle is placed very low—not much higher than the apex of the canine tooth when the bone is resting on a flat surface. It is long transversely and the inner part of the articular surface is much the wider and extends over the posterior surface. Its long axis is a little oblique, the inner end being inclined somewhat downward and forward. The coronoid process is very extensive and is bent slightly outward and backward.

The body of the =hyoid bone= is a slightly curved transverse rod; it is compressed from before backward, and bears no lingual process. The thyroid cornua are permanently attached to the body by cartilage; they diverge widely, curve inward, and are compressed laterally. The small cornua are short, prismatic, and strong. The middle cornua are commonly a little longer than the great cornua; they are compressed laterally, and are slightly enlarged at the ends, which are joined by cartilage to the adjacent cornua. The great cornua are bent outward and are somewhat twisted.

THE SKULL AS A WHOLE

The different breeds of dog display great variations in the form and size of the skull. Those which have a long narrow skull (_e. g._, greyhound, collie) are designated =dolichocephalic=. Other dogs (_e. g._, bulldog, small spaniels, pugs) have very broad, short skulls and are termed =brachycephalic=. Intermediate forms (e. g., fox terrier, dachshund) are =mesaticephalic=.

The length is usually measured from the occipital crest to the anterior end of the premaxillary suture, and the breadth between the summits of the zygomatic arches. The cephalic index is the relation of the breadth to the length, assuming the latter equal 100; the formula is: (breadth × 100)/(length) = cephalic index. The index of extreme dolichocephalic breeds is about 50 or even less, as in the greyhound, and that of brachycephalic specimens may be as high as 90, as in the bulldog and pugs. Among the mesaticephalic types are the fox terrier, with an index of about 70, and the white Pomeranian, with one about 72 to 75. The cranio-facial index is the relation of the distance from the occipital crest to the fronto-nasal suture to that between the latter and the nasal notch. It varies from 10 ■ 3 in extreme brachycephalic breeds to 10 ■ 7 in extreme dolichocephalic subjects.

The =superior surface= shows the wide outward curve of the zygomatic arches, and the great extent of the temporal fossæ. The latter are separated by the sagittal crest, which in the larger breeds is very strong and prominent, and is continued by the diverging frontal ridges to the supraorbital processes. The frontal and nasal regions are centrally depressed, and are more or less concave in profile. The nasal region is narrow and is terminated in front by a nasal notch. In the extreme brachycephalic breeds the differences

are very striking. The cranium is strongly convex in both directions and is considerably longer than the face. The sagittal crest is more or less effaced and is formed by the interparietal only. The parieto-frontal crests are separated by an interval behind and diverge to the supraorbital processes, so that the temporal fossæ are widely separated. The frontal region is wide, strongly convex, and has a shallow central depression. The nasal region is very short, relatively wide, and centrally depressed. In profile there is a marked depression at the fronto-nasal junction, producing what is termed by fanciers the "stop" of the face.

On the =lateral surface= the great extent of the temporal fossa is seen. The orbit communicates freely with the fossa, the posterior part of the orbital margin being absent in the dry skull. The axis of the orbital cavity forms a much smaller angle with the median plane than in the horse and ox. A distinct crest marks the limit between the orbital cavity proper and the extensive pterygo-palatine fossa. The preorbital region is somewhat triangular, concave in its length, and convex from above downward. The infraorbital foramen is on its lower part above the third cheek tooth. In extreme brachycephalic breeds the orbit is relatively very large and the preorbital region extremely short but high. In the bulldog the lower jaw protrudes beyond the upper—a condition known as prognathism. The opposite condition, brachygnathism, is seen in the dachshund.

[Illustration:

FIG. 126.—SKULL OF BRACHYCEPHALIC DOG, DORSAL VIEW WITHOUT MANDIBLE.]

Striking features on the =basal surface= of the cranium are the width and flatness of the basioccipital, the small size of the paramastoid processes, the large size and rounded shape of the bulla ossea, and the grooved form of the articular surfaces for the mandible. The posterior nares are long and narrow and are not divided by the vomer. The hard palate is usually about half the length of the skull. It is commonly marked by a median crest or rough line, and on each side are the anterior and accessory palatine foramina and the palatine grooves. The width is greatest between the fourth pair of cheek teeth, and here there is in most skulls a pronounced depression on either side. The length, width, and contour vary greatly in different breeds.

The angle of divergence of the rami of the mandible varies from 25 to 30 degrees; it is smallest in the greyhound, largest in extreme brachycephalic types, _e. g._, bulldog, pug.

The =posterior= or =nuchal surface= is somewhat triangular, with the base below. The summit is formed by the occipital crest, which projects very strongly backward in the large breeds. Below it there are two very distinct rough imprints for muscular attachment. In some skulls there is a thin median crest, in others a rounded elevation. Laterally are the temporal crests and the mastoid processes. There is usually a foramen in the temporo-occipital suture above the root of the paramastoid process. The foramen magnum varies greatly in form; most often the transverse diameter is the greater, but in some skulls it is equaled or exceeded by the vertical diameter.

The =cranial cavity= (Fig. 124) corresponds in form and size with the cranium, specially in those breeds in which the various crests are more or less effaced and the frontal sinuses are small. The basi-cranial axis is almost parallel with the palate, and the floor is flattened. The anterior fossa is narrow and is only slightly higher than the middle one. The olfactory fossæ are very deep and the crista galli is little developed. The sella turcica is variable in depth, and the dorsum sellæ is relatively high and bears clinoid processes laterally. The cerebral and cerebellar compartments are well marked off laterally by the petrosal crests and above by the tentorium osseum. The base of the latter is traversed by a canal which connects the two parieto-temporal canals. The anterior angle of the petrous temporal is perforated by a canal for the fifth cranial nerve.

[Illustration:

FIG. 127.—SKULL OF BRACHYCEPHALIC DOG, LATERAL VIEW WITHOUT MANDIBLE.]

The =nasal cavity= (Fig. 373) conforms to the shape of the face. Its anterior aperture is large and nearly circular in most dogs. The complex inferior turbinals occupy the anterior part of the cavity to a large extent, except near the aperture. Behind the inferior turbinals is the large opening of the maxillary sinus. Behind this the cavity is divided by a horizontal plate (Lamina transversalis) into a large upper olfactory region or fundus nasi and a lower naso-pharyngeal canal. The fundus is occupied largely by the ethmoturbinals. The posterior nares are undivided and are in general long and narrow, but vary with the shape of the skull.

The =frontal sinus= is of considerable size in the large breeds, but is confined to the frontal bone. It is usually divided into a small anterior and a much larger posterior compartment, each of which opens into the superior ethmoidal meatus. The sinus is very small in extreme brachycephalic types.

The =maxillary sinus= is small, and is in such free communication with the nasal cavity as to make it rather a recess than a true sinus. It is bounded internally by the lamina papyracea of the ethmoid, and its outer wall is crossed obliquely by the lacrimal canal. The roots of the molar teeth do not project up into it.

BONES OF THORACIC LIMB

The =clavicle= is a small, thin, irregularly-triangular bony or cartilaginous plate. It is embedded in the mastoido-humeralis muscle in front of the shoulder joint and forms no articulation with the rest of the skeleton. (It is nearly an inch long in a large cat and is a slender curved rod.)

[Illustration:

FIG. 128.—RIGHT SCAPULA OF DOG, EXTERNAL VIEW.

_a_. Supraspinous fossa; _b_, infraspinous fossa; _c_, spine; _d_, upper broad end of spine; _e_, acromion; _f_, glenoid cavity; _g_, tuberosity; _h_, vertebral border; _i_, posterior angle; _k_, scapular notch. (Ellenberger-Baum, Anat. d. Hundes.)]

[Illustration:

FIG. 129.—LEFT SCAPULA OF DOG, COSTAL SURFACE.

_a_, Subscapular fossa; _b_, _b_, _b_, muscular lines; _c_, _c_, limiting line between subscapular fossa and serratus area; _d_, glenoid cavity; _e_, _f_, tuberosity; _g_, nutrient foramen. (Ellenberger-Baum, Anat. d. Hundes.)]

The =scapula= is relatively long and narrow. The spine increases gradually in height from above downward and divides the external surface into two nearly equal fossæ. Its free edge is thick and rough above, and at the lower part is thin and bent backward. The =acromion= is short and blunt and is opposite the rim of the glenoid cavity. The subscapular fossa is very shallow and is marked by rough lines. The rough area above it for the attachment of the serratus magnus is large and quadrilateral in front, narrow and marginal behind. The anterior border is thin, strongly convex, and sinuous. The posterior border is straight and thick. The vertebral border is convex and thick and bears a band of cartilage. The cervical angle is rounded. The dorsal angle is thick and square. The neck is well defined and bears a rough eminence posteriorly. The glenoid cavity is continued forward upon the lower face of the scapular tuberosity, which is blunt and bears no distinct coracoid process. There is a rough eminence on the posterior surface of the neck, from which the long head of the triceps arises. The cervical angle is opposite the first thoracic spine, the dorsal angle lies above the vertebral end of the fourth rib, and the articular angle at a point just in front of the sternal end of the first rib in the ordinary standing position. The shoulder has a great range of movement on the chest-wall.

The =humerus= is relatively very long, rather slender, and has a slight spiral twist. The shaft is somewhat compressed laterally, especially in its upper two-thirds; this part is curved in varying degree, convex in front. The deltoid tuberosity has the form of a low ridge, and it is continued by a crest which runs upward and backward and bears a tubercle on its upper part. Another line runs from it down the anterior aspect and forms the inner boundary of the very shallow musculo-spiral groove. The nutrient foramen is about in the middle of the posterior surface. A slight elevation on the proximal third of the inner surface represents the teres tubercle. The head is long and strongly curved from before backward. The neck is better marked than in the horse. The undivided external tuberosity is placed well forward and extends little above the level of the head. The internal tuberosity is small. The bicipital groove is undivided and is displaced to the inner side by the extension forward of the external tuberosity. The distal end bears an oblique trochlear articular surface for articulation with the radius and ulna, the outer part of which is the more extensive and is faintly grooved. The epicondyles are prominent. The coronoid and olecranon fossæ often communicate through a large =supratrochlear foramen=.

[Illustration:

FIG. 130.—LEFT HUMERUS OF DOG, EXTERNAL VIEW.

_a_, Head; _b_, neck; _c_, crest; _d_, external tuberosity; _e_, mark for insertion of infraspinatus tendon; _f_, external condyle; _g_, external condyloid crest; _h_, coronoid fossa; _i_, olecranon fossa. (Ellenberger-Baum, Anat. d. Hundes.)]

[Illustration:

FIG. 131.—LEFT RADIUS AND ULNA OF DOG, ANTERO-EXTERNAL VIEW.

_A_, Radius; _B_, ulna; _a_, groove for tendon of extensor carpi radialis: _b_, groove for common extensor tendon; _c_, proximal articular surface of radius; _d_, olecranon; _e_, beak (proc. anconeus) of ulna; _f_, semilunar notch; _g_, coronoid process; _h_, facet for radius; _i_, groove for lateral extensor tendon; _k_, groove for tendon of extensor carpi obliquus. (Ellenberger-Baum, Anat. d. Hundes.)]

The two bones of the forearm are relatively long and articulate with each other at either end in such a manner as to allow of slight movement. A narrow interosseous space separates their shafts. The =radius= is flattened from before backward and increases in size from above downward. The shaft forms two curves; one of these, an anterior convexity, involves the whole shaft; the other, an inner convexity, affects the upper part. The anterior surface is convex in both directions and is marked by a groove for the oblique extensor of the carpus. The posterior surface presents the nutrient foramen in its upper third, and bears a rough line (Crista interossea) externally for the attachment of the interosseous ligament. The proximal end (Capitulum radii) is relatively small and is supported by a distinct neck (Collum radii). It bears a concave surface (Fovea capituli) above for articulation with the humerus, and a convex marginal area (Circumferentia articularis) behind for the ulna. The bicipital tuberosity is small. There is a large external tuberosity and below this a rough eminence. The distal extremity is much wider. It has an extensive concave carpal articular surface. Its inner border projects downward, forming the =styloid process= of the radius. Externally there is a concave facet (Incisura ulnaris radii) for the ulna. In front are three distinct grooves for the extensor tendons. The =ulna= is well developed, but diminishes in size from above downward. It crosses the posterior surface of the radius from within outward. The shaft is large and three-sided in its upper two-thirds, smaller and more rounded below. Its anterior surface is in general rough. The nutrient foramen is near the proximal end. A vascular groove descends from it and indicates the course of the interosseous artery. The proximal end is relatively short. It is concave and smooth internally, convex and rough externally. The olecranon is grooved and bears three prominences, of which the posterior one is large and rounded. The semilunar notch is wide below and completes the surface for articulation with the trochlea of the humerus. Below it is a concave surface (Incisura radialis) which articulates with the back of the head of the radius, and below this is a fossa, which receives a tuberosity of the radius. The distal end (Capitulum ulnæ) is small and is produced to a blunt point (Processus styloideus ulnæ). It articulates with the ulnar carpal below, and has a convex facet on its antero-internal aspect for the radius.

[Illustration:

FIG. 132.—SKELETON OF DISTAL PART OF THORACIC LIMB OF DOG, EXTERNAL VIEW.

_4_, Radial + intermediate carpal bone; _5_, ulnar carpal; _6_, accessory carpal; _7_, second carpal; _8_, third carpal; _9_, fourth carpal; _10–14_, first to fifth metacarpals; _15_, first phalanx; _16_, second phalanx; _17_, third phalanx. (After Leisering's Atlas.)]

The =carpus= comprises seven bones, three in the proximal row and four in the distal. The numerical reduction in the upper row is apparently due to the fusion of the radial and intermediate, constituting a large bone which articulates with almost all of the distal surface of the radius and with the bones of the lower row. It projects prominently on the posterior surface of the carpus. The ulnar carpal is long; it articulates with the radius and ulna above and the accessory behind; below it rests on the fourth carpal and is prolonged downward to articulate with the fifth metacarpal also. The accessory is cylindrical, constricted in its middle and enlarged at each end; the anterior extremity articulates with the ulna and ulnar carpal bone. The first carpal is the smallest bone of the lower row; it articulates with the second carpal externally and the first metacarpal distally. The second carpal is wedge-shaped, the base being posterior; its upper surface is convex, and its lower is concave and rests on the second metacarpal. The third carpal is somewhat like the second; its lower surface is concave and articulates chiefly with the third metacarpal. The fourth carpal is the largest of the row; it articulates with the fourth and fifth metacarpals below. Two small bones or cartilages may be found at the junction of the two rows behind, and a third small bone articulates with the inner side of the radiointermediate.[27]

Five =metacarpal bones= are present. The first is much the shortest; the third and fourth are the longest, and are about one-fifth longer than the second and fifth. The fifth is the widest at the proximal end and is slightly shorter than the second. They are close together above, but diverge somewhat below; the first is separated from the second by a considerable interosseous space. They are so arranged as to form a convex dorsal surface, and a concave volar surface, which corresponds to the hollow of the palm of the hand in man. Each consists of a shaft and two extremities. The shaft is compressed from before backward. In the third and fourth it is almost four-sided, in the second and fifth three-sided, in the first rounded. The proximal ends (Bases) articulate with each other and with the corresponding carpal bones. The carpal articular surface formed by them is concave from side to side, convex from before backward. The distal ends (Capitula) have articular surfaces of the nature of a head, but bear a sagittal ridge behind, except the first, which is grooved.

[Illustration:]

FIG. 133.—SECOND AND THIRD PHALANGES OF DOG.

_a_, Wing of third phalanx; _b_, coronary ridge; _c_, foramen for digital artery; _d_, ungual surface of third phalanx; _e_, second phalanx; _f_, first phalanx; _g_, elastic dorsal ligaments. (From Leisering's Atlas.)]

The five =digits= have three phalanges each, except the first, which has two. The third and fourth digits are the longest; the first is very short and does not come in contact with the ground in walking. The =first phalanges= of the chief digits have four-sided shafts, which are slightly curved forward. The proximal end of each has a concave surface for articulation with the metacarpal bone and is deeply notched behind. The distal end has a trochlea for articulation with the second phalanx, and lateral depressions for ligamentous attachment. The =second phalanges= are about two-thirds of the length of the first phalanges. The proximal articular surface consists of two cavities separated by a sagittal ridge. The distal extremity is wider and flatter than that of the first. The =third phalanges= correspond in general to the form of the claws. The base has an articular surface adapted to the second phalanx and is encircled by a collar of bone. The volar surface bears a wing or tuberosity, and on either side of this is a foramen. The ungual part is a curved rod with a blunt-pointed free end. It is rough and porous. Its base forms with the collar previously mentioned a deep groove, into which the proximal border of the claw is received. The two phalanges of the first digit resemble in arrangement the first and third phalanges of the other digits.

Nine =volar sesamoids= are usually present. Two are found at each metacarpo-phalangeal joint of the chief digits. They are high and narrow, articulate with the distal end of the metacarpal bone in front, and have a small facet on the base for the first phalanx. On this joint of the first digit there is usually a single flattened sesamoid, but exceptionally two are present. The distal volar sesamoids remain cartilaginous. A nodular =dorsal sesamoid= occurs in the anterior part of the capsule of the metacarpo-phalangeal joints, and cartilaginous nodules are found in a similar position in connection with the joints between the first and second phalanges.

BONES OF THE PELVIC LIMB

The =ilium= is nearly parallel with the median plane and its axis is only slightly oblique with regard to the horizontal plane. The gluteal surface is concave. The iliac surface is almost flat. The auricular surface faces almost directly inward, and in front of it there is an extensive rough area. The ilio-pectineal line is very distinct and is uninterrupted. The anterior border or crest is strongly convex, thick, and rough. The internal angle is represented by a thickened part which bears two eminences, homologous with the posterior superior and posterior inferior iliac spines of man. The external angle also has two prominences, which are equivalent to the two anterior spines present in man. The shaft is almost sagittal and is compressed laterally. Above it is smooth and rounded, and below it bears a crest externally which terminates at a tuberosity in front of the acetabulum.

The =ischium= has a twisted appearance owing to the fact that its acetabular part is nearly sagittal while the posterior part is almost horizontal. The two bones also diverge behind and the tubera are flattened and everted. The superior ischiatic spine is low and thick; its posterior part is marked by transverse grooves and has a prominent outer lip. There is no lesser sciatic notch. The ischial arch is relatively small and is semi-elliptical.

[Illustration:]

FIG. 134.—OSSA COXARUM OF DOG, LEFT POSTERIOR VIEW.

_a_. Crest; _b_, _c_, internal angle; _d_, great sciatic notch; _e_, _f_, external angle; _g_, posterior gluteal line; _h_, gluteal fossa of wing; _i_, shaft of ilium; _k_, anterior gluteal line; _l_, auricular surface; _m_, ilio-pectineal line; _n_, depression for origin of rectus femoris; _o_, acetabulum; _p_, acetabular, and _q_, symphyseal branch of pubis; _r_, psoas tubercle; _s_, obturator foramen; _s′_, obturator notch; _t_, line for origin of coccygeus; _u_, superior ischiatic spine; _v_, external border of ischium; _w_, tuber ischii; _x_, ischial arch. (Ellenberger-Baum, Anat. d. Hundes.)]

[Illustration:]

FIG. 135.—LEFT FEMUR OF DOG, ANTERIOR VIEW.

_a_, Head; _b_, neck; _c_, trochanter major; _d_, trochanter minor; _e_, rudimentary trochanter tertius; _f_, rough line; _g_, trochlea; _h_, _i_, condyles; _k_, suprapatellar fossa. (Ellenberger-Baum, Anat. d. Hundes.)]

[Illustration:

FIG. 136.—LEFT TIBIA AND FIBULA OF DOG, ANTERO-EXTERNAL VIEW.

_A_, Tibia; _B_, fibula; _a_, external condyle of tibia; _b_, spine; _c_, crest of tibia; _d_, muscular notch; _e_, internal malleolus; _f_, head of fibula; _g_, interosseous space; _h_, external malleolus (distal end of fibula); _i_, groove for tendon. (Ellenberger-Baum, Anat. d. Hundes.)]

The symphyseal part of the =pubis= is thick and fuses late with the opposite bone. There is no subpubic groove.

The =acetabulum= is about twice as far from the external angle of the ilium as from the tuber ischii. The fossa acetabuli is deep, and is bounded internally by a flat plate of bone; its floor is so thin as to be translucent. There is a small notch behind.

The =obturator foramen= resembles in outline an equilateral triangle with the angles rounded off.

[Illustration:

FIG. 137.—SKELETON OF DISTAL PART OF PELVIC LIMB OF DOG, EXTERNAL VIEW.

_6_, Tibial tarsal bone; _7_, fibular tarsal; _8_, central tarsal; _9_, second tarsal; _10_, third tarsal; _11_, fourth tarsal; _12_, metatarsal bones; _13_, first phalanx. The first tarsal bone is not visible in the figure. (After Leisering's Atlas.)]

The inlet of the =pelvis= is very oblique. It is almost circular in the female, but in the male it is elliptical and the conjugate diameter is the longer. The cavity is narrowest between the acetabula, and very wide behind. The floor is concave and relatively narrow in front, wide and flat behind.

The =femur= is relatively much longer than in the horse or ox. The shaft is regularly cylindrical, except near the extremities, where it is wider and compressed from before backward. It is strongly curved in its lower two-thirds, convex in front. The posterior surface is flattened transversely, narrow in the middle, and widens toward each end. It is bounded by two rough lines (Labium laterale, mediale) which diverge toward the extremities. The third trochanter and the plantar (supracondyloid) fossa are absent. There are two supracondyloid crests, the inner one being small. The nutrient foramen is in the upper third of the posterior surface. The head is a little more than a hemisphere and has a shallow depression behind and external to its center. The neck is well defined. The trochanter major does not extend as high as the head; a thick ridge runs from its anterior surface to the neck. The internal trochanter has the form of a blunt tuberosity. The trochanteric fossa is round and deep. The ridges of the trochlea are practically sagittal in direction and are almost similar. The intercondyloid fossa is wide. Just above each condyle posteriorly there is a facet for articulation with the sesamoid (of Vesal), which is developed in the origin of the gastrocnemius muscle.

The =tibia= is about the same length as the femur. The shaft forms a double curve; the upper part is convex internally, the lower part externally. The proximal third is prismatic, but is compressed laterally and is long from before backward. The remainder is almost regularly cylindrical. The crest is short but very prominent. The nutrient foramen is usually in the upper third of the external border. The tuberosity is not grooved, but bears a distinct mark where the ligamentum patellæ is attached. There is a small facet for the fibula on the postero-external part of the external condyle, and a small sesamoid bone in the tendon of origin of the popliteus is in contact with the posterior angle of the latter. The distal end is quadrangular and relatively small. The articular grooves and ridge are almost sagittal. There is a facet externally for articulation with the fibula. There is a vertical groove internally and a shallower one behind—both for tendons.

The =fibula= extends the entire length of the region. It is slender, somewhat twisted, and enlarged at either end. The upper part of the shaft is separated from the tibia by a considerable interosseous space, but the lower part is flattened and closely applied to the tibia. The proximal end is flattened and articulates with the external condyle of the tibia. The distal end is somewhat thicker and forms the external malleolus. It articulates internally with the tibia and the tibial tarsal bone. Externally it bears two tubercles.

The =patella= is long and narrow. The anterior surface is convex in both directions. The articular surface is convex from side to side and slightly concave from above downward.

The =tarsus= comprises seven bones. The tibial tarsal consists of a body, neck, and head, like the bone in man. The body presents a trochlea above for articulation with the tibia and fibula. The posterior surface has three facets for articulation with the fibular tarsal bone. The head is directed a little inward and articulates with the central. The fibular tarsal has a long anterior process or "beak,"

but the inner process (sustentaculum) is short. The tuber calcis is grooved from before backward. The central has a concave proximal surface adapted to the head of the tibial tarsal. Its distal surface articulates with the first, second, and third tarsals. It bears two tubercles posteriorly. The first tarsal is flattened and irregularly quadrangular; it articulates above with the central and below with the first metatarsal. The second tarsal is the smallest and is wedge-shaped; it articulates below with the second metatarsal bone. The third tarsal is also wedge-shaped, the base being in front; it articulates with the third metatarsal below. The fourth tarsal is remarkably high, and resembles a quadrangular prism; it articulates with the fibular tarsal above, the fourth and fifth metatarsal below, and the central and third tarsal bones internally. A groove for the tendon of the peroneus longus crosses its outer and posterior surface, and above it are one or two tubercles.

Five =metatarsal bones= are present. The first is commonly very small and has the form of a blunt cone, somewhat compressed laterally. It articulates with the first tarsal and furnishes insertion to the tibialis anterior muscle. In some cases it fuses with the first tarsal; when the first digit is well developed, its metatarsal may resemble the others (except in size) or be reduced in its proximal part to a fibrous band. The other metatarsals are a little longer than the corresponding metacarpals. Their proximal ends are elongated from before backward and have posterior projections, which in the case of the third and fourth usually bear facets for articulation with two small rounded sesamoid bones. In other respects they resemble the metacarpals.

The first digit is often absent. When present, its development varies and it contains one or two phalanges. In other cases the digit is double. The phalanges of the other digits resemble those of the fore limb.

ARTHROLOGY

THE ARTICULATIONS OR JOINTS

An =articulation= or =joint= is formed by the union of two or more bones or cartilages by other tissue. Bone is the fundamental part of most joints; in some cases a bone and a cartilage, or two cartilages, form a joint. The uniting medium is chiefly fibrous tissue or cartilage, or a mixture of these. Union of parts of the skeleton by muscles (Synsarcosis), as in the attachment of the thoracic limb in the horse, will not be considered in this section.

Joints may be classified—(_a_) anatomically, according to their mode of development, the nature of the uniting media, and the form of the joint surfaces; (_b_) physiologically, with regard to the amount and kind of movement or the absence of mobility in them; (_c_) by a combination of the foregoing considerations.

The classification of joints is still in a very unsatisfactory state, and, unfortunately, the same term is used in various senses by different authors. The two main subdivisions proposed by Hepburn are: (1) Those in which the uniting medium is coextensive with the opposed joint surfaces, and in which a direct union of these surfaces is thereby effected. (2) Those in which the uniting medium has undergone interruption in its structural continuity, and in which a cavity of greater or less extent is thus formed in the interior of the joint. This distinction is of considerable importance clinically.

Three chief subdivisions of joints are usually recognized—viz., =synarthroses=, =diarthroses=, and =amphiarthroses=.

SYNARTHROSES

In this group the segments are united by fibrous tissue or cartilage, or a mixture of the two in such a manner as practically to preclude movement; hence they are often termed fixed or immovable joints. There is no joint cavity. Many of these joints are temporary, the uniting medium being invaded by the process of ossification, with a resulting ankylosis or synostosis. The chief classes in this group of joints are as follows:

(1) =Suture.=—This term (Sutura) is applied to those joints in the skull in which the adjacent bones are closely united by fibrous tissue—the sutural ligament. In many cases the edges of the bones have irregular interlocking margins, forming the =sutura serrata=, _e. g._, the frontal suture. In others the edges are beveled and overlap, forming the =sutura squamosa=, _e. g._, the parieto-temporal suture. If the edges are plane or slightly roughened, the term =sutura harmonia= is applied to the joint, _e. g._, the nasal suture.

(2) =Synchondrosis.=—In these the two bones are united by cartilage, _e. g._, the joint between the basioccipital and the sphenoid bone. Very few of these joints are permanent.

(3) =Symphysis.=—This term is usually limited to a few median joints which connect symmetrical parts of the skeleton, _e. g._, symphysis pelvis, symphysis mandibulæ. The uniting media are cartilage and fibrous tissue. In some cases a cleft-like rudimentary joint cavity occurs.

(4) =Gomphosis.=—This term is applied to the implantation of the teeth in the alveoli.

DIARTHROSES

These joints are characterized by the presence of a joint cavity and by their mobility. They are often called movable or true joints. The structures which enter into their formation are:

1. The =joint surfaces= (Facies articulares), which are usually more or less expanded. They are in most cases smooth, and vary much in form. They are formed of specially dense bone, which differs histologically from ordinary compact substance. In certain cases (_vide_ Osteology) the surface is interrupted by non-articular cavities known as =synovial fossæ=.

2. The =articular cartilages= (Cartilagines articulares), usually hyaline in type, form a covering over the articular surfaces of the bones. They vary in thickness in different joints; they are thickest on the areas of the greatest pressure, and usually tend to accentuate the curvature of the bone, _i. e._, on a concave surface the peripheral part is the thickest, while on a convex surface the central part is the thickest. The articular cartilages are non-vascular, very smooth, and have a bluish tinge in the fresh state. They diminish the effects of concussion and greatly reduce friction.

[Illustration:

FIG. 138.—DIAGRAM OF SECTION OF DIARTHROSIS.

_f.l._, Fibrous layer, _s.l._, synovial layer of joint capsule. The articular cartilages are white, bones dotted, and the joint cavity black in the figure.]

3. The =joint capsule= (Capsula articularis) is, in its simplest form, a sac, the margins of which are attached around the articulating surfaces. It consists of two layers—an external one, composed of fibrous tissue (Stratum fibrosum), and an internal one, the synovial layer or membrane (Stratum synoviale). The =fibrous layer=, sometimes termed the capsular ligament, is attached either close to the margins of the articular surfaces or at a variable distance from them. Its thickness varies greatly in different situations: in certain places it is extremely thick, and sometimes cartilage or bone develops in it; in other places it is practically absent, the capsule then consisting only of the synovial membrane. Parts of the capsule may undergo thickening and so form ligaments, which are not separable, except artificially, from the rest of the capsule. The =synovial layer= lines the joint cavity except where this is bounded by the articular cartilages; it stops normally at the margin of the latter. It is a thin membrane, and is richly supplied by close networks of vessels and nerves. It frequently forms =folds= (Plicæ synoviales) and =villi= (Villi synoviales), which project into the cavity of the joint. The folds commonly contain pads of fat which fill up interstices and vary in form and position in various phases of movement. The synovial membrane secretes a fluid, the =synovia=, which resembles white-of-egg and lubricates the joint.[28] In many places the membrane forms extra-articular pouches, which facilitate the play of muscles and tendons.

The =joint cavity= (Cavum articulare) is inclosed by the synovial membrane and the articular cartilages. Normally, it is, strictly speaking, only a potential cavity, which contains nothing but a small amount of synovia.

The student must guard against a false conception of the joint cavity which may result from dissections and diagrams, in which an actual cavity of considerable extent appears to exist. A correct idea of the intimate apposition of the parts is best obtained from the study of frozen sections. It is also instructive to examine joints which have been injected so as to distend the capsule fully. It is then seen that the cavity is often of much greater potential extent than one might suppose, and that the capsule is often very irregular in form, _i. e._, forms a variety of sacculations.

The foregoing are constant and necessary features in all diarthroses. Other structures which enter into the formation of these joints are ligaments, articular discs or menisci, and marginal cartilages.

4. =Ligaments.=—These are strong bands or membranes, usually composed of white, fibrous tissue, which bind the bones together. They are pliable, but practically inelastic. In a few cases, however, _e. g._, ligamenta flava, ligamentum nuchæ, they are composed of elastic tissue. They may be subdivided, according to position, into =periarticular= and =intraarticular=. Periarticular ligaments are frequently blended with or form part of the fibrous capsule; in other cases they are quite distinct. Strictly speaking,

intraarticular ligaments, though within the fibrous capsule, are not in the joint cavity; the synovial membrane is reflected over them. The term seems justifiable, however, on practical grounds. Ligaments which connect directly opposed surfaces of bones are termed interosseous. The special names are based usually on their position, form, and attachments, _e. g._, lateral or collateral, cruciate, sacro-iliac, etc. In many places muscles, tendons, and thickenings of the fasciæ function as ligaments and increase the security of the joint. Atmospheric pressure and cohesion play a considerable part in keeping the joint surfaces in apposition.

5. =Articular discs= or =menisci= are plates of fibro-cartilage or dense fibrous tissue placed between the articular cartilages, and divide the joint cavity partially or completely into two compartments. They render certain surfaces congruent, _e. g._, femoro-tibial joint, allow greater range or variety of movement, and diminish concussion.

6. A =marginal cartilage= (Labrum glenoidale) is a ring of fibro-cartilage which encircles the rim of an articular cavity. It enlarges the cavity and tends to prevent fracture of the margin.

=Vessels and Nerves.=—The =arteries= form anastomoses around the larger joints, and give off branches to the extremities of the bones and to the joint capsule. The synovial membrane has a close-meshed network of capillaries; the latter form loops around the margins of the articular cartilages, but do not usually enter them. The =veins= form plexuses. The synovial membrane is also well supplied with lymphatics. Nerve-fibers are especially numerous in and around the synovial membrane and there are special nerve-endings, _e. g._, Pacinian bodies and the articular end-bulbs described by Krause.

=Movements.=—The movements of a joint are determined chiefly by the form and extent of the joint surfaces and the arrangement of the ligaments. They are usually classified as follows:

1. =Gliding.=—This refers to the sliding of one practically plane surface on another, as in the joints between the articular processes of the cervical vertebræ.

2. =Angular Movements.=—In these cases there is movement around one or more axes. Motion which diminishes the angle included by the segments forming the joint is termed =flexion=, while that which tends to bring the segments into line with each other is called =extension=.

With reference to the joints of the lower parts of the limbs, it seems advisable to employ the terms =dorsal= and volar or =plantar flexion=, since these joints can be “overextended.” Similarly, the terms =dorsal= and =ventral flexion= should be applied to the corresponding movements of the spinal column. The meaning of the term =lateral flexion= is evident. These movements are all rotations around axes which are approximately either transverse or vertical. Depression, elevation, and lateral movement of the lower jaw fall in this category.

3. =Circumduction.=—This designates movements in which the distal part of the limb describes a circle or a segment of one. In man such movement is easily performed, but in quadrupeds it is possible to a limited degree only, and is to be regarded usually as an indication of disease.

4. =Rotation.=—As a matter of convenience, this term is reserved to indicate rotation of one segment around the longitudinal axis of the other segment forming the joint. It is seen typically in the atlanto-axial joint.

5. =Adduction= and =abduction= designate respectively movement of a limb toward and away from the median plane, or of a digit toward and away from the axis of the limb.

=Classification.=—This is based on the form of the joint surfaces and the movements which occur. The following chief classes may be recognized:

1. =Arthrodia=, or gliding joint. In these the surfaces are practically flat, admitting of gliding movement. Examples: carpo-metacarpal joints; joints between the articular processes of the cervical and thoracic vertebræ.

2. =Ginglymus=, or hinge-joint. In this class the joint surfaces consist usually of two condyles, or of a segment of a cylinder or cone, which are received by corresponding cavities. In typical cases the movements are flexion and extension, _i. e._, around a single transverse axis. Examples: occipito-atlantal and elbow joints.

3. =Trochoid=, or pivot joint. In these the movement is limited to rotation of one segment around the longitudinal axis of the other. Example: atlanto-axial joint.

4. =Enarthrosis=, or ball-and-socket joint. These are formed by a surface of approximately spherical curvature, received into a corresponding cavity. They are multiaxial, and allow of the greatest variety of movement, _e. g._, flexion, extension, rotation, abduction, adduction, circumduction. Examples: hip and shoulder joints.[29]

AMPHIARTHROSES

These joints, as the name indicates, share some characters with both of the preceding groups. In them the segments are directly united by a plate of fibro-cartilage, and usually by ligaments also. The amount and kind of movement are determined by the shape of the joint surfaces and the amount and pliability of the uniting medium.[30] These joints are all medial in position, and are best illustrated by the joints between the bodies of the vertebræ. There is usually no joint cavity, but in certain situations a rudimentary one exists.

THE ARTICULATIONS OF THE HORSE

JOINTS AND LIGAMENTS OF THE VERTEBRÆ

The movable vertebræ form two sets of articulations, viz., those formed by the bodies, and those formed by the articular processes of adjacent vertebræ; the former are termed =intercentral=, and the latter, =interneural=. Associated with these are ligaments uniting the arches and processes; some of these are =special=, _i. e._, confined to a single joint, while others are =common=, _i. e._, extend along the entire vertebral column or a considerable part of it. The joints between the atlas and axis and between the former and the skull require separate consideration.

INTERCENTRAL ARTICULATIONS

These are =amphiarthroses=, formed by the junction of the extremities of the bodies of adjacent vertebræ. The =articular surfaces= in the cervical region consist of a cavity on the posterior end of the body of the anterior vertebra, and a corresponding convexity or head of the succeeding vertebra. In the other regions the surfaces are much flattened. The uniting media are:

1. The =intervertebralfibro-cartilages= (Fibrocartilagines intervertebrales). Each of these is a disc which fits into the space between the bodies of two adjacent vertebræ, to which it is intimately attached. The discs are thinnest in the middle of the thoracic region, thicker in the cervical and lumbar regions, and thickest in the coccygeal region. Each consists of a dense fibrous peripheral part (Annulus fibrosus), and a soft pulpy central part (Nucleus pulposus).

[Illustration:

FIG. 139.—SAGITTAL SECTION OF LAST TWO THORACIC AND FIRST LUMBAR VERTEBRÆ, SHOWING LIGAMENTS AND SPINAL CORD (MEDULLA). (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The fibrous ring consists of laminæ of fibrous tissue and fibro-cartilage, which pass obliquely between the two vertebræ and alternate in direction, forming an X-shaped arrangement. The central part of the ring is largely cartilaginous, and gradually assumes the character of the pulpy center. The latter is very elastic and is compressed, so that it bulges considerably from the surface of sections; it consists of white and elastic fibers, connective-tissue cells, and peculiar clear, transparent cells of various sizes. It is a remnant of the notochord. There are joint cavities in the cervical intercentral joints, and in those between the last cervical and the first thoracic, and between the last lumbar and the sacrum. In the latter the cavity is coextensive with the extremities of the bodies; in the former, it is usually not so extensive.

2. The =inferior common ligament= (Ligamentum longitudinale ventrale) lies on the ventral surface of the bodies of the vertebræ and the intervertebral fibro-cartilages, to which it is firmly attached. It begins about the fourteenth or fifteenth thoracic vertebra, and is at first a narrow, thin band. Further back it becomes gradually thicker and wider, and terminates on the pelvic surface of the sacrum by spreading out and blending with the periosteum. It is strongest in the lumbar region, where the tendons of the crura of the diaphragm fuse with it.

3. The =superior common ligament= (Ligamentum longitudinale dorsale) lies on the floor of the vertebral canal from the dens or odontoid process to the sacrum. It is narrow over the middles of the vertebral bodies, and widens over the intervertebral fibro-cartilages, to which it is very firmly attached.

This ligament is in relation with the spinal veins on either side, and in the middle of each vertebra a transverse anastomotic branch passes under the ligament.

INTERNEURAL ARTICULATIONS

Each typical vertebra presents two pairs of articular processes, which form diarthroses with the two adjacent vertebræ. The =articular surfaces= are extensive, flat, and oval in the cervical region, small and flat in the thoracic region, while in the lumbar region the anterior ones are concave and the posterior convex. The joint capsule is strong and ample in the cervical region, in conformity with the large size and greater mobility of these joints in the neck. In the thoracic and lumbar regions the capsule is small and close. These joints are arthrodia.

Associated with these joints are the =ligamenta flava=, which connect the arches of adjacent vertebræ. They are membranous and consist largely of elastic tissue.

[Illustration:

FIG. 140.—LIGAMENTUM NUCHÆ OF HORSE.

_1_, Scapula; _1′_, cartilage of scapula; _4_, lamellar part of ligamentum nuchæ; _x_, wing of atlas. (After Ellenberger-Baum, Anat. für Künstler.)]

The =supraspinous ligament= extends medially from the occipital bone to the sacrum. From the withers backward it consists of a strong cord of fibrous tissue, attached to the summits of the vertebral spines. In the neck and withers it is remarkably modified to form the ligamentum nuchæ, which requires more extended notice.

The =ligamentum nuchæ= is a powerful elastic apparatus, the principal function of which is to assist the extensor muscles of the head and neck. It extends from the occipital bone to the withers, where it is directly continuous with the supraspinous ligament. It consists of two parts—funicular and lamellar. The =funicular part= (Pars occipitalis) arises from the external occipital protuberance and the fossa below it, and is inserted into the summits of the vertebral spines at the withers. Two =bursæ= are usually found under it in the adult. The =supra-atloid bursa= lies between the ligament and the dorsal arch of the atlas. The =supraspinous bursa= occurs usually over the fourth thoracic spine, but may be over the third and may extend to the fifth.[31] In the neck the funicular part consists for the greater part of two bands closely applied and attached to each other. Near and at the withers it broadens greatly, forming an expansion three to five inches (ca. 8 to 12.5 cm.) in width, the lateral margins of which are thin and overlie the trapezius and rhomboideus muscles. Behind the higher spines it becomes narrower and thinner, and is continued by the white fibrous lumbo-dorsal ligament.[32] A mass of fat and elastic tissue lies upon the ligament as far back as the withers. It varies greatly in amount in different subjects, and is most developed in stallions of draft breeds, in which it forms the basis of the “crest.” The =lamellar portion= (Pars cervicalis) consists of two laminæ separated medially by a layer of loose connective tissue. Each lamina is formed of digitations which arise from the second and third thoracic spines and from the funicular portion, are directed downward and forward, and end on the spines of the cervical vertebræ, except the first and last. The digitation which is attached to the spine of the axis is very thick and strong. Behind this they diminish in size and strength; that to the sixth cervical is quite thin and feeble, or may be absent.

The =interspinous ligaments= (Ligamenta interspinalia) extend between the spines of contiguous vertebræ. In the cervical region they are narrow elastic bands, and in the thoracic and lumbar regions they consist of white fibers directed obliquely downward and forward.

The =intertransverse ligaments= (Ligamenta intertransversaria) are membranes which connect adjacent transverse processes in the lumbar region.

INTERTRANSVERSE ARTICULATIONS

These joints (peculiar to equidæ) are diarthroses formed by the transverse processes of the last two lumbar vertebræ and the alæ of the sacrum. A similar joint between the fourth and fifth lumbar processes is frequently present. The =articular surfaces= have an elongated oval form, the anterior one being concave and the posterior one convex. The capsule is tight, and is reinforced ventrally.

SACRAL AND COCCYGEAL ARTICULATIONS

In the foal the bodies of the five sacral vertebræ form joints which resemble somewhat those in the posterior part of the lumbar region. These joints are invaded by the process of ossification early, so that the consolidation of the sacrum is usually complete, or nearly so, at three years.

The coccygeal vertebræ are united by relatively thick intervertebral fibro-cartilages, which have the form of biconcave discs. Special ligaments are not present, but there is a continuous sheath of fibrous tissue. The movement in this region is extensive and varied. In old horses the first coccygeal vertebra is often fused with the sacrum.

MOVEMENTS OF THE VERTEBRAL COLUMN

The movements of the spine, exclusive of those at the atlanto-axial joint, are dorsal, ventral, and lateral flexion, and rotation. The range of movement at a single joint is very small, but the sum of the movements is considerable. The movements are freest in the cervical and coccygeal regions. Rotation is extremely limited in the thoracic and lumbar regions.

ATLANTO-AXIAL ARTICULATION

This is a trochoid or pivot joint, of a rather peculiar character. The articular surfaces are: (1) On the lateral masses of the atlas, two somewhat saddle-shaped facets, which are usually confluent ventrally; (2) on the axis, reciprocal saddle-shaped surfaces which extend upon the odontoid process and are confluent on its ventral aspect. It will be observed that the joint surfaces are not at all accurately adapted to each other, so that only limited areas are in contact at any time.

The =joint capsule= is attached around the margins of the articular surfaces. It is loose and ample enough laterally to allow extensive movement.

The =superior atlanto-axial ligament= (Ligamentum interarcuale) is membranous and reinforces the capsule dorsally.

The =interspinous ligament= (Ligamentum inter-spinale) consists of two elastic bands which extend from the dorsal arch of the atlas to the spine of the axis.

The =inferior atlanto-axial ligament= (Ligamentum dentis externum) arises from the ventral tubercle of the atlas and is attached by two branches on the ventral spine of the axis.

The =odontoid ligament= (Ligamentum dentis internum) is short, very strong, and somewhat fan-shaped. It extends from the rough concave dorsal surface of the dens or odontoid process, widens in front, and is attached to the transverse rough area on the inner surface of the ventral arch of the atlas.

=Movements.=—The atlas and the head rotate upon the axis; the axis of rotation passes through the center of the odontoid process and body of the axis.

[Illustration:

FIG. 141.—ATLANTO-OCCIPITAL AND ATLANTO-AXIAL JOINTS OF HORSE, DORSAL VIEW AFTER REMOVAL OF DORSAL ARCH OF ATLAS.

_a_, Joint capsule of left part of atlanto-occipital joint; _b_, lateral ligament of same; _c_, _c′_, odontoid ligament; _d_, atlanto-occipital joint capsule; _e_, joint capsule of articulation between axis and third cervical vertebra; _f_, interspinous ligament; _1_, occipital bone; _2_, atlas; _3_, axis; _4_, third cervical vetrebra. (Ellenberger-Baum, Anat. d. Haustiere.)]

THE ATLANTO-OCCIPITAL ARTICULATION

This joint may be classed as a ginglymus. The =articular surfaces= of this joint are: (1) On the atlas, two deep oval cavities; (2) the corresponding condyles of the occipital bone.

The joint surfaces are oblique, coming very close to the median line ventrally, but separated by a considerable interval dorsally. Posteriorly, a triangular rough area cuts into the middle of each articular surface on the atlas.

There are two roomy =joint capsules=, which sometimes communicate ventrally, especially in old subjects.

The =superior atlanto-occipital membrane= extends from the dorsal arch of the atlas to the upper margin of the foramen magnum. It is blended with the capsules and contains many elastic fibers.

The =inferior atlanto-occipital membrane= extends from the ventral arch of the atlas to the lower margin of the foramen magnum. It is narrower and thinner than the superior membrane, and also fuses with the joint capsules.

The =lateral ligaments= are two short bands which are partially blended with the capsules. Each is attached to the border of the wing of the atlas near the intervertebral foramen, and to the outer surface of the paramastoid or styloid process of the occipital bone.

=Movements.=—These are chiefly flexion and extension. A small amount of lateral oblique movement is also possible.

ARTICULATIONS OF THE THORAX

COSTO-VERTEBRAL ARTICULATIONS

Each typical rib forms two joints with the vertebral column, one by its head, and one by its tubercle. They are termed respectively costo-central and costo-transverse joints.

[Illustration:

FIG. 142.—COSTO-VERTEBRAL ARTICULATION, ANTERIOR VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

I. The =costo-central articulations= (Articulationes capitulorum) are trochoid or rotatory joints, formed by the junction of the head of the rib with the bodies of two adjacent vertebræ and the intervertebral fibro-cartilage. The two facets on the head of the rib are separated by a non-articular groove, and correspond to the two concave facets (Foveæ costales) on the vertebral bodies. The capsules are rather tight, and are covered by the accessory ligaments, which are as follows: 1. The =radiate ligament= (Ligamentum capituli costæ radiatum) extends ventrally from the neck of the rib to spread out on the vertebral bodies and the intervertebral fibro-cartilage. 2. The =conjugal ligament= (Ligamentum conjugale)—absent from the first joint—is attached to the groove on the head of the rib, passes transversely into the vertebral canal, and divides under the superior common ligament into two branches; one of these is attached to the body of the anterior vertebra; the other is continued across to the head of the opposite rib, and is attached to the intervertebral fibro-cartilage. The joint cavity is divided into two compartments by the conjugal ligament. 3. The =ligament of the neck= of the rib (Ligamentum colli costæ) is a strong band which crosses the joint dorsally. It is attached on the vertebra above the costal facet and on the neck of the rib.

II. The =costo-transverse articulations=. These occur between the facets on the tubercles of the ribs and those on the transverse processes of the vertebræ. They are gliding joints. The =capsule= is reinforced by the =superior costo-transverse ligament= (Ligamentum costo-transversarium dorsale), a distinct strong band which arises on the transverse process and ends on the non-articular part of the tubercle. It is covered by the levator costæ muscle, and begins to be quite distinct at the fifth joint.

The cavity for the head of the first rib is formed by concave facets on the bodies of the last cervical and first thoracic vertebræ. The conjugal ligament is absent, but the ligament of the neck is short and strong. The radiate ligament is very strong, and consists of two bands. In the case of the last two or three ribs the costo-central and costo-transverse joints are confluent, and the various structures are correspondingly modified.

=Movements.=—The chief movement is rotation around an axis which connects the centers of the head and tubercle of the rib. The movement is very limited in the anterior part of the series of joints, but very considerable in the posterior part.

In the case of the first rib, the movement is evidently extremely limited. The facet for the tubercle of the rib is deeply concave, and the axis of rotation is almost transverse. Further back the facets on the transverse processes become flat, and the axis of rotation gradually approaches a longitudinal direction. This, in connection with the mobility of the ventral ends of the asternal ribs and their elasticity, allows a great increase here in the range of movement, the effect of which is to enlarge (chiefly) the transverse diameter of the thorax.

COSTO-CHONDRAL ARTICULATIONS

The costo-chondral junctions are synarthroses. The rib has a concave surface which receives the convex end of the cartilage. They are united by the continuity of the strong periosteum and perichondrium.

CHONDRO-STERNAL ARTICULATIONS

These joints (Articulationes sternocostales) are diarthroses formed by the junction of the cartilages of the sternal ribs with the sternum. The articular ends of the cartilages (except the first) are somewhat enlarged, and present surfaces of cylindrical curvature. The articular surfaces on the sternum for the first pair of cartilages are placed close together on the dorsal border of the cariniform cartilage (Manubrium sterni); the other seven are placed laterally at the junction of the segments. The capsules are strong and tight; the first pair of joints has a common capsule, and the cartilages articulate with each other medially. The lower ends of the first pair of ribs are firmly attached to each other by dense fibrous tissue, which is prolonged forward along the upper margin of the cariniform cartilage and is continuous behind with the sternal ligament. Each of the other capsules is reinforced dorsally by the =superior costo-sternal ligament= (Ligamentum sternocostale radiatum), composed of radiating fibers which blend with the sternal ligament. The movement is rotation around a nearly vertical axis, except in the case of the first pair of joints.

INTERCHONDRAL LIGAMENTS

The eighth and ninth costal cartilages are firmly united by fibrous tissue. The chondro-xiphoid ligament attaches the ninth costal cartilage to the xiphoid cartilage. The remaining cartilages are rather loosely attached to each other by elastic tissue.

STERNAL ARTICULATIONS

In the new-born foal the sternum has seven bony segments (Sternebræ), united by persisting cartilage. The last two segments coalesce within a few weeks after birth. In old subjects there is more or less ossification of the intersegmental cartilage, which may lead to partial fusion of adjacent segments, especially posteriorly. The =sternal ligament= (Ligamentum sterni proprium internum) lies on the thoracic surface of the sternum. It arises on the first segment, and divides opposite the second chondro-sternal joint into three bands. The median band passes backward and spreads out on the last segment and the xiphoid cartilage. The lateral branches—thicker and wider—lie along the lateral borders above the chondro-sternal joints, and end at the cartilage of the eighth rib; they are covered by the transversus thoracis muscle.

THE ARTICULATIONS OF THE SKULL

TEMPORO-MANDIBULAR ARTICULATION

This joint (Articulatio mandibularis) is the only diarthrosis formed between bones of the skull.

The =articular surfaces= are dissimilar in form and size. That on the squamous temporal bone is concavo-convex, and the long axis is directed outward and somewhat forward; it consists of a glenoid cavity, which is continued upon the postglenoid process behind, and a condyle in front. The mandible presents a transversely elongated condyle.

The =articular disc= is placed between the joint surfaces, which it renders congruent. Its upper and lower surfaces are molded upon the temporal and mandibular surfaces respectively, and its circumference is attached to the joint capsule; thus it divides the joint cavity into upper and lower compartments, the former being the more roomy.

The =joint capsule= is strong and tight. It is reinforced by two ligaments. The =external ligament= (Ligamentum laterale) extends obliquely across the anterior part of the outer surface of the capsule, from which it is not distinctly separable. The =posterior ligament= (Ligamentum posterius) is an elastic band which is attached above to the postglenoid process, and below to a line on the posterior face of the neck of the mandible.

=Movements.=—The chief movements take place around a transverse axis passing through both joints. Associated with this hinge-like action is slight gliding movement, as in opening and shutting the mouth. When the mouth is shut, the condyle lies under the glenoid cavity. When the mandible is depressed, the condyle moves forward under the articular eminence of the temporal bone, carrying the disc with it. In protrusion and retraction of the lower jaw the gliding movement just described occurs without the hinge-like rotation of the condyle. These movements are similar in both joints. In the lateral movements (as usually performed in mastication) the action consists of rotation of the condyles around a vertical axis, while the disc glides forward on one side and backward on the other.

THE SYNARTHROSES OF THE SKULL

Most of the bones of the skull are united with the adjacent bones by =sutures=; a few are united by cartilage. The difference in the uniting medium depends on the fact that most of these bones are developed in membrane, but some are preformed in cartilage. Most of these joints are temporary, and are obliterated at various periods during development and growth. Their importance rests on the fact that so long as they persist, continuous growth is possible. They are usually designated according to the bones which enter into their formation, _e. g._, spheno-squamous, naso-frontal, internasal, etc. Special names (borrowed from human anatomy) are sometimes used; thus the interparietal, the parieto-occipital, and the parieto-frontal sutures are often called the sagittal, lambdoid, and coronal respectively.

Detailed description of the sutures has not sufficient clinical value to justify much addition to the statements made in the osteology in this connection. The obliteration or closure of the sutures is, however, worthy of brief mention. The cranial sutures are usually all closed at seven years, but the apex only of the petrous temporal is fused with the occipital and squamous temporal. Most of the facial sutures are practically closed at ten years, although complete synostosis may in some be delayed for years or may not occur at all; the nasal suture, for example, often persists even in advanced age, so far as its anterior part is concerned.

The principal =synchondroses= are: (1) That between the basioccipital and the body of the sphenoid (Synchondrosis sphenooccipitalis); (2) that between the presphenoid and postsphenoid (Synchondrosis intersphenoidalis); (3) those between the parts of the occipital bone (Synchondroses intraoccipitales). The first is usually ossified at four years, the second at three years, and the occipital bone is consolidated at two years.

The =symphysis= of the lower jaw (Symphysis mandibulæ) ossifies at one to six months.

THE HYOIDEAN ARTICULATIONS

The =temporo-hyoid articulation= is an amphiarthrosis, in which the dorsal angle of the proximal end of the great cornu (Stylo-hyal) is attached by a short bar of cartilage to the hyoid process of the petrous temporal bone. The cartilage (Arthrohyal) is about half an inch (ca. 1 to 1.5 cm.) in length. The chief movement is hinge-like, the axis of motion passing transversely through both joints.

The =intercornual articulation= is an amphiarthrosis formed by the junction of the distal extremity of the great cornu with the proximal end of the small cornu (kerato-hyal). They are united by a very short piece of cartilage, in which there is usually a small nodule of bone in the young subject. This nodule, the epihyal or middle cornu, is usually fused with the great cornu in the adult. The chief movement here is also hinge-like, the angle between the cornua being increased or diminished.

The =basi-cornual articulation= is a diarthrosis formed by the junction of each small cornu (kerato-hyal) with the body (basi-hyal). The small cornu has a concave facet which articulates with the convex facet on either end of the dorsal surface of the body. The capsule is ample enough to allow considerable movement, which is chiefly hinge-like. The movements of the hyoid bone are concerned chiefly in the acts of mastication and swallowing. In the latter the distal parts of the hyoid bone are moved forward and upward, carrying the root of the tongue and the larynx with them, and then return to their former position.

THE ARTICULATIONS OF THE THORACIC LIMB

In the absence of the clavicle the thoracic limb forms no articulation with the trunk, unless we regard as such the union by muscles. The movement of the shoulder on the chest-wall is chiefly rotation around a transverse axis passing through the scapula behind the upper part of the spine.

THE SHOULDER JOINT

The shoulder or scapulo-humeral joint (Articulatio scapulo-humeralis) is formed by the junction of the distal end of the scapula with the proximal end of the humerus. The =articular surfaces= are: (1) On the scapula, the glenoid cavity; (2) on the humerus, the head. Both surfaces are approximately spherical and similar in curvature, but the humeral surface is much more extensive than that of the scapula.

The =joint capsule= is ample enough to allow the bones to be drawn apart about an inch (ca. 2 to 3 cm.); but this requires a very considerable amount of force unless air is admitted into the joint cavity. The fibrous layer (or capsular ligament) is not attached to the margin of the joint surfaces, but at a distance of one to two centimeters from it. It is strengthened in front by two diverging

elastic bands, which arise on the scapular tuberosity and end on the lips of the bicipital groove. A pad of fat is interposed between the capsule and the tendon of the biceps.

Ligaments are absent from this joint, but the muscles and tendons around it afford remarkable security, so that dislocation seldom or never occurs. The large extent of the head of the humerus is also of importance in this regard.

The principal muscles which are attached around the joint and act as ligaments are: externally, the supraspinatus, infraspinatus, and teres minor; internally, the subscapularis; in front, the biceps and supraspinatus; behind, the triceps.

=Movements.=—While it is a typical enarthrosis in structure, and capable of the various movements of the ball-and-socket joint, the chief normal movements are flexion and extension. In the position of rest the angle formed between the scapula and humerus posteriorly is about 110° to 120°; in flexion it is reduced to about 80°, and in extension it is increased to about 145°. Adduction and abduction are very restricted, the former being limited chiefly by the infraspinatus, the latter by the subscapularis and the low insertion of the superficial pectoral muscles. Rotation is somewhat freer, but does not exceed 33°, when all the muscles are removed (Franck).

THE ELBOW JOINT

This, the cubital articulation (Articulatio cubiti), is a ginglymus formed between the distal extremity of the humerus and the proximal ends of the bones of the forearm.

[Illustration:

FIG. 143.—LEFT ELBOW JOINT OF HORSE, POSTERIOR VIEW. THE CAPSULE IS REMOVED. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =articular surfaces= are: (1) A trochlear surface formed by the condyles of the humerus and the groove between them; (2) the corresponding glenoid cavities and ridge on the proximal extremity of the radius, together with the semilunar notch of the ulna.

The articular surface of the condyles does not extend upon the back of the extremity, but the groove which receives the semilunar notch of the ulna extends up into the olecranon fossa. In the fore part of the groove there is a synovial fossa. The surface on the outer condyle is smaller than that of the inner one, and is subdivided into two unequal parts by a shallow furrow. On the lower part of the semilunar notch and the adjacent part of the ridge on the radius are synovial fossæ.

The =joint capsule= is extremely thin behind, where it forms a pouch in the olecranon fossa under the anconeus muscle and a pad of fat. In front it is strengthened by oblique fibers (Ligamentum obliquum or anterior ligament), and laterally it fuses with the lateral ligaments. Small pouches of the =synovial membrane= lubricate the origins of the flexors of the carpus and digit and the small radio-ulnar joints. There are two lateral ligaments.

The =internal lateral ligament= (Ligamentum collaterale radiale) is attached above to an eminence on the internal epicondyle of the humerus, and divides into two parts: the long, superficial part ends on the inner border of the radius, just below the level of the interosseous space; the deep, short part is inserted into the internal tuberosity of the radius. (The superficial part represents the pronator teres muscle, which is only exceptionally present in the horse.)

The =external lateral ligament= (Ligamentum collaterale ulnare) is short and strong. It is attached above to a depression on the external epicondyle of the humerus, and below to the external tuberosity of the radius, just below the margin of the articular surface.

=Movements.=—This joint is a typical ginglymus, the only movements being flexion and extension around an axis which passes through the upper attachments of the lateral ligaments. In the standing position the articular angle (in front) is about 140° to 150°. The range of movement is about 55° to 60°. Complete extension is prevented chiefly by the tension of the lateral ligaments and the biceps muscle. (The axis of movement is slightly oblique, so that in flexion the forearm is carried somewhat outward.)

[Illustration:

FIG. 144.—LEFT CARPAL JOINTS OF HORSE, EXTERNAL VIEW.

The capsule has been removed, _g_, Radius; _12_, large metacarpal bone. (After Ellenberger-Baum, Anat. f. Künstler.)]

[Illustration:

FIG. 145.—LEFT CARPAL JOINTS OF HORSE, ANTERIOR VIEW.

The capsule has been removed. The smaller ligaments are shown. (After Ellenberger-Baum, Anat. f. Künstler.)]

THE RADIO-ULNAR ARTICULATION

In the foal the shaft of the ulna is attached to the radius above and below the interosseous space by the =interosseous ligament=. Below the space the two bones become fused before adult age is reached. Above the space the ligament usually persists, but may undergo more or less ossification in extreme old age. The =transverse= or =arciform ligaments= (Ligamentum transversum ulnare et radiale ulnæ et radii) consist of fibers which pass above the interosseous space from either border of the shaft of the ulna to the posterior surface of the radius. The proximal radio-ulnar articulation, formed by two small convex facets on the ulna and the corresponding facets on the posterior surface of the proximal extremity of the radius, is inclosed in the capsule of the elbow joint and does not require separate consideration. The distal extremity of the ulna fuses early with the radius, and is, therefore, regarded usually as a part of the latter.

=Movement.=—This is inappreciable, the forearm being fixed in the position of pronation.

THE CARPAL JOINTS

These joints taken together constitute the composite =articulatio carpi=, or what is popularly termed the "knee-joint" in animals.[33] This consists of three chief joints, viz., (1) The =radio-carpal joint=, formed by the distal end of the radius and the proximal row of the carpus; (2) the =intercarpal joint=, formed between the two rows of the carpus; (3) the =carpo-metacarpal joint=, formed between the distal row of the carpus and the proximal ends of the metacarpal bones. The proximal and middle joints may be regarded as ginglymi, although they are not typical or pure examples of hinge-joints. The distal joint is arthrodial. In addition there are arthrodial joints formed between adjacent bones of the same row (Articulationes interosseæ). All these constitute a very composite joint, with numerous ligaments. The articular surfaces have been described in the Osteology.

The =joint capsule= may be regarded, so far as the fibrous part is concerned, as being common to all three joints. It is attached close to the margin of the articular surface of the radius above and the metacarpus below; its deep face is also attached to a considerable extent to the carpal bones and to the small ligaments. Its anterior part, the =dorsal= or =anterior common ligament=, is rather loose, and assists in forming the fibrous canals for the extensor tendons. Its posterior part, the =volar= or =posterior common ligament=, is very thick and dense, and is closely attached to the carpal bones. It levels up the irregularities of the skeleton here, and forms the smooth anterior wall of the carpal canal. It is continued downward to form the =subcarpal= or =inferior check ligament=, which blends with the tendon of the flexor perforans about the middle of the metacarpus.

[Illustration:

FIG. 146.—FRONTAL SECTION OF CARPAL JOINTS OF HORSE (RIGHT SIDE).

_l.u._, External, _l.r._, internal, lateral ligament; _Cr_, radial carpal; _Ci_, intermediate carpal; _Cu_, ulnar carpal; _C2_, second carpal; _C3_, third carpal; _C4_, fourth carpal; _Mc2_, second (internal) metacarpal; _Mc3_, third (large) metacarpal; _Mc4_, fourth (external) metacarpal.]

The =synovial membrane= forms three sacs corresponding to the three joints. The =radio-carpal sac= is the most voluminous; it includes the joints formed by the accessory carpal bone, and also those between the proximal carpal bones as far as the interosseous ligaments. The =intercarpal sac= sends extensions upward and downward between the bones of the two rows as far as the interosseous ligaments; it communicates between the third and fourth carpal bones with the =carpo-metacarpal sac=. The latter is very limited in extent, and is closely applied to the bones; it incloses the carpo-metacarpal joint, and lubricates also the lower parts of the joints between the distal carpal bones and the intermetacarpal joints.

The =external lateral ligament= (Ligamentum carpi collaterale ulnare) is attached above to the external tuberosity of the distal end of the radius. Its long superficial part is attached below to the proximal end of the external small metacarpal chiefly, but some fibers end on the large metacarpal bone. A canal for the lateral extensor tendon separates a short deep band which ends on the ulnar carpal bone. Other deep fibers connect the latter with the fourth carpal bone, and the fourth carpal with the metacarpus.

The =internal lateral ligament= (Ligamentum carpi collaterale radiale) resembles the preceding in general, but is stronger and wider distally. It is attached above to the internal tuberosity of the distal end of the radius and ends below on the proximal ends of the large and inner small metacarpal bones. Deep fasciculi are detached to the radial and second carpal bones. The first carpal bone, when present, is usually embedded in the posterior part of the distal end of the ligament. The posterior part of the ligament is fused with the posterior annular ligament (Ligamentum carpi transversum), and concurs in the formation of a canal for the tendon of the flexor carpi internus.

A number of special short ligaments connect two or more adjacent bones; only the most distinct of these will be described here.

The accessory carpal bone is connected with adjacent bones by three ligaments (Fig. 444). The proximal one is a short band which extends from the accessory carpal in front of the groove on its outer face and is inserted into the distal end of the radius behind the groove for the lateral extensor tendon. A middle band connects the accessory with the ulnar carpal. The distal ligament consists of two strong bands which pass from the lower margin of the accessory to the fourth carpal and the proximal end of the outer metacarpal bone; these bands transmit the action of the muscles, which are inserted into the accessory carpal bone. The other bones of the proximal row are connected by two anterior or dorsal ligaments, which are transverse in direction, and two interosseous ligaments. An oblique ligament passes from an eminence on the posterior surface of the radial carpal bone to a small depression on the radius internal to the facet for the accessory carpal bone.

Two ligaments connect the proximal and distal rows posteriorly. The inner one joins the radial to the second and third carpal, and the outer one attaches the ulnar to the third and fourth carpals.

The bones of the distal row are connected by two strong transverse anterior or dorsal ligaments and two interosseous ligaments.

There are four carpo-metacarpal ligaments. Two oblique anterior bands connect the third carpal with the large metacarpal. Two interosseous ligaments pass downward from the interosseous ligaments of the distal row to end in depressions in the interstices between the proximal ends of the metacarpal bones.

[Illustration:

FIG. 147.—LEFT CARPAL JOINTS OF HORSE, INNER VIEW.

_g_, Radius; _12_, large (third) metacarpal bone. (After Ellenberger-Baum, Anat. für Künstler.)]

=Movements.=—Taking the joint as a whole, the chief movements are flexion and extension. In the standing position the joint is extended. When the joint is flexed, slight lateral movement and rotation can be produced by manipulation. The anterior part of the capsule is, of course, tense during flexion, the posterior part in extension.

The movement practically all occurs at the radio-carpal and intercarpal joints, the articular surfaces of which are widely separated in front during flexion, but remain in contact behind. The distal row remains in contact with the metacarpus. The intermediate and ulnar carpals move together as one piece, but the radial does not move so far as the intermediate, so that the anterior and interosseous ligaments connecting these bones become tense and oblique in direction.

THE FETLOCK JOINT

This, the =metacarpo-phalangeal articulation= (Articulatio metacarpo-phalangea), is a ginglymus formed by the junction of the distal end of the large (third) metacarpal bone, the proximal end of the first phalanx, and the proximal sesamoid bones.

=Articular Surfaces.=—The surface on the large metacarpal bone is approximately cylindrical in curvature, but is divided into two slightly unequal parts by a sagittal ridge. This is received into a sort of socket formed by the first phalanx below and the two sesamoids together with the intersesamoid ligament behind. The latter is a mass of fibro-cartilage in which the sesamoid bones are largely embedded. It extends above the level of the sesamoids, and is grooved to receive the ridge on the metacarpal bone; its posterior surface forms a smooth groove for the deep flexor tendon.

[Illustration:

FIG. 148.—SAGITTAL SECTION OF DISTAL PART OF LIMB OF HORSE.

_1_, Large metacarpal bone; _3_, fetlock joint; _4_, proximal sesamoid bone; _5_, first phalanx; _6_, pastern joint; _7_, second phalanx; _8_, coffin joint; _9_, third phalanx; _10_, distal sesamoid (navicular bone); _12_, suspensory ligament; _14_, deep flexor tendon; _15_, superficial flexor tendon; _16_, posterior annular ligament of fetlock; _20_, inferior sesamoidean ligaments; _21_, extensor tendon; _24_, plantar cushion; _25_, periople; _28_, wall of hoof; _29_, sole of hoof; _A_, navicular bursa, proximal part. (After Ellenberger-Baum, Anat. für Künstler.)]

[Illustration:

FIG. 149.—ARTICULAR SURFACES OF FIRST PHALANX AND SESAMOIDS AT FETLOCK, WITH INTERSESAMOID AND SUSPENSORY LIGAMENTS. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =joint capsule= is attached around the margin of the articular surfaces. It is thick and ample in front; here a bursa is interposed between it and the extensor tendons, but the tendons are also attached to the capsule. Posteriorly it forms a thin-walled pouch which extends upward between the metacarpal bone and the suspensory ligament about as high as the point of bifurcation of the latter. The capsule is reinforced by two lateral ligaments.

The =lateral ligaments=, =external= and =internal= (Ligamentum collaterale ulnare, radiale) are partially divided into two layers: the =superficial layer= arises from the eminence on the side of the distal end of the large metacarpal bone, and passes straight to the rough lateral area below the margin of the articular surface of the first phalanx; the =deep layer=, shorter and much stronger, arises in the lateral depression on the distal end of the metacarpal bone, and passes obliquely downward and backward to be inserted into the outer surface of the sesamoid and the proximal end of the first phalanx.

The capsule is further strengthened by a layer of oblique fibers which pass over the lateral ligament on either side and end on the extensor tendon and the proximal extremity of the first phalanx. It may properly be regarded as fascia rather than ligament.

[Illustration:

FIG. 150.—LIGAMENTS AND TENDONS OF DISTAL PART OF LIMB OF HORSE.

Mc.III, Large metacarpal bone; Ph.I, first phalanx; Ph.II, second phalanx; Ph.III, third phalanx; 1, deep flexor tendon; 2, band from first phalanx to plantar cushion. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

=Movements.=—These are of the nature of flexion and extension, the axis of motion passing through the upper attachments of the lateral ligaments. In the ordinary standing position the joint is in a state of partial =dorsal flexion=, the articular angle (in front) being about 140° to 150°. (In the hind limb it is about 5° greater.) Diminution of this angle (sometimes termed "overextension") is normally very limited on account of the resistance offered by the sesamoidean apparatus, but it varies considerably in amount in different subjects. =Volar flexion= is limited only by contact of the heels with the metacarpus. During volar flexion a small amount of lateral flexion is possible.

THE SESAMOIDEAN LIGAMENTS

Under this head will be described a number of important ligaments which are connected with the sesamoid bones and form a sort of stay apparatus or brace.

The =intersesamoidean ligament= (Ligamentum intersesamoideum) not only fills the space between and unites the sesamoid bones, but also extends above them, entering into the formation of the articular surface of the fetlock joint. Other facts in regard to it have been given above.

The =lateral sesamoidean ligaments=, outer and inner (Ligamenta sesamoidea ulnare et radiale), arise on the abaxial surface of each sesamoid bone, pass forward, and divide into two branches, one of which ends in the depression on the distal end of the large metacarpal bone, the other on the eminence on the proximal end of the first phalanx. They are partly covered by the branches of the suspensory or superior sesamoidean ligament.

[Illustration:

FIG. 151.—DEEP DISSECTION OF DISTAL PART OF RIGHT FORE LIMB OF HORSE, SHOWING JOINTS AND LIGAMENTS, POSTERIOR VIEW.

1, Lateral cartilage; 2, tendon surface of navicular bone; 3, inferior navicular or interosseous ligament; 4, insertion of deep flexor tendon. Small arrows point to openings made in capsules of pastern and coffin joints. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =suspensory= or =superior sesamoidean ligament= (Musculus interosseus medius) lies for the greater part in the metacarpal groove, where it has the form of a wide, thick band. It is attached above to the upper part of the posterior surface of the large metacarpal bone and to the distal row of carpal bones. At the lower fourth of the metacarpus it divides into two diverging branches. Each branch passes to the abaxial face of the corresponding sesamoid, on which a considerable part, is attached. The remainder passes obliquely downward and forward to the anterior surface of the first phalanx, where it joins the extensor tendon. This ligament possesses considerable elasticity, and is the highly modified interosseous medius muscle. It consists mainly of tendinous tissue, but contains a variable amount of striped muscular tissue, especially in its deep part and in young subjects. Its principal function is to support the fetlock, _i. e._, to prevent excessive dorsal flexion of the joint when the weight is put on the limb. The branches which join the common extensor tendon limit volar flexion of the interphalangeal joints in certain phases of movement.

The =inferior sesamoidean ligaments= are three in number—superficial, middle, and deep. The =superficial= or =straight ligament= (Ligamentum sesamoideum rectum) is a flat band and is somewhat wider above than below.[34] It is attached above to the bases of the sesamoid bones and the intersesamoid ligament, below to the complementary fibro-cartilage of the proximal end of the second phalanx. The =middle ligament= is triangular, with thick, rounded margins (Ligamenta obliqua) and a thin central portion.[35] Its base is attached to the sesamoid bones and intersesamoid ligament, and its deep face to the triangular rough area on the posterior surface of the first phalanx. The =deep= or =cruciate ligament= (Ligamenta sesamoidea cruciata) consists of two thin layers of fibers which arise on the base of the sesamoid bones, cross each other, and end on the opposite eminence on the proximal end of the first phalanx.

The =short sesamoidean ligaments= (Ligamenta sesamoidea brevia) are best seen by opening the joint in front and pushing the sesamoid bones backward; they are covered by the synovial membrane. Each is a short band which extends from the anterior part of the base of the sesamoid bone outward to the posterior margin of the articular surface of the first phalanx.

The inferior sesamoidean ligaments may be regarded as digital continuations of the suspensory ligament, the sesamoid bones being intercalated in this remarkable stay apparatus by which the fetlock is supported and concussion diminished.

THE PASTERN JOINT

This, the =proximal interphalangeal articulation= (Articulatio phalangis secundæ), is a ginglymus formed by the junction of the distal end of the first phalanx and the proximal end of the second phalanx.

The =articular surfaces= are: (1) On the first phalanx, two slightly unequal convex areas with an intermediate shallow groove; (2) on the second phalanx, a corresponding surface, completed behind by a plate of fibro-cartilage.

The =joint capsule= is close fitting in front and laterally, where it blends with the extensor tendon and the lateral ligaments respectively. Behind it pouches upward a little and is reinforced by the straight sesamoidean ligament and the branches of the superficial flexor tendon.

There are two lateral and four volar ligaments.

The =lateral ligaments=, internal and external (Ligamentum collaterale radiale, ulnare) are very short and strong bands which are attached above on the eminence and depression on each side of the distal end of the first phalanx, and below on the eminence on either side of the proximal end of the second phalanx. The direction of the ligaments is about vertical and, therefore, does not correspond to the digital axis.

The =volar= or =posterior ligaments= consist of central and lateral pairs of bands which are attached below to the posterior margin of the proximal end of the second phalanx and its complementary fibro-cartilage. The lateral pair is attached above to the middle of the borders of the first phalanx, the central pair lower down and on the margin of the triangular rough area.

These ligaments are very commonly thickened as a result of chronic inflammation, and then are not well defined. The central ones blend below with the branches of the superficial flexor tendon and with the straight sesamoidean ligament.

=Movements.=—These are very limited, and consist of flexion and extension. The axis of motion passes transversely through the distal end of the first phalanx. In the standing position the joint is extended. A small amount of volar flexion is possible, and in this

position slight lateral flexion and rotation can be produced by manipulation. Dorsal flexion is prevented by the lateral, volar, and straight sesamoidean ligaments.

THE COFFIN JOINT

This joint, technically termed the =distal interphalangeal articulation= (Articulatio phalangis tertiæ), is a ginglymus formed by the junction of the second and third phalanges and the third sesamoid bone.

=Articular Surfaces.=—The surface on the distal end of the second phalanx is convex from before backward, concave transversely. The articular surface of the third phalanx slopes sharply upward and forward; its central part is prominent, and is flanked by two glenoid cavities. It is completed behind by the articular surface of the third sesamoid or navicular bone.

[Illustration:

FIG. 152.—LATERAL LIGAMENTS OF PASTERN JOINT AND SUSPENSORY LIGAMENTS OF NAVICULAR BONE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

=Joint Capsule.=—This is attached around the margins of the articular surfaces. In front and laterally it is tight, and is blended with the extensor tendon and the lateral ligaments respectively. Posteriorly, it forms a considerable pouch which extends upward to about the middle of the second phalanx, where it is separated by a fibrous membrane from the digital synovial sheath. Laterally small pouches project outward (especially during volar flexion) against the lateral cartilages, just behind the lateral ligaments.[36]

=Ligaments.=—The =lateral ligaments=, external and internal (Ligamentum collaterale ulnare, radiale), are short strong bands which are attached above in the depressions on either side of the lower part of the second phalanx, under cover of the lateral cartilage. They widen below and end in the depressions on either side of the extensor process and on the anterior end of the lateral cartilages.

The =suspensory navicular ligaments=, external and internal (Ligamentum sesamoideum collaterale ulnare, radiale),[37] are strong, somewhat elastic bands, which form a sort of suspensory apparatus for the third sesamoid. They are attached superiorly in and above the depressions on either side of the distal end of the first phalanx and are here partly blended with the lateral ligaments of the pastern joint. They are directed obliquely downward and backward, and end chiefly on the ends and proximal border of the third sesamoid, but detach a branch to the inner surface of each lateral cartilage and wing of the third phalanx.

The =inferior navicular ligament= (Ligamentum phalangeo-sesamoideum) reinforces the capsule interiorly. It is a strong layer of fibers which extend from the distal border of the third sesamoid to the tendon surface of the third phalanx, near the posterior margin of the articular surface.

=Movements.=—The chief movements are flexion and extension. In the standing position the joint is extended. During volar flexion a very small amount of lateral movement and rotation can be produced by manipulation. Dorsal flexion is very limited.

Dorsal flexion appears to be checked mainly by the deep flexor tendon, since in cases of rupture of the latter the toe turns up. The slight mobility of the posterior part of the socket for the second phalanx (formed by the third sesamoid) diminishes concussion when the weight comes on the foot.

LIGAMENTS OF THE LATERAL CARTILAGES

In addition to the bands mentioned above, which attach the lateral cartilages to the extremities of the navicular bone, there are three ligaments on either side which attach the cartilages to the phalanges.

An ill-defined elastic band passes from the middle part of the border of the first phalanx to the upper part of the cartilage, detaching a branch to the plantar cushion.

A short strong band connects the anterior extremity of the cartilage with the rough eminence on the second phalanx in front of the attachment of the lateral ligament of the coffin joint.

The lower border of the cartilage is covered externally by fibers which attach it to the wing of the third phalanx.

THE ARTICULATIONS OF THE PELVIC LIMB

THE SACRO-ILIAC ARTICULATION

This joint (Articulatio sacro-iliaca) is a diarthrosis formed between the auricular surfaces of the sacrum and ilium. These surfaces are not smooth in the adult, but are marked by eminences and depressions, and are covered by a thin layer of cartilage. The joint cavity is a mere cleft, and is often crossed by fibrous bands.

The =capsule= is very close fitting, and is attached around the margins of the articular surfaces. It is reinforced by the =ventral sacro-iliac ligament= (Ligamentum sacro-iliacum ventrale), which surrounds the joint, and is exceedingly strong above.

The =movements= are inappreciable in the adult—stability, not mobility, being the chief desideratum.

The following ligaments may be regarded as accessory to the joint, although not directly connected with it.

The =dorsal sacro-iliac ligament= (Ligamentum sacro-iliacum dorsale breve) is a strong band which is attached to the internal angle (Tuber sacrale) of the ilium and the summits of the sacral spines.

The =lateral sacro-iliac ligament= (Ligamentum sacro-iliacum dorsale longum) is a triangular, thick sheet which is attached in front to the internal angle and border of the ilium above the great sciatic notch, and below to the lateral border of the sacrum. It blends above with the dorsal sacro-iliac ligament, below with the sacro-sciatic ligament, and behind with the coccygeal fascia.

The =sacro-sciatic ligament= (Ligamentum sacrospinosum et tuberosum) is a quadrilateral sheet which completes the lateral pelvic wall. Its upper border is attached to the border of the sacrum and the transverse processes of the first and second coccygeal vertebræ. Its lower border is attached to the superior ischiatic spine and tuber ischii. Between these it bridges over the external border of the ischium and completes the lesser sciatic foramen. The anterior border is concave, and completes the greater sciatic foramen. The posterior border is fused with the vertebral head of the semimembranosus muscle.

The =ilio-lumbar ligament= (Ligamentum ilio-lumbale) is a triangular sheet which attaches the ends of the lumbar transverse processes to the ventral surface of the ilium below the attachment of the longissimus muscle (Fig. 184).

[Illustration:

FIG. 153.—LEFT OS COXÆ AND ADJACENT PARTS OF SACRUM AND FEMUR OF HORSE. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

SYMPHYSIS PELVIS

The =symphysis pelvis= is formed by the junction of the two ossa coxarum at the ventral median line. In the young subject the bones are united by a layer of cartilage; in the adult the latter is gradually replaced by bone, the process beginning in the pubic portion and extending backward. The union is strengthened by white fibrous tissue above and below, and a transverse band also covers the anterior border of the pubis (pecten). No appreciable movement occurs even before synostosis takes place.

OBTURATOR MEMBRANE

This (Membrana obturatoria) is a thin layer of fibrous tissue which covers the obturator foramen, leaving, however, a passage (Canalis obturatorius) for the obturator vessels and nerve.

THE HIP JOINT

This joint (Articulatio coxæ) is an enarthrosis formed by the proximal end of the femur and the acetabulum.

=Articular Surfaces.=—The head of the femur presents an almost hemispherical articular surface, which is continued a short distance on the upper surface of the neck. It is more extensive than the socket which receives it. Internally it is cut into by a deep notch for the attachment of the round and pubo-femoral ligaments. The acetabulum is a typical cotyloid cavity. Its articular surface is somewhat crescentic, being deeply cut into internally by the acetabular notch and fossa. It is increased and deepened by a ring of fibro-cartilage, the =cotyloid ligament= (Labrum glenoidale), which is attached to the bony margin; that part of the ligament which crosses the notch is called the =transverse ligament= (Fig. 456).

[Illustration:

FIG. 154.—PELVIC LIGAMENTS AND HIP JOINT.

_1_, Dorsal sacro-iliac ligament; _2_, lateral sacro-iliac ligament; _3_, sacro-sciatic ligament; _4_, greater sciatic foramen; _5_, lesser sciatic foramen; _6_, line of attachment of intermuscular septum between biceps femoris and semitendinosus; _7_, capsule of hip joint; _8_, rectus parvus or capsularis muscle; _9_, outer tendon of origin of biceps femoris; _10_, internal, _11_, external, angle of ilium; _12_, shaft of ilium; _13_, superior ischiatic spine; _14_, pubis; _15_, tuber ischii; _16_, trochanter major; _17_, semimembranosus; _18_, fifth lumbar spine; _19_, _20_, first and second coccygeal vertebræ.]

The =joint capsule= is roomy. It is attached around the margin of the acetabulum and the neck of the femur. It is thickest externally.

The attachment on the femur is about 1 cm. from the margin of the articular surface, except above, where 2 to 3 cm. of the neck is intracapsular. A thin oblique band corresponding in direction with the rectus parvus muscle reinforces the antero-external part of the capsule; this appears to be the feeble homologue of the very strong ilio-femoral ligament of man. The capsule is very thin under the ilio-psoas, and is adherent to the muscle. Internally, its fibrous part is perforated by the pubo-femoral and round ligaments and the articular vessels.

The =round ligament= (Ligamentum teres) is a strong hand which is attached in the subpubic groove close to the acetabular notch, passes outward, and ends in the notch on the head of the femur (Fig. 456).

The =pubo-femoral ligament= (Ligamentum accessorium) does not occur in the domestic animals other than the equidæ. It is a strong band detached from the prepubic tendon of the abdominal muscles (Fig. 456). It is directed outward, backward, and upward, passes through the acetabular notch above the transverse ligament, and ends behind the round ligament in the notch on the head of the femur. The origin of the pectineus muscle is perforated by the ligament, which furnishes attachment to the greater part of the fibers of the muscle.

[Illustration:

FIG. 155.—LEFT STIFLE JOINT OF HORSE, EXTERNAL VIEW, IN PARTIAL FLEXION.

The capsules have been removed. _18_, Femur; _20_, patella; _21_, tibia; _a″_, internal patellar ligament; _b_, external femoro-patellar ligament; _d_, external semilunar cartilage. (After Ellenberger-Baum, Anat. für Künstler.)]

The =synovial membrane= is reflected over the intracapsular parts of these ligaments and covers the fossa acetabuli. A pouch also extends from the acetabular notch for a variable distance along the subpubic groove above the pubo-femoral ligament.

=Movements.=—This joint is capable of all the movements of a ball-and-socket joint, viz., flexion, extension, abduction, adduction, rotation, and circumduction. The greatest range of movement is displayed in flexion and extension. When standing at rest, the joint is partially flexed, the articular angle (in front) being about 100° to 115°. The other movements occur to a very limited extent in normal action.

Abduction appears to be checked by tension of the round ligament. The pubo-femoral ligament is tensed most promptly by inward rotation of the thigh.

THE STIFLE JOINT

This joint (Articulatio genu), which corresponds to the knee-joint of man, is the largest and most elaborate of all the articulations. Taken as a whole, it may be classed as a ginglymus, although it is not a typical example of the group. In reality it consists of two joints—the =femoro-patellar= and the =femoro-tibial=.

The =femoro-patellar articulation= (Articulatio femoro-patellaris) is formed between the trochlea of the femur and the articular surface of the patella.

[Illustration:

FIG. 156.—LEFT STIFLE JOINT OF HORSE, LATERAL VIEW.

The capsules are distended and the external patellar ligament is removed.]

=Articular Surfaces.=—The trochlea consists of two slightly oblique ridges, with a wide and deep groove between them. The inner ridge is much the larger of the two, especially at its upper part, which is wide and rounded. The outer ridge is much narrower, and is more regularly curved; its upper part lies about an inch behind a frontal plane tangent to the inner ridge. The articular surface of the patella is much smaller than that of the trochlea. It is completed internally by a supplementary plate of fibro-cartilage (Fibrocartilago patellæ), which curves over the internal surface of the inner lip of the trochlea. A narrow strip of cartilage is found along the outer border also. The articular cartilage on the trochlea completely covers both surfaces of the inner ridge, but only a narrow marginal area on the external surface of the outer ridge.

=Joint Capsule.=—This is thin and is very capacious. On the patella it is attached around the margin of the articular surface, but on the femur the line of attachment is at a varying distance from the articular surface. On the inner side it is an inch or more from the articular cartilage; on the outer side and above, about half an inch. It pouches upward under the quadriceps femoris for a distance of two or three inches, a pad of fat separating the capsule from the muscle. Below the patella it is separated from the straight ligaments by a thick pad of fat, but inferiorly it is in contact with the femoro-patellar capsules. The joint cavity is the most extensive in the body. It usually communicates with the inner femoro-tibial joint cavity by a slit-like opening situated at the lowest part of the inner ridge of the trochlea. A similar, but smaller, communication with the outer femoro-patellar capsule is often found at the lowest part of the outer ridge.

The inner communication appears to be constant in adult horses, but is liable to be overlooked on account of the fact that it is covered by a valvular fold of the synovial membrane. It is about half an inch wide, and lies under the narrow articular area which connects the trochlea and internal condyle. The outer communication occurs in 18 to 25 per cent. of cases, according to Baum. It is instructive to distend this capsule and thus obtain an idea of its potential capacity and relations ([Fig. 156]).

[Illustration:

FIG. 157.—STIFLE JOINT OF HORSE, FRONT VIEW, IN EXTENSION.

The capsules are removed. _18_, Femur; _20_, patella; _21_, tibia. (After Ellenberger-Baum, Anat. für Künstler.)]

=Ligaments.=—The =lateral femoro-patellar ligaments=, external and internal (Ligamentum femoro-patellare fibulare, tibiale), are two thin bands which reinforce the capsule on either side. The external ligament is fairly distinct; it arises from the external epicondyle of the femur just above the lateral femoro-tibial ligament, and ends on the external border of the patella. The internal ligament is thinner and is not distinct from the capsule; it arises above the internal epicondyle, and ends on the patellar fibro-cartilage.

The =patellar ligaments= (Ligamenta patellæ), also called the straight ligaments of the patella, are three very strong bands which attach the patella to the tuberosity of the tibia. The =external patellar ligament= is attached above to the outer part of the anterior surface of the patella, and below to the outer part of the tuberosity. It receives a strong tendon from the biceps femoris muscle. The =middle patellar ligament= extends from the front of the apex of the patella to the lower part of the groove on the tuberosity of the tibia, a bursa being interposed between the ligament and the upper part of the groove. The =internal patellar ligament= is attached above to the patellar fibro-cartilage, and ends on the tuberosity of the tibia, internally to the groove. It is joined by the common aponeurosis of the gracilis and sartorius. These so-called ligaments are, in reality, the tendons of insertion of the quadriceps femoris muscle, and transmit the action of the latter to the tibia; they also function similarly for the other muscles attached to them as noted above.

It will be noticed that the upper attachments are further apart than the lower ones, so that the ligaments converge below. The inner ligament is especially oblique. The middle ligament is more deeply placed than the others, and therefore cannot usually be felt distinctly in the living animal.

[Illustration:

FIG. 158.—SEMILUNAR CARTILAGES AND CRUCIAL LIGAMENTS OF RIGHT STIFLE OF HORSE.

_F_, Femoral ligament of external cartilage. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =femoro-tibial articulation= (Articulatio femoro-tibialis) is formed between the condyles of the femur, the proximal end of the tibia, and the interposed semilunar cartilages.

=Articular Surfaces.=—The condyles of the femur are slightly oblique in direction. The articular surface of the outer one is more strongly curved than that of the inner one; the latter is confluent below with the inner ridge of the trochlea, while the narrow ridge which connects the external condyle with the trochlea is usually non-articular. The saddle-shaped surfaces of the condyles of the tibia are not adapted to the femoral condyles, and are in contact with only a small part of them.

[Illustration:

FIG. 159.—PROXIMAL ENDS OF RIGHT TIBIA AND FIBULA OF HORSE, WITH SEMILUNAR CARTILAGES AND CRUCIAL LIGAMENTS, EXTERNAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The =semilunar cartilages= (Meniscus lateralis, medialis) are two C-shaped or crescentic discs of fibro-cartilage which produce congruence in the articular surfaces. Each has an upper concave surface adapted to the condyle of the femur, and a lower surface which fits the corresponding condyle of the tibia. The external cartilage does not cover the outer and posterior part of the condyle, over which the tendon of origin of the popliteus muscle plays. The peripheral border is thick and convex, the central one very thin and concave. The fibrous ends or =cornua= are attached to the tibia in front of and behind the spine. The external cartilage has a third attachment by means of an oblique band (Ligamentum femorale menisci lateralis) which passes from the posterior cornu to the posterior part of the intercondyloid fossa of the femur.

The cornua of the internal cartilage (Ligamenta tibiæ anterius et posterius menisci medialis) are attached in front of and behind the inner eminence of the spine. The anterior cornu of the external cartilage (Ligamentum tibiæ anterius menisci lateralis) is attached in front of the outer eminence of the spine. The posterior cornu bifurcates; the lower branch (Ligamentum tibiæ posterius menisci lateralis) is inserted at the popliteal notch, the upper (Ligamentum femorale menisci lateralis) in a small fossa in the extreme posterior part of the intercondyloid fossa.

The =joint capsule= is attached to the margin of the tibial articular surface, but on the femur the line of attachment is for the greater part about half an inch from the articular margin. It is also attached to the convex borders of the semilunar cartilages and to the crucial ligaments. It is strong posteriorly, but in front it practically consists only of the synovial layer. There are two synovial sacs, corresponding to the double nature of the articular surfaces; they do not usually communicate, and each is partially divided into an upper and a lower compartment by the semilunar cartilage. The inner sac pouches upward about half an inch over the condyle of the femur. The external sac invests the tendon of origin of the popliteus muscle, and also pouches downward about three or four inches (ca. 8 to 10 cm.) beneath the peroneus tertius and long extensor muscles (Fig. 156). As stated above, the outer sac sometimes communicates with the femoro-patellar joint cavity, and the inner sac usually, if not always, does so in the adult.

[Illustration:

FIG. 160.—LEFT STIFLE JOINT OF HORSE, INTERNAL VIEW IN EXTREME EXTENSION.[38]

_18_, Femur; _20_, patella (base); _21_, tibia; _d_, internal semilunar cartilage. (After Ellenberger-Baum, Anat. für Künstler.)]

=Ligaments.=—There are four of these—two lateral and two crucial.

The =internal lateral ligament= (Ligamentum collaterale tibiale) is attached above to the prominent internal epicondyle of the femur, and below to a rough area below the margin of the internal condyle of the tibia.

The =external lateral ligament= (Ligamentum collaterale fibulare) is somewhat thicker; it arises from the upper depression on the external epicondyle, and ends on the head of the fibula. It covers the tendon of the origin of the popliteus muscle, and a bursa is interposed between the lower part of the ligament and the margin of the external condyle of the tibia.

The =crucial ligaments= are two strong rounded bands situated mainly in the intercondyloid fossa of the femur, between the two synovial sacs. They cross each other somewhat in the form of an X, and are named according to their tibial attachments. The =anterior crucial ligament= (Ligamentum cruciatum anterius) arises in the central fossa on the tibial spine, extends upward and backward, and ends on the upper part of the inner surface of the external condyle of the femur. The =posterior crucial ligament= (Ligamentum cruciatum posterius) is internal to the preceding, and is somewhat larger. It is attached to an eminence at the popliteal notch of the tibia, is directed upward and forward, and ends in the anterior part of the intercondyloid fossa of the femur.

[Illustration:

FIG. 161.—RIGHT STIFLE JOINT OF HORSE; SAGITTAL SECTION PASSING THROUGH OUTER PART OF INNER RIDGE OF TROCHLEA AND INTERCONDYLOID FOSSA.

_1_, Anterior crucial ligament; _2_, posterior crucial ligament; _3_, posterior cornu of internal semilunar cartilage; _4_, femoral ligament of external semilunar cartilage; _5_, articular artery; _6_, part of vastus internus.]

It may be added that these ligaments do not lie in a sagittal plane, but are somewhat twisted across each other; outward rotation of the leg untwists and slackens them.

=Movements.=—The principal movements of the stifle joint as a whole are flexion and extension. In the ordinary standing position the articular angle (behind) is about 140° to 150°. Flexion is limited only by contact of the leg with the thigh if the hock is also flexed. Extension is incomplete, _i. e._, the femur and tibia cannot be brought into the same straight line. Rotation is limited, and is freest during semiflexion. The patella glides on the femoral trochlea upward in extension, downward in flexion.

Extension is checked mainly by tension of the crucial and lateral ligaments. In extreme extension, which is accompanied by slight outward rotation of the leg, the patella can be pushed upward and inward so that its fibro-cartilage hooks over the upper end of the inner ridge of the trochlea, but it will not remain there unless held in position. When pressure is removed, the base of the patella tips forward and the cartilage lies upon the most prominent part of the trochlear ridge. During flexion, which is accompanied by slight inward rotation of the leg, the condyles of the femur and the semilunar cartilages glide backward on the tibia; the movement of the external condyle and cartilage is greater than that of the inner one. In extreme flexion the patellar and posterior crucial ligaments are tense; the other ligaments are relaxed. The movement of the patella is gliding with coaptation, _i. e._, different parts of the opposing articular surfaces come into contact successively. Only a narrow transverse strip (ca. 1.5 to 2 cm. wide) of the patella is in contact with the trochlea at a time.

TIBIO-FIBULAR ARTICULATION

The head of the fibula articulates with a crescentic facet just below the outer margin of the external condyle of the tibia. The =joint capsule= is strong and close. The shaft of the fibula is attached to the external border of the tibia by the =interosseous membrane= of the leg (Membrana interossea cruris); this is perforated about an inch from its proximal end by an opening which transmits the anterior tibial vessels to the front of the tibia. A fibrous cord usually extends from the distal end of the shaft of the fibula to the external malleolus. The latter is the distal end of the fibula which has fused with the tibia. No appreciable movement occurs in this joint.

[Illustration:

FIG. 162.—LEFT HOCK JOINT OF HORSE, EXTERNAL VIEW.]

[Illustration:

FIG. 163.—LEFT HOCK JOINT OF HORSE, INTERNAL VIEW.

_21_, Tibia; _24_, tuber calcis; _25_, large metatarsal bone; _47_, long external lateral ligament; _51_, long internal lateral ligament. (After Ellenberger-Baum, Anat. für Künstler.)]

THE HOCK JOINT

This is a composite joint made up of a number of articulations (Articulationes tarsi). These are: (1) The tibio-tarsal articulation; (2) the intertarsal articulations; (3) the tarso-metatarsal articulation.

The =tibio-tarsal articulation= (Articulatio talo-cruralis) is a typical ginglymus formed by the trochlea of the tibial tarsal bone (astragalus or talus) and the corresponding surface of the distal end of the tibia. The ridges and grooves of these surfaces are directed obliquely forward and outward at an angle of about 12° to 15°, with a sagittal plane. The trochlear surface is about twice as extensive as that on the tibia, and its ridges have a spiral curvature. The other articulations are arthrodia, which have joint surfaces and ligaments of such a nature as to allow only a minimal amount of gliding motion.

As in the case of the carpal joints, it is convenient to describe first the common capsule and ligaments, which are the more important practically, and then to consider very briefly the special ligaments.

The fibrous part of the =joint capsule= is attached around the margin of the tibial articular surface above and the metatarsal surfaces below; it is also attached in part to the free surface of the bones which it covers, and blends with the lateral ligaments. Its anterior part (anterior ligament) is rather thin; in distention of the capsule, as in "bog-spavin," its antero-internal part, which is not bound down by the tendons passing over the joint, forms a fluctuating swelling over the inner ridge of the trochlea. The posterior part (posterior and tarso-metatarsal ligaments) is very thick, and is intimately attached to the tarsal bones. Its superficial face is in part cartilaginous, and forms a smooth surface for the perforans tendon. Superiorly, it pouches upward behind the distal end of the tibia for a distance of about two inches (ca. 5 cm.). Interiorly, it is continued downward, forming the =subtarsal= or =check ligament=, which unites with the perforans tendon about the middle of the metatarsus.

[Illustration:

FIG. 164.—LEFT HOCK JOINT OF HORSE, ANTERIOR VIEW.

_21_, Tibia; _22_, trochlea of tibial tarsal bone; _25_, large metatarsal bone; _50_, dorsal or oblique ligament. (After Ellenberger-Baum, Anat. für Künstler.)]

There are four =synovial sacs=: 1. The =tibio-tarsal sac= lubricates the proximal joint, and is much the largest and most important. It is chiefly involved in the swelling produced by excess of fluid in the joint cavity, when the capsule bulges antero-internally and postero-superiorly. 2. The =first intertarsal sac= lines the joints formed by the tibial and fibular tarsal bones above, and the central and fourth tarsals below; it communicates in front with the proximal synovial capsule. 3. The =second intertarsal sac= lubricates the joints formed between the central tarsal and the bones below and on either side. 4. The =tarso-metatarsal sac= lubricates the joints formed between the tarsal and metatarsal bones, those between the proximal ends of the metatarsal bones, and those formed by the third tarsal with the bones on either side.

=Common Ligaments.=—The =external lateral ligament= (Ligamentum collaterale fibulare longum et breve) consists of two distinct bands which cross each other. The =long= (superficial) =ligament= arises on the posterior part of the external malleolus, is directed almost straight downward, and is attached to the fibular and fourth tarsal bones and the large and external small metatarsal bones. It forms a canal for the lateral extensor tendon. The =short= (deep) =ligament= arises on the anterior part of the external malleolus, is directed chiefly backward, and ends on the rough excavation on the external surface of the tibial tarsal and the adjacent surface of the fibular tarsal bone.

[Illustration:

FIG. 165.—LEFT HOCK JOINT OF HORSE, POSTERIOR VIEW.

_21_, Tibia; _24_, tuber calcis. (After Ellenberger-Baum, Anat. für Künstler.)]

The =internal lateral ligament= (Ligamentum collaterale tibiale longum et breve) also consists of two parts which cross each other. The =long ligament= arises on the posterior part of the internal malleolus, becomes wider below, and is attached on the lower tuberosity of the tibial tarsal, the large and outer small metatarsal bones, and the inner surface of the lower tarsal bones which it covers. The =short ligament= lies largely under cover of the long one. It extends from the anterior part of the internal malleolus, runs backward and somewhat downward, and divides into two branches; one of these ends on the upper tuberosity on the inner surface of the tibial tarsal bone, the other on the sustentaculum tali.

The =plantar= or =calcaneo-metatarsal ligament= (Ligamentum tarsi plantare) is a very strong flat band which covers the outer part of the posterior surface of the tarsus. It is attached to the posterior surface of the fibular and fourth tarsal bones and the proximal end of the external metatarsal bone.

The =dorsal= or =oblique ligament= (Ligamentum tarsi dorsale) is a triangular sheet which is attached above to the lower tuberosity on the inner face of the tibial tarsal bone, and spreads out below on the central and third tarsal bones, and the proximal ends of the large and inner small metatarsal bones, to all of which it is attached.

=Special Ligaments.=—A considerable number of short bands which connect adjacent bones of the tarsus and metatarsus are described by various authors; some of these are quite distinct; others are difficult to isolate. Most of them are not of sufficient importance to justify detailed description.

(1) The =tibial= and =fibular tarsal= bones are united by four bands (astragalo-calcaneal ligaments). The =internal ligament= extends from the sustentaculum tali to the adjacent part of the tibia tarsal, blending with the short lateral ligament. The =external ligament= extends from the anterior process of the fibular tarsal to the adjacent part of the external ridge of the trochlea. The =superior ligament= extends from the posterior margin of the trochlea to the fibular tarsal. The =interosseous ligament= is deeply placed in the sinus tarsi between the two bones, and is attached in the rough areas of the opposed surfaces.

(2) The smaller bones are attached to each other as follows: The central and third tarsal are united by an interosseous and an oblique anterior ligament (scaphoido-cunean ligaments). The central and fourth tarsal are united by an interosseous and a transverse external ligament (cuboido-scaphoid ligament). The third and fourth tarsals are similarly connected (cuboido-cunean ligaments). The third tarsal is joined by an interosseous (intercunean) ligament to the (fused) first and second tarsals; the latter are connected with the fourth tarsal by a transverse posterior ligament.

(3) The smaller bones are connected with the upper row as follows: The central is attached to the tibial tarsal by posterior and interosseous (astragalo-seaphoid) ligaments, and to the fibular tarsal by a short oblique (calcaneo-scaphoid) band. The fourth is attached to the fibular tarsal by interosseous and posterior (calcaneo-cuboid) ligaments. The (fused) first and second tarsals are connected with the fibular tarsal by a posterior (calcaneo-cunean) ligament.

(4) The lower tarsal bones are connected with the metatarsus by tarso-metatarsal ligaments, which are not distinct from the common ligaments, except in the case of the interosseous ligament between the third tarsal and metatarsal bones.

[Illustration:

FIG. 166.—SAGITTAL SECTION OF HOCK OF HORSE.]

=Movements.=—These are flexion and extension, which take place at the tibio-tarsal joint. The movements between the tarsal bones, and between the latter and the metatarsus, are so limited as to be negligible so far as the action of the joint as a whole is concerned. In the standing position the articular angle (in front) is about 150° to 160°. Complete extension is prevented by tension of the lateral ligaments. Flexion is checked only by contact of the metatarsus with the leg, provided the stifle joint is also flexed. Owing to the fact that the axis of motion is slightly oblique, the lower part of the limb deviates somewhat outward during flexion.

The movements of the hock joint must correspond with those of the stifle on account of the tendinous bands in front and behind (peroneus tertius and flexor perforatus), which extend from the lower part of the femur to the tarsus and metatarsus.

The remaining joints differ in no material respect from those of the thoracic limb.

COMPARATIVE ARTHROLOGY[39]

JOINTS AND LIGAMENTS OF THE VERTEBRÆ

=Ox.=—The ligamentum nuchæ is better developed than in the horse. The funicular part is clearly divided into two lateral halves, which are round at their occipital attachment, but from the axis backward become rapidly wider and flat. This wide portion is almost sagittal, lies on either side of the vertebral spines, and is covered by the trapezius and rhomboideus muscles. From the highest part of the withers (third thoracic spine) it gradually diminishes in size and fades out in the lumbar region. The lamellar part is thick, and consists of anterior and posterior parts. The anterior part is double; its fibers proceed from the funicular part to the second, third, and fourth cervical spines. The posterior part is single; its fibers extend from the first thoracic spine to the fifth, sixth, and seventh cervical spines.

[Illustration:

FIG. 167.—LIGAMENTUM NUCHÆ OF OX.

_a_, Funicular part; _b_, wide portion; _c_, _d_, lamellar part; _e_, interspinous ligaments; _1_, spinous process of first thoracic vertebra; _2_, axis. (Ellenberger-Baum, Anat. d. Haustiere.)]

The inferior common ligament is very strong in the lumbar region.

The intervertebral fibro-cartilages are thicker than in the horse.

The interspinous ligaments of the back and loins consist largely of elastic tissue.

There are no intertransverse joints in the lumbar region.

=Pig.=—The ligamentum nuchæ is represented by a fibrous raphé and thin layers of elastic tissue which extend between the cervical spines.

The atlanto-occipital and atlanto-axial joints resemble those of the dog.

The interspinous ligaments of the neck are elastic.

=Dog.=—The ligamentum nuchæ consists of a small fibrous band which extends from the spine of the axis to the anterior thoracic spines; it may be regarded as a mere fibrous raphé between the right and left muscles.

There are interspinous muscles instead of ligaments in the neck.

There are three ligaments in connection with the odontoid process. The two alar ligaments (Ligamenta alaria) arise on either side of the odontoid process, diverge, and end on either side of the foramen magnum. The transverse ligament of the atlas (Ligamentum transversum atlantis) stretches across the dorsal surface of the odontoid process and binds it down on the ventral arch of the atlas, a bursa being interposed. It is attached on either side to the lateral masses of the atlas.

The two capsules of the atlanto-occipital joint communicate with each other, and usually with the capsule of the atlanto-axial joint also.

ARTICULATIONS OF THE THORAX

=Ox.=—The second to the eleventh costo-chondral joints inclusive are diarthroses with close capsules, reinforced externally. (They are synchondroses in the sheep.) The upper parts of the cartilages are attached to each other by distinct elastic ligaments (Ligamenta intercostalia).

The first pair of chondro-sternal joints are separate from each other; intercrossing fibers unite the costo-chondral junctions above the joints.

The first segment of the sternum forms a diarthrosis with the body. The anterior joint surface is concave, the posterior convex. The joint (Articulatio intersternalis) is surrounded by a close capsule, and the joint surfaces are attached to each by a small intraarticular ligament. Limited lateral movement is possible. (In the sheep the joint is a synchondrosis.)

Both surfaces of the sternum are covered by a layer of fibrous tissue.

=Pig.=—The second to the fifth or sixth costo-chondral joints are diarthroses. The intersternal articulation and the sternal ligaments resemble those of the ox.

=Dog.=—The first chondro-sternal joints do not coalesce.

The internal sternal ligament divides into three bands.

TEMPORO-MANDIBULAR ARTICULATION

=Ox.=—The articular surfaces are of such a character as to permit more extensive lateral movement than in the horse.

The condyle of the mandible is relatively small and is concave transversely. The temporal articular surface is extensive and is convex in both directions. The postglenoid process is small.

=Pig.=—The considerable longitudinal diameter of the temporal articular surfaces and the very small size of the postglenoid process allow great freedom of protraction and retraction of the lower jaw. Lateral movement is limited. The posterior ligament is absent.

=Dog.=—The articular surfaces allow extremely little lateral or gliding movement. They are cylindrical in curvature, and the interarticular disc is very thin. The posterior ligament is absent.

The other articulations of the skull are sufficiently described in the Osteology.

Articulations of the Thoracic Limb

SHOULDER JOINT

=Ox.=—The articular angle is about 100°.

=Pig and Dog.=—The joint capsule communicates freely with the bicipital bursa. There is a rudimentary marginal cartilage around the rim of the glenoid cavity. In the dog there is usually a strong band extending from the acromion to the outer part of the capsule; another band (Ligamentum coraco-acromiale) often stretches between the scapular tuberosity and the acromion.

ELBOW JOINT

=Ox.=—No important differences exist. The upper part of the interosseous radio-ulnar ligament is commonly ossified in the adult.

=Pig.=—There are no important differences. The radius and ulna are so firmly united by the interosseous ligament as to prevent any appreciable movement between them.

=Dog.=—The joint capsule is reinforced in front by an oblique ligament which arises on the front of the external condyle of the humerus above the joint surface, and joins the terminal part of the biceps and brachialis below. The external lateral ligament is thick and divides into two parts; the anterior part is attached to the radius and blends with the annular ligament; the posterior part widens below, forming a sort of cap, and is attached to the ulna. The internal lateral ligament also divides into two branches; the anterior branch ends on the inner surface of the neck of the radius; the posterior enters the interosseous space and is attached to both bones. An elastic band (Ligamentum olecrani) extends from the outer surface of the internal epicondyle to the anterior border of the ulna.

There are two radio-ulnar joints. The proximal radio-ulnar joint is included in the capsule of the elbow, but is provided with an annular ligament which extends from the lower part of the external ligament across the front of the proximal end of the radius to the ulna, blending with the biceps and brachialis tendons. The distal joint is formed by a concave facet on the radius and a convex one on the radius, and is surrounded by a tight capsule. The interosseous membrane unites the shafts of the two bones. The movements consist of limited rotation of the radius (ca. 20°), carrying the paw with it. The ordinary position is termed pronation; outward rotation is supination.[40]

THE CARPAL JOINTS

These have the same general arrangement as in the horse. Numerous minor differences naturally exist, but must be excluded from this brief account, which contains only important special features.

The lateral movements are freer, especially in the dog, but flexion is not so complete: the anatomical explanation of these facts lies in the nature of the articular surfaces and certain ligamentous differences. The lateral ligaments are much weaker, the long external one being especially small in the ox. Two oblique, somewhat elastic, bands cross the front of the radio-carpal and intercarpal joints. The proximal one is attached to the distal end of the radius and passes downward and outward to the ulnar carpal bone; the other one connects the radial and fourth carpal bones in a similar fashion.

In the ox the short lateral ligaments are well defined, a ligament connects the accessory carpal with the distal end of the ulna, and strong bands connect the distal bones with the metacarpus.

The interosseous and interordinal ligaments vary with the number of carpal bones present in the different species.

INTERMETACARPAL JOINTS

In the ox the small (fifth) metacarpal bone articulates with the large metacarpal, but not with the carpus. The joint cavity is connected with that of the carpo-metacarpal sac. The proximal end of the small metacarpal bone is attached by a ligament to the fourth carpal, and another band extends from its distal part to the side of the large metacarpal. There is also an interosseous ligament, which is permanent and allows a small amount of movement.

The chief metacarpal bones of the pig, and the second to the fifth of the dog, articulate with each other at their proximal ends, and are connected by interosseous ligaments, which do not, however, unite them closely, as in the horse.

[Illustration:

FIG. 168.—DISTAL PART OF LIMB OF OX, SHOWING LIGAMENTS AND TENDONS. ONE DIGIT AND CORRESPONDING ARTICULAR PART OF METACARPAL BONE ARE REMOVED.

_a_, Suspensory ligament; _a′_, branch of _a_ to superficial flexor tendon; _a″_, _a■_, lateral and central branches of _a_; _b_, deep flexor tendon; _b′_, branch of _b_ to digit removed; _c_, _c′_, superficial flexor tendon; _d_, _d′_, intersesamoid ligament (cut); _e_, interdigital lateral ligament of fetlock joint; _f_, tendon of common extensor; _g_, proximal interdigital ligament; _h_, digital annular ligament; _i_, posterior annular ligament of fetlock; _k_, lateral ligament of pastern joint; _l_, distal interdigital ligament; _m_, crucial interdigital ligament (cut); _m′_, _m″_, attachments of _m_ to second phalanx and distal sesamoid bone; _n_, suspensory ligament of distal sesamoid; _o_, anterior elastic ligament; _p_, lateral volar ligament of pastern joint; _1_, metacarpus, sawn off at _1′_; _2_, first phalanx; _3_, second phalanx; _4_, third phalanx. (Ellenberger-Baum, Anat. d. Haustiere.)]

METACARPO-PHALANGEAL JOINTS

=Ox.=—There are two joints, one for each digit. The two capsules communicate posteriorly. The two interdigital lateral ligaments (Ligamenta collateralia interdigitalia) result from the bifurcation of a band which arises in the furrow between the divisions of the distal end of the large metacarpal bone; they spread out and end on the proximal ends of the first phalanges. A strong =superior interdigital ligament= (Ligamentum interdigitale), consisting of short intercrossing fibers, unites the middles of the interdigital surfaces of the first phalanges.

Crucial ligaments (Ligamenta phalango-sesamoideæ) connect the sesamoids with the proximal end of the opposite first phalanx.

The intersesamoid ligament connects all four sesamoids, and extends upward much less than in the horse.

The lateral sesamoidean ligaments end almost entirely on the first phalanges.

The superficial inferior sesamoidean ligament is absent. The middle inferior sesamoidean ligaments of each digit are two short strong bands which extend from the distal margins of the sesamoids to the proximal ends of the first phalanges. The deep inferior sesamoidean ligaments are strong and distinctly crucial.

[Illustration:

FIG. 169.—LIGAMENTS AND TENDONS OF DIGITS OF PIG, VOLAR VIEW.

_a_, Superficial flexor tendon; _b_, deep flexor tendon; _b′_, branches of _b_ to accessory digits; _c_, _c′_, annular ligaments; _d-d■_, ligaments of accessory digits; _e_, cruciate interdigital ligaments; _f_, _f′_, spiral band around the flexor tendons of the accessory digits; _g_, abductor of accessory digit. (Ellenberger-Baum, Anat. d. Haustiere.)]

[Illustration:

FIG. 170.—LIGAMENTS AND TENDONS OF PAW OF DOG, HIND LIMB, VOLAR VIEW.

_a_, _a′_, Superficial flexor tendon; _b_, tendon to large pad; _c_, lumbricales muscles; _d_, interossei muscles; _e_, _f_, annular ligaments at metatarsophalangeal joints; _g_, suspensory ligament of large pad; _h_, digital annular ligaments; _i_, deep flexor tendon; _k_, distal sesamoid; _l_, suspensory ligament of _k_; _m_, suspensory ligament of digital pad; _n_, digital pads. (Ellenberger-Baum, Anat. d. Haustiere.)]

The suspensory or superior sesamoidean ligament is more distinctly muscular than in the horse—indeed in the young animal it consists almost entirely of muscular tissue. At the distal third of the metacarpus it divides into three branches. These give rise to five subdivisions, either by bifurcation of the lateral branches or trifurcation of the middle branch. The four lateral bands end on the sesamoid bones and the distal end of the large metacarpal bone, and detach slips to the extensor tendons. The middle band passes through the groove between the two divisions of the distal end of the metacarpus, and divides into two branches which join the tendons of the proper extensors of the digits; it sends fibers also to the interdigital lateral ligaments and to the central sesamoids. About the middle of the metacarpus the suspensory ligament detaches a band which unites lower down with the superficial flexor tendon, thus inclosing the tendon of the deep flexor of the digit; it also blends with the thick fascia of the region.

The latter gives off a band on either side to the accessory digits, and a tendinous band descends from each accessory digit to the third phalanx and sesamoid bone, blending with the tendon of the corresponding proper extensor.

=Pig.=—There are four metacarpo-phalangeal joints, each of which has a capsule, lateral, intersesamoidean, and crucial sesamoidean ligaments. Since distinct interosseous muscles are present, there are, of course, no suspensory ligaments.

=Dog.=—There are five metacarpo-phalangeal joints, each having its own capsule and indistinct lateral ligaments. A small sesamoid bone occurs in the anterior part of each capsule, over which the corresponding extensor tendon plays. The intersesamoidean ligaments do not extend above the sesamoids. The cruciate ligaments are present, as well as a fibrous layer which attaches the distal margins of the sesamoids to the posterior surface of the proximal end of the first phalanx.

INTERPHALANGEAL JOINTS

=Ox.=—The two proximal joints have separate capsules, and broad, but rather indistinct, lateral ligaments. Each joint has also two central and two lateral volar ligaments. The central ligaments are largely fused to form a strong band. The lateral ones extend from the borders of the first phalanx to the proximal end of the second phalanx.

The distal interphalangeal joints have, in addition to the capsules and lateral ligaments, bands which reinforce them on either side. The central or interdigital pair arise in the depressions on the distal ends of the first phalanges, receive fibers from the second phalanges, and end on the interdigital surfaces of the third phalanges at the margin of the articular surface. The lateral pair have a similar course, but are thinner, and end on the corresponding third sesamoid. An elastic band crosses the front of the second phalanx obliquely, from the distal end of the first phalanx to the extensor process of the third phalanx.

The =crucial= or =inferior interdigital ligaments= (Ligamenta cruciata interdigitalia) are two strong bands which limit the separation of the digits. They are attached above to the lateral (or abaxial) eminences on the proximal ends of the second phalanges (blending with the lateral ligaments), cross the deep flexor tendon obliquely, and reach the interdigital space, where they intercross and blend. Most of the fibers end on the third sesamoid of the opposite side, but some are attached to the interdigital aspect of the second phalanx and the third sesamoid of the same side. In the sheep there is, instead of the foregoing, a transverse ligament which is attached on either side to the interdigital surfaces of the second and third phalanges and the third sesamoid bone. It is related below to the skin, above to a pad of fat.

=Pig.=—The interphalangeal joints of the chief digits resemble in general those of the ox. The inferior interdigital ligament resembles, however, that of the sheep, and is intimately adherent to the skin. There is, besides, a remarkable arrangement of ligaments which connect the small digits with each other and with the chief digits.

This apparatus is somewhat complex, but its chief features are as follows: A superior interdigital ligament is attached on either side to the third phalanges of the small digits, while centrally it blends with the annular ligaments of the flexor tendons behind the metacarpo-phalangeal joints of the chief digits. Two bands (central longitudinal interdigital ligaments) arise on the bases of the small digits, cross the flexor tendons obliquely downward and inward, pass through the superior interdigital ligament, and blend below with the inferior interdigital ligament. Two lateral bands (lateral longitudinal interdigital ligaments) are attached in common with the superior interdigital ligaments to the third phalanges of the small digits, and blend below with the outer part of the inferior interdigital ligament.

=Dog.=—Each joint has a capsule and two lateral ligaments. The distal joints have also two elastic =dorsal ligaments= (Ligamenta dorsalia), which extend from the proximal end of the second phalanx to the ridge at the base of the third phalanx (Fig. 133). They produce dorsal flexion of the joint, and thus raise or retract the claws when the flexor muscles relax. The distal sesamoids are represented by complementary cartilages attached to the volar margins of the articular surfaces of the third phalanges.

Three interdigital ligaments restrict the spreading apart of the digits. Two of these cross the volar surface of the proximal parts of the chief digits, _i. e._, one for the second and third, the other for the fourth and fifth; they blend with the annular ligaments on either side. The third ligament is attached on either side to the foregoing ligaments and the annular ligaments of the third and fourth digits, and curves downward centrally, ending in the large pad on the paw.

ARTICULATIONS OF THE PELVIC LIMB

SACRO-ILIAC JOINT

This joint and the pelvic ligaments present no very striking differences in the other animals. The sacro-sciatic ligament in the dog is a narrow but strong band which extends from the posterior part of the lateral margin of the sacrum to the tuber ischii; it is the homologue of the ligamentum sacro-tuberosum of man.

HIP JOINT

=Ox.=—The shallowness of the acetabulum is compensated by the greater size of the marginal cartilage. The head of the femur has a smaller radius of curvature than that of the horse, and the articular surface extends a considerable distance outward on the upper surface of the neck. The round ligament is entirely intraarticular; it is small, and sometimes absent. The pubo-femoral or accessory ligament is absent.

There are no important differences in the other animals.

STIFLE JOINT

=Ox.=—There is a considerable communication between the femoro-patellar and inner femoro-tibial joint cavities; this is situated as in the horse, but is wider. A small communication with the external femoro-tibial capsule sometimes occurs. The two femoro-tibial capsules usually communicate. The middle patellar ligament is not sunken, as there is no groove on the tuberosity of the tibia where it is attached. The external patellar ligament fuses completely with the tendon of insertion of the biceps femoris, and a synovial bursa is interposed between them and the external condyle of the femur.

In the other animals there is a single ligamentum patellæ, and the synovial sacs communicate so freely as to constitute a common joint cavity. In the dog the semilunar cartilages are united anteriorly by a transverse ligament, and the posterior part of the capsule contains the two Vesalian sesamoids, which articulate with the condyles of the femur.

TIBIO-FIBULAR JOINTS

=Ox.=—The proximal end of the fibula fuses with the external condyle of the tibia. The distal end remains separate, and forms an arthrosis with the distal end of the tibia; the movement here is imperceptible, as the two bones are closely united by strong peripheral fibers.

=Pig.=—The superior joint is provided with a capsule which is reinforced in front and behind by fibrous tissue.

The interosseous ligament attaches the shaft of the fibula to the outer border of the tibia.

The inferior joint is included in the capsule of the hock joint, and is strengthened by oblique anterior and posterior ligaments. There is also an interosseus ligament.

=Dog.=—The arrangement is essentially the same as in the pig, but there is no interosseous ligament in the inferior joint.

HOCK JOINT

=Ox.=—There is very considerable mobility at the first intertarsal joint, the capsule of which is correspondingly roomy. The short external lateral ligament is attached below on the tibial tarsal only. A strong transverse ligament attaches the external malleolus (distal end of the fibula) to the back of the tibial tarsal bone. The dorsal or oblique ligament is narrow and thin.

=Pig.=—The arrangement in general resembles that of the ox.

=Dog.=—The long lateral ligaments are very small, and the short ones double. The plantar ligament is weak, and ends on the fourth metacarpal bone. No distinct dorsal (or oblique) ligament is present. Movement occurs almost exclusively at the tibio-tarsal joint.

The remaining joints resemble those of the thoracic limb.

THE MUSCULAR SYSTEM

MYOLOGY

The =muscles= (Musculi) are the active organs of motion. They are characterized by their property of contracting when stimulated. Muscular tissue is of three kinds: (_a_) =Striated= or striped; (_b_) =non-striated=, unstriped, or smooth; and (_c_) =cardiac=. Only the first of these varieties will be considered in this section. The striped muscles, being for the most part directly or indirectly connected with the skeleton, are often termed =skeletal= or somatic, while unstriped muscle may be spoken of as =visceral= or splanchnic. The former cover the greater part of the skeleton, and thus in a large measure determine the form of the animal. They are red in color, the shade varying in different muscles and under various conditions.

Muscles vary greatly in =form=, and may be classified as—(_a_) =Long=; (_b_) =short=; (_c_) =flat=; (_d_) =ring-like= or =orbicular=. Long muscles are found chiefly in the limbs, while the flat or broad muscles occur principally in the trunk, where they assist in forming the walls of the body cavities. The ring-like or orbicular muscles circumscribe orifices which they close, and are hence termed =sphincters=.

=Attachments.=—The muscles are attached to =bones=, =cartilages=, =ligaments=, =fasciæ=, or the =skin=. In all cases the attachment is by means of fibrous tissue, the muscle-fibers not coming into direct relation with the bone or cartilage. The perimysium of the muscle may fuse directly with the periosteum or perichondrium (fleshy attachment), or the union may be by means of intermediary fibrous structures called =tendons= or =aponeuroses= (tendinous attachment). Tendons may be funicular, ribbon-like, or in the form of membranous sheets; to the latter the term aponeurosis is commonly applied.

In certain positions, especially where tendons play over joints or are subjected to great pressure, =sesamoid bones= develop in the original tendon tissue. Some of these are large and constant, as the patella and the great sesamoids of the fetlock.

The accessory structures connected with the muscles are the =synovial membranes= and the =fasciæ=.

[Illustration:

FIG. 171.—DIAGRAMS OF CROSS-SECTIONS OF TENDON SHEATH (A) AND BURSA (B); T, TENDON.]

The =synovial membranes= are arranged in two principal forms: (_a_) =Bursal=; (_b_) =vaginal=. A =bursa= (Bursa mucosa) is a simple sac interposed between the tendon or muscle and some deeper seated structure—most commonly a bony prominence. A =vagina tendinis= or =tendon sheath= differs from a bursa in the fact that the synovial sac is folded around the tendon more or less completely, so that two layers can be distinguished; of these, the inner one adheres closely to the tendon, while the outer lines the groove or canal in which the tendon lies. The two layers are continuous along a fold termed the =mesotendon=. The arrangement is shown in Fig. 171.[41] The articular synovial membranes in some places form extra-articular pouches, which facilitate the play of tendons.

The =fasciæ= are sheets of connective tissue, mainly of the white fibrous variety, with a greater or less admixture of elastic fibers in certain cases. Two layers may usually be recognized. Of these, the =superficial fascia= (Fascia subcutanea) is composed of loose connective tissue which may contain more or less fat and is subcutaneous. The =deep fascia= is composed of one or more layers of dense fibrous tissue spread over the surface of the muscles chiefly. Its deep face may be very loosely attached to the underlying structures or may fuse with the epimysium, tendons, bones, or ligaments. In some parts, especially the limbs, septal plates pass between the muscles and are attached to the bones or ligaments; these are termed =intermuscular septa=. In this way many muscles are inclosed in fibrous sheaths which hold them in position. Not uncommonly special bands stretch across the grooves in which tendons play, converting these into canals. Such bands are termed =vaginal= or =annular ligaments=. The deep fascia is often so distinctly tendinous in structure, furnishing attachment to special tensor muscles, as to render the distinction between fascia and aponeurosis quite arbitrary. Bursæ occur in certain situations between the fascia and underlying structures (subfascial bursæ), or between the fascia and the skin (subcutaneous bursæ).

It is convenient to divide the description of a muscle into seven heads, viz.: (1) Name, followed by important synonyms; (2) position and form; (3) attachments; (4) action; (5) structure; (6) relations; (7) blood and nerve supply.

1. The =name= is determined by various factors, viz.: (_a_) The action, _e. g._, extensor, adductor, etc.; (_b_) the shape, _e. g._, quadratus, triangularis; (_c_) the direction, _e. g._, rectus, obliquus; (_d_) the position, _e. g._, the subscapularis, iliacus; (_e_) the division (into heads, etc.), _e. g._, biceps, triceps, etc.; (_f_) the size, _e. g._, major, minor, etc.; (_g_) the attachments, _e. g._, sterno-cephalicus, mastoido-humeralis; (_h_) the structure, _e. g._, semitendinosus. In most cases two or more of these factors have combined to produce the name, _e. g._, adductor magnus, longus colli, obliquus externus abdominis.

2. The =shape= is, in many cases, sufficiently definite to allow the use of such terms as triangular, quadrilateral, fan-shaped, long, flat, fusiform, ring-like, etc.

3. The =attachments= are in most cases to bone, but many muscles are attached to cartilage, ligaments, fascia, the skin, etc. It is usual to apply the term =origin= to the attachment which always or more commonly remains fixed when the muscle contracts. The term =insertion= designates the movable attachment. Such a distinction cannot always be made, as the action may be reversible, or both attachments may be freely movable.

4. The =action= belongs rather to physiological study, but is briefly indicated in anatomical descriptions.

5. The =structure= includes the direction of the muscle-fibers, the arrangement of the tendons, the synovial membranes, and any other accessory structures, _e. g._, annular ligaments and reinforcing sheaths and bands. The relation of the muscle-fibers to the tendon varies, and this fact has given rise to special terms. Thus a muscle in which the fibers converge to either side of the tendon is termed =bipennate=; while one in which this arrangement exists only on one side of the tendon is called =unipennate=. The terms fleshy and tendinous are used to indicate the relative amounts of muscular and tendinous tissue. The muscular tissue is often spoken of as the =belly= (Venter) of the muscle. In the case of the long muscles, the origin is often termed the =head= (Caput). Muscles having two or more heads are called biceps, triceps, etc. =Digastric= muscles are those which have two bellies joined by an intermediate tendon. Ring-like muscles which circumscribe openings are termed =sphincters=, on account of their action.

6. The =relations= are, of course, important on surgical grounds.

7. The =nerve-supply= is of clinical interest, and is important for the determination of homologies.

FASCIÆ AND MUSCLES OF THE HORSE

PANNICULUS CARNOSUS

The =panniculus carnosus= (Musculus cutaneus) is a thin muscular layer developed in the superficial fascia. It is intimately adherent in great part to the skin, but has very little attachment to the skeleton. It does not cover the entire body, and may be conveniently divided into facial, cervical, thoracic, and abdominal portions, each of which will be described with the muscles of the corresponding region.

THE FASCIÆ AND MUSCLES OF THE HEAD

The muscles of the head may be divided into three groups, viz.: (1) Superficial muscles, including the panniculus and those of the lips, cheeks, nostrils, eyelids, and external ear; (2) the orbital muscles; (3) the muscles of mastication.

The =superficial fascia= forms an almost continuous layer, but is very scanty around the natural orifices. It contains a number of the thin superficial muscles, so that care must be exercised in removing the skin. Over the frontal and nasal bones the fascia blends with the periosteum.

The =deep fascia= is of special interest in three regions. The =temporal fascia= covers the temporalis muscle, and is attached to the parietal and frontal crests internally, and to the zygomatic arch externally. The =buccal fascia= covers the buccinator muscle and the free part of the outer surface of the ramus of the jaw. Superiorly it is attached to the facial crest, and posteriorly it forms a band (Ligamentum pterygomandibulare) which stretches from the hamulus of the pterygoid bone to the mandible behind the last molar tooth. It is directly continuous with the =pharyngeal fascia=, which is attached to the great and thyroid cornua of the hyoid bone, covers the lateral walls of the pharynx, and blends dorsally with the median raphé of the constrictor muscles of the latter.

SUPERFICIAL MUSCLES

1. =Panniculus carnosus.=—The facial panniculus (M. cutaneus faciei) consists of a thin and usually incomplete muscular stratum, which covers the submaxillary space and the masseter muscle. A branch from it passes forward to the angle of the mouth and blends with the orbicularis oris; this part (M. cutaneus labiorum) retracts the angle of the mouth. (A number of the superficial muscles of the face may be considered modified parts of the panniculus, _e. g._, the corrugator supercilii, malaris, zygomaticus, etc.)

MUSCLES OF THE LIPS AND CHEEKS

1. =Orbicularis oris.=—This is the sphincter muscle of the mouth; it is continuous with the other muscles which converge to the lips. It lies between the skin and the mucous membrane of the lips, and is intimately adherent to the former. Most of the fibers run parallel to the free edges of the lips and have no direct attachment to the skeleton.

Action.—It closes the lips.

Blood-supply.—Palato-labial, facial, and mental arteries.

Nerve-supply.—Facial nerve.

[Illustration:

FIG. 172.—MUSCLES OF HEAD OF HORSE, LATERAL VIEW. THE PANNICULUS IS REMOVED.

_a_, Levator labii superioris proprius; _b_, levator nasolabialis; _c_, mastoido-humeralis; _d_, sterno-cephalicus; _d′_, tendon of _d_; _e_, omo-hyoideus; _f_, dilatator naris lateralis; _g_, zygomaticus; _h_, buccinator; _i_, depressor labii inferioris; _k_, orbicularis oris; _l_, dilatator naris superior; _m_, masseter; _n_, parotido-auricularis; _o_, zygomatico-auricularis; _p_, interscutularis; _p′_, fronto-scutularis, pars temporalis; _q_, cervico-auricularis profundus major; _r_, cervico-auricularis superficialis; _s_, obliquus capitis anterior; _t_, splenius; v, stylo-maxillaris; _y_, mastoid tendon of mastoido-humeralis; _2_, posterior, _3_, anterior, border of external ear; _8_, scutiform cartilage; _9_, zygomatic arch; _10_, depression behind supraorbital process; _18_, temporo-mandibular articulation; _27_, facial crest; _30′_, angle of jaw; _37_, external maxillary vein; _38_, jugular vein; 39, facial vein; _40_, parotid duct; _41_, transverse facial vein; _42_, masseteric vein; _43_, facial nerve; _44_, parotid gland; _45_, chin; _x_, wing of atlas. (After Ellenberger-Baum, Anat. für Künstler.)]

2. =Levator nasolabialis= (Levator labii superioris alæque nasi).—This thin muscle lies directly under the skin, and chiefly on the lateral surface of the nasal region.

Origin.—The frontal and nasal bones.

Insertion.—(1) The upper lip and the outer wing of the nostril; (2) the commissure of the lips.

Action.—(1) To elevate the upper lip and the commissure; (2) to dilate the nostril.

Structure.—The muscle arises by a thin aponeurosis. The belly is also thin, and divides into two branches, between which the lateral dilator of the nostril passes. The dorsal branch reaches the nostril and upper lip, blending with the lateral dilator; the ventral one is much smaller, and blends at the labial commissure with the orbicularis and buccinator.

Relations.—Superficially, the skin, fascia, and lateral dilator (in part); deeply, the levator labii superioris proprius, lateral dilator (in part), buccinator, branches of the facial vessels and nerve, and the infraorbital artery and nerve.

Blood-supply.—Facial and palato-labial arteries.

Nerve-supply.—Facial nerve.

[Illustration:

FIG. 173.—MUSCLES OF HEAD OF HORSE, DORSAL VIEW. THE PANNICULUS IS REMOVED.

_a_, Levator labii superioris proprius; _a′_, common tendon of a with opposite muscle; _b_, levator nasolabialis; _f_, dilatator naris lateralis; _g_, zygomaticus; _l_, dilatator naris superior; _n_, parotido-auricularis; _o″_, scutulo-auricularis superficialis superior; _p_, interscutularis; _p′_, fronto-scutularis, pars temporalis; _r_, cervico-auricularis superficialis; _u_, corrugator supercilii; _x_, transversus nasi; _2_, posterior, _3_, anterior, border of external ear; _8_, scutiform cartilage; _9_, zygomatic arch; _10_, supraorbital depression; _35_, inner wing of nostril, containing lamina of alar cartilage; _39_, facial vein. (After Ellenberger-Baum, Anat. für Künstler.)]

3. =Levator labii superioris proprius.=—This lies on the dorso-lateral aspect of the face, partly covered by the preceding muscle.

Origin.—The lacrimal, malar, and maxillary bones at their junction.

Insertion.—The upper lip, by a common tendon, with its fellow.

Action.—Acting with its fellow, to elevate the upper lip. This action, if carried to the fullest extent, results in eversion. In unilateral action the lip is drawn upward and to the side of the muscle acting.

Structure.—The muscle has a short, thin tendon of origin. The belly is at first flattened, but becomes narrower and thicker, then tapers over the false nostril, to terminate in a tendon. The tendons of the two muscles unite over the alar cartilages of the nostrils, forming an expansion which spreads out in the substance of the upper lip.

Relations.—Superficially, the skin, the levator nasolabialis, and the angular vessels of the eye; deeply, the superior and transverse dilators of the nostril and the infraorbital artery and nerve.

Blood-supply.—Facial artery.

Nerve-supply.—Facial nerve.

4. =Zygomaticus.=—This very thin muscle lies immediately under the skin of the cheek.

Origin.—The fascia covering the masseter muscle below the facial crest.

Insertion.—The commissure of the lips, blending with the buccinator.

Action.—To retract and raise the angle of the mouth.

Structure.—Fleshy, with a thin aponeurotic origin.

Relations.—Superficially, the skin; deeply, the buccinator.

Blood-supply.—Facial artery.

Nerve-supply.—Facial nerve.

5. =Incisivus superior= (Depressor labii superioris).—This lies under the mucous membrane of the upper lip.

Origin.—The alveolar border of the premaxilla from the second incisor to the first cheek tooth.

Insertion.—The upper lip.

Action.—To depress the upper lip.

6. =Incisivus inferior.=—This is arranged in the lower lip like the preceding muscle in the upper one.

Origin.—The alveolar border of the mandible from the second incisor to a point near the first cheek tooth.

Insertion.—The skin of the lower lip and the prominence of the chin.

Action.—To raise the lower lip.

7. =Mentalis= (Levator menti).—This is situated in the prominence of the chin. Its fibers arise from each side of the body of the mandible and are inserted into the skin of the chin. It is mingled with fat and strands of connective tissue, in which the roots of the tactile hairs are embedded. It raises and corrugates the skin to which it is attached.

8. =Depressor labii inferioris.=—This muscle lies on the outer surface of the ramus of the mandible, along the ventral border of the buccinator.

Origin.—The alveolar border of the mandible near the coronoid process and the maxillary tuberosity, in common with the buccinator.

Insertion.—The lower lip.

Action.—To depress and retract the lower lip.

Structure.—The tendon of origin and the belly are fused with the buccinator as far forward as the first cheek tooth. From this point forward the belly is distinct and rounded, terminating in a tendon which spreads out in the lower lip, blending with the orbicularis and the muscle of the opposite side.

Relations.—Superficially, the skin, masseter, facial vessels, and parotid duct; deeply, the mandible and inferior labial artery.

Blood-supply.—Facial artery.

Nerve-supply.—Facial nerve.

9. =Buccinator.=—This muscle lies in the lateral wall of the mouth, extending from the angle of the mouth to the maxillary tuberosity.

Origin.—The external surface of the maxilla above the interdental space and the molar teeth; the alveolar border of the mandible at the interdental space and also posteriorly where it turns upward to the coronoid process; the pterygo-mandibular ligament.

Insertion.—The angle of the mouth, blending with the orbicularis oris.

Action.—To flatten the cheeks, thus pressing the food between the teeth; also to retract the angle of the mouth.

Structure.—Two layers may be recognized. The =superficial layer= (Pars buccalis) extends from the angle of the mouth to the masseter. It is incompletely pennate, having a longitudinal raphé on which most of the muscle-fibers converge. The upper fibers are directed chiefly downward and backward, the lower ones upward and backward. The =deep layer= (Pars molaris) consists mainly of longitudinal fibers. It blends in part with the superficial layer of the orbicularis; it has a small tendinous attachment to the coronoid process behind, and is united below with the depressor labii inferioris.

Relations.—Superficially, the skin and fascia, the zygomaticus, levator nasolabialis, lateral dilator of the nostril, the superior buccal glands, the parotid duct, the facial vessels, and branches of the facial nerve; deeply, the mucous membrane of the mouth and the inferior buccal glands.

Blood-supply.—Facial and buccinator arteries.

Nerve-supply.—Facial nerve.

MUSCLES OF THE NOSTRILS

1. =Levator nasolabialis.=—This has been described (p. 214).

2. =Dilatator naris lateralis= (M. caninus).—This thin, triangular muscle lies on the lateral nasal region, and passes between the two branches of the levator nasolabialis.

Origin.—The maxilla, close to the anterior extremity of the facial crest.

Insertion.—The outer wing of the nostril.

[Illustration:

FIG. 174.—NASAL AND SUPERIOR LABIAL MUSCLES OF HORSE.

_a_, _a′_, Dilatator naris transversus; _b_, levator labii superioris proprius; _b′_, tendon of _b_; _b″_, common tendon of two levatores labii superioris proprii; _c_, _c′_, dilatator naris inferior; _d_, _e_, dilatator naris superior; _f_, orbicularis oris; _g_, levator nasolabialis, a portion of which is removed; _h_, dilatator naris lateralis (cut); _i_, cornu of alar cartilage; _k_, nostril; _k′_, false nostril; _l_, nasal diverticulum; _m_, nasal bone. (After Ellenberger-Baum, Top. Anat. d. Pferdes.)]

Action.—To dilate the nostril.

Structure.—The muscle has a flat tendon of origin, passes between the two branches of the levator nasolabialis, and spreads out in the external wing of the nostril. The lower fibers blend with the orbicularis oris.

Relations.—Superficially, the skin, fascia, and the labial branch of the levator nasolabialis; deeply, the maxilla and the nasal branch of the levator nasolabialis.

Blood-supply.—Facial artery.

Nerve-supply.—Facial nerve.

3. =Dilatator naris transversus= (M. transversus nasi).—This is an unpaired, quadrilateral muscle, which lies between the nostrils. It consists of two layers.

Attachments.—Superficial layer, the superficial faces of the laminæ of the alar cartilages; deep layer, the convex edges of the cornua of the same.

Action.—To dilate the nostrils.

Structure.—It is composed of transverse fleshy fibers, which blend below with the orbicularis.

Relations.—Superficially, the skin, fascia, and tendinous expansion of the levator labii superioris proprius; deeply, the alar cartilages, the extremity of the septum nasi, and the palato-labial artery.

Blood-supply.—Palato-labial artery.

Nerve-supply.—Facial nerve.

4. =Dilatator naris superior= (Pars dorsalis m. lateralis nasi).—This very thin muscle occupies the angle between the nasal process of the premaxilla and the nasal bone.

Origin.—The lateral border of the nasal bone.

Insertion.—The inner wall of the false nostril and the parietal lamina of the septal cartilage.

Action.—To dilate the vestibule of the nasal cavity.

Structure.—Fleshy.

Relations.—Superficially, the skin, fascia, and levator labii superioris proprius; deeply, the parietal cartilage and false nostril.

Blood-supply.—Facial artery.

Nerve-supply.—Facial nerve.

5. =Dilatator naris inferior= (Pars ventralis m. lateralis nasi).—This is a similar but thicker muscle, which lies on the nasal process of the premaxilla.

Origin.—The maxilla and the nasal process of the premaxilla.

Insertion.—The cartilaginous prolongations of the turbinal bones and the inner wall of the false nostril.

Action.—To rotate the turbinal outward and dilate the nostril and the vestibule of the nasal cavity.

Structure.—Fleshy. A division into two or more parts may be recognized. A small part posteriorly is inserted into the cartilage of the dorsal turbinal bone, while the bulk of the muscle is inserted into the cartilage of the ventral turbinal bone. A few fibers also pass between the cornu of the alar cartilage and the outer wing of the nostril.

Relations.—Superficially, the levator labii superioris proprius, the levator nasolabialis, and the lateral nasal artery; deeply, the maxilla, the premaxilla, and the anterior nasal branch of the infraorbital nerve.

Blood-supply.—Facial artery.

Nerve-supply.—Facial nerve.

MUSCLES OF THE EYELIDS

1. =Orbicularis oculi.=—This is a flat, elliptical, sphincter muscle, situated in and around the eyelids, the portion in the upper lid being much broader than that in the lower. The chief attachment is to the skin of the lids, but some bundles are attached to the palpebral ligament at the inner canthus and to the lacrimal bone. Its action is to close the lids.

2. =Corrugator supercilii.=—This is a very thin, small muscle, which arises over the root of the supraorbital process and spreads out in the upper eyelid, blending with the orbicularis. Its action is to assist in raising the upper lid or, especially in pathological conditions, to wrinkle the skin.

3. =Malaris.=—This is a very thin muscle, which varies much in different subjects. It extends from the fascia in front of the orbit to the lower lid. Its action is to depress the lower lid.

The foregoing muscles receive their blood-supply from the facial, transverse facial, supraorbital, and infraorbital arteries; the nerve-supply is derived from the facial nerve.

4. =Levator palpebræ superioris.=—This slender, flat muscle is almost entirely within the orbital cavity. It arises on the pterygoid crest, passes forward above the rectus oculi superior and below the lacrimal gland, and terminates in a thin tendon in the upper lid.

Action.—To elevate the upper lid.

Blood-supply.—Ophthalmic artery.

Nerve-supply.—Oculomotor nerve.

MUSCLES OF MASTICATION

The muscles of this group are six in number in the horse. They arise chiefly from the upper jaw and the base of the cranium, and are all inserted into the mandible.

1. =Masseter.=—This muscle extends from the zygomatic arch and facial crest over the broad part of the mandibular ramus. It is semi-elliptical in outline.

Origin.—By a strong tendon from the zygomatic arch and the facial crest.

Insertion.—The outer surface of the broad part of the ramus of the mandible.

Action.—Its action is to bring the jaws together. Acting singly, it also carries the lower jaw toward the side of the contracting muscle.

Structure.—The superficial face of the muscle in its upper part is covered by a strong, glistening aponeurosis, and several tendinous intersections partially divide the muscle into layers. The fibers of the superficial layer take origin from the malar and maxilla only, and diverge somewhat to their insertion close to the thick ventral border of the lower jaw. The fibers of the deep layer arise from the entire area of origin, and pass straight to the border of the mandible; it will be noted that a small part, near the temporo-maxillary joint, is not covered by the superficial layer. The two layers are separable only above and behind; elsewhere they are fused.

Relations.—Superficially, the skin and panniculus, the parotid gland, the transverse facial and masseteric vessels, and the facial nerve; deeply, the ramus of the mandible, the buccinator, depressor labii inferioris, and mylo-hyoideus muscles, the superior buccal glands, the buccinator nerve, and two large varicose veins which join the facial vein at the anterior edge of the muscle. The facial vessels and parotid duct run along the anterior edge of the muscle; the duct, however, bends forward about the middle of the border and leaves the muscle.

Blood-supply.—Transverse facial and masseteric arteries.

Nerve-supply.—Mandibular nerve.

2. =Temporalis.=—This muscle occupies the temporal fossa.

Origin.—The rough part of the temporal fossa and the crests which surround it.

Insertion.—The coronoid process of the mandible, which it envelops.

Action.—Chiefly to raise the lower jaw, acting with the masseter and internal pterygoid muscles.

Structure.—The surface of the muscle is covered with a glistening aponeurosis, and strong tendinous intersections are found in its substance. The inner edge of the muscle is quite thin, but as the fibers converge toward the much smaller area of insertion, the muscle becomes nearly an inch thick. It fuses somewhat with the masseter.

Relations.—Superficially, the scutiform cartilage and anterior muscles of the external ear and the orbital fat; deeply, the temporal fossa and the deep temporal vessels and nerves.

Blood-supply.—Superficial and deep temporal, and mastoid arteries.

Nerve-supply.—Mandibular nerve.

3. =Pterygoideus internus= (s. medialis).—This muscle occupies a position on the inner surface of the ramus of the mandible similar to that of the masseter on the outside.

Origin.—The crest formed by the pterygoid process of the sphenoid and the palate bone.

Insertion.—The concave inner surface of the broad portion of the ramus of the mandible, and the inner lip of the lower border.

Action.—Acting together, to raise the lower jaw; acting singly, to produce also lateral movement of the jaw.

Structure.—The muscle is capable of division into two parts. The principal part is superficial (internal), and its fibers are, for the most part, vertical in direction. It contains much tendinous tissue (septa). The smaller portion is external to the foregoing, and its fibers are directed downward and backward.

[Illustration:

FIG. 175.—SAGITTAL SECTION OF HEAD OF HORSE, SHOWING DEEP PTERYGO-MAXILLARY REGION, AND NASAL AND CRANIAL CAVITIES.

_1_, Cerebral compartment of cranial cavity; _2_, cerebellar compartment of same; _3_, tentorium osseum; _4_, tentorium cerebelli; _5_, sphenoidal sinus; _6_, hamulus of pterygoid bone-tendon of tensor palati cut off short at anterior border of hamulus; _7_, mylo-glossus. The olfactory mucous membrane is shaded.]

Relations.—Externally, the ramus of the mandible, the external pterygoid muscle, the inferior alveolar vessels and nerve, and the lingual and mylo-hyoid nerves; internally, the great cornu of the hyoid bone, the tensor palati, pterygo-pharyngeus, palato-pharyngeus, mylo-hyoideus, digastricus, and stylo-hyoideus muscles, the guttural pouch, the external maxillary vessels, the ninth and twelfth nerves, the submaxillary salivary gland, the submaxillary and parotid ducts, and the submaxillary and pharyngeal lymph glands.

Blood-supply.—Internal maxillary, masseteric, and inferior alveolar arteries.

Nerve-supply.—Mandibular nerve.

4. =Pterygoideus externus= (=s. lateralis=).—This muscle is considerably smaller than the preceding one, and is situated external to its upper part.

Origin.—The external surface of the pterygoid process of the sphenoid bone.

Insertion.—The inner surface of the neck and the inner part of the anterior border of the condyle of the mandible.

Action.—Acting together, to draw the lower jaw forward; acting singly, to move the jaw laterally, _i. e._, toward the side opposite to the muscle acting. The latter action is due to the fact that the origin is nearer to the median plane than the insertion.

[Illustration:

FIG. 176.—SUBMAXILLARY AND LARYNGEAL REGIONS OF HORSE, AFTER REMOVAL OF SKIN AND PANNICULUS.

_c_, Mastoido-humeralis; _d_, sterno-cephalicus; _e_, omo-hyoideus and sterno-hyoideus; _h_, buccinator; _i_, depressor labii inferioris; _m_, masseter; _v_, stylo-maxillaris; _w_, mylo-hyoideus; _2_, posterior, _3_, anterior, border of external ear; _30′_, angle of jaw; _36_, submaxillary lymph glands; _37_, external maxillary vein; _39_, facial continuation of _37_; _40_, parotid duct; _44_, parotid gland; _45_, prominence of chin; _x_, wing of atlas. (After Ellenberger-Baum, Anat. für Künstler.)]

Structure.—The muscle is almost entirely fleshy, and the fibers are almost longitudinal in direction. Some of them are inserted into the edge of the interarticular meniscus.

Relations.—Externally, the temporo-maxillary articulation and the temporalis muscle; internally, the internal pterygoid and tensor palati muscles. The internal maxillary artery crosses the lower face of the muscle and dips in between it and the tensor palati. The mandibular nerve lies on the ventral surface, and the buccinator nerve perforates the origin of the muscle.

Blood-supply.—Internal maxillary and inferior alveolar arteries.

Nerve-supply.—Mandibular nerve.

5. =Stylo-maxillaris= (s.-mandibularis) (M. jugulomandibularis).—This is a short muscle extending from the paramastoid or styloid process of the occipital bone to the posterior border of the lower jaw; it is covered by the parotid gland.

Origin.—The paramastoid or styloid process of the occipital bone, in common with the posterior belly of the digastricus.

Insertion.—The posterior border of the ramus of the mandible.

Action.—To depress the lower jaw and open the mouth.

Structure.—The muscle contains a good deal of tendinous tissue. It blends with the posterior belly of the digastricus.

Relations.—Superficially, the parotid gland, the tendon of the sterno-cephalicus, and the fibrous expansion which connects it with the tendon of the mastoido-humeralis; deeply, the guttural pouch, the external carotid artery, the ninth and twelfth nerves, the pharynx, and the submaxillary gland.

Blood-supply.—External carotid artery.

Nerve-supply.—Facial nerve.

6. =Digastricus.=—This muscle is composed of two fusiform, flattened bellies, united by a round tendon.

Origin.—The paramastoid or styloid process of the occipital bone, in common with the preceding muscle.

Insertion.—The inner surface of the lower border of the mandible behind the symphysis.

Action.—It assists in depressing the lower jaw and opening the mouth. If the mandible be fixed and both bellies contract, the hyoid bone and the base of the tongue are raised, as in the first phase of deglutition.

Structure.—The posterior belly has the appearance of a branch detached from the inner surface of the stylo-maxillaris. It passes downward and forward, and is succeeded by a small rounded tendon. The latter perforates the tendon of insertion of the stylo-hyoideus, and is provided with a =synovial sheath=. The anterior belly is larger and terminates by thin tendinous bundles.

Relations.—The posterior belly has practically the same relations as the stylo-maxillaris. The intermediate tendon is in contact externally with the internal pterygoid muscle, the submaxillary gland and duct, and the external maxillary artery. The anterior belly lies in the submaxillary space between the ramus of the jaw and the mylo-hyoideus muscle; the sublingual vessels run along its upper border.

Blood-supply.—External carotid and sublingual arteries.

Nerve-supply.—Facial and mandibular nerves.

THE HYOID MUSCLES

This group consists of eight muscles, one of which, the hyoideus transversus, is unpaired.

1. =Mylo-hyoideus.=—This muscle, together with its fellow, forms a sort of sling between the two rami of the lower jaw, in which the tongue is supported.

Origin.—The inner surface of the alveolar border of the mandible.

Insertion.—(1) A median fibrous raphé extending from the symphysis to the hyoid bone; (2) the lingual process and body of the hyoid bone.

Action.—It raises the floor of the mouth, the tongue, and the hyoid bone.

Structure.—Each muscle consists of a thin curved sheet, the fibers passing downward from their origin and then curving toward the median raphé. It is chiefly fleshy, and is thickest behind. The anterior superficial part of the muscle is termed the mylo-glossus.

Relations.—On the superficial surface of the muscles are the ramus, the internal pterygoid and digastricus muscles, and the submaxillary lymph glands. The deep surface is in contact with the mucous membrane of the mouth, the stylo-glossus, hyo-glossus, and genio-hyoideus muscles, the sublingual gland and vessels, the submaxillary duct, and the lingual and hypoglossal nerves.

Blood-supply.—Sublingual artery.

Nerve-supply.—Mylo-hyoid branch of the mandibular nerve.

2. =Stylo-hyoideus.=—This is a slender, fusiform muscle, having a direction nearly parallel to that of the great cornu of the hyoid bone (Fig. 436).

Origin.—The heel-like prominence on the proximal extremity of the great cornu of the hyoid bone.

Insertion.—The anterior part of the thyroid cornu of the hyoid bone.

Action.—It draws the base of the tongue and the larynx upward and backward.

Structure.—It arises by a thin, short tendon, and has a fusiform belly. The tendon of insertion is perforated for the passage of the intermediate tendon of the digastricus, and at this point there is a small synovial sheath.

Relations.—Superficially, the internal pterygoid muscle and the parotid gland; deeply, the guttural pouch, the pharynx, the external carotid and maxillary arteries, and the hypoglossal nerve.

Blood-supply.—External carotid artery.

Nerve-supply.—Facial nerve (stylo-hyoid branch).

3. =Occipito-hyoideus= (M. jugulo-hyoideus; occipito-styloideus).—This is a small triangular muscle, which lies in the space between the paramastoid process and the great cornu of the hyoid bone.

Origin.—The paramastoid (styloid) process of the occipital bone.

Insertion.—The proximal extremity and ventral edge of the great cornu of the hyoid bone.

Action.—It carries the distal extremity of the great cornu backward and upward. Acting with the genio-hyoideus and digastricus, it raises the hyoid bone and the larynx.

Structure.—The muscle is somewhat triangular, its fibers being longer as the ventral border is approached. It blends with the posterior belly of the digastricus.

Relations.—Superficially, the parotid gland; deeply, the guttural pouch.

Blood-supply.—Occipital artery.

Nerve-supply.—Facial nerve.

4. =Genio-hyoideus.=—This is a long, spindle-shaped muscle, which lies under the tongue in contact with its fellow of the opposite side (Fig. 243).

Origin.—The angle of union of the rami of the mandible.

Insertion.—The extremity of the lingual process of the hyoid bone.

Action.—It draws the hyoid bone and tongue forward.

Structure.—The muscle arises by a short tendon, which is succeeded by the belly, composed of long bundles of parallel fibers.

Relations.—Below, the mylo-hyoideus; above, the hyo-glossus, stylo-glossus, genio-glossus, the sublingual gland, submaxillary duct, and the lingual nerve.

Blood-supply.—Sublingual artery.

Nerve-supply.—Hypoglossal nerve.

5. =Kerato-hyoideus.=—This small triangular muscle lies in the space between the thyroid and small cornu, under cover of the hyo-glossus (Fig. 243).

Origin.—The posterior edge of the small cornu and the adjacent part of the ventral border of the great cornu.

Insertion.—The dorsal edge of the thyroid cornu.

Action.—It raises the thyroid cornu and the larynx.

Relations.—The muscle is crossed outwardly by the lingual artery.

Blood-supply.—Lingual artery.

Nerve-supply.—Glosso-pharyngeal nerve.

6. =Hyoideus Transversus.=—This is a thin, unpaired muscle, which extends transversely between the two small cornua of the hyoid bone.

Attachments.—The small cornua close to the junction with the great cornua.

Action.—When relaxed, its upper surface is concave; when it contracts, it elevates the root of the tongue.

Structure.—Fleshy, composed of parallel transverse bundles.

Blood-supply.—Lingual artery.

Nerve-supply.—Glosso-pharyngeal nerve.

7. =Sterno-thyro-hyoideus=, and

8. =Omo-hyoideus.=—These are described with the muscles on the ventral surface of the neck.

THE FASCIÆ AND MUSCLES OF THE NECK

It is convenient to divide the muscles of the neck into ventral and lateral groups, the two lateral groups being separated from each other by the ligamentum nuchæ.

THE FASCIÆ OF THE NECK

The =superficial fascia= is in part two-layered, and contains the cervical portion of the panniculus. The fasciæ of the right and left sides are attached along the dorsal line of the neck to the ligamentum nuchæ, while along the ventral line they meet in a fibrous raphé. A deep layer is detached which passes underneath the panniculus, bridges over the jugular furrow, and crosses over the deep face of the mastoido-humeralis and omo-hyoideus to join the superficial layer. It again separates to pass under the cervical trapezius, and become attached to the ligamentum nuchæ. Along the ventral line a septum is detached which separates the sterno-cephalici. Two other layers in front of the shoulder inclose the prescapular lymph glands.

The =deep fascia= also forms two layers. The =superficial layer= is attached to the wing of the atlas and the lower edge of the trachelo-mastoideus and scalenus. Passing downward, it incloses the trachea, and, together with the deep layer, furnishes sheaths for the vagus and sympathetic nerves and the carotid artery. Passing upward it detaches septa between the extensor muscles of the spine. Anteriorly it covers the thyroid gland, the guttural pouch, the adjacent vessels and nerves and the larynx, and is attached to the mastoid process of the temporal bone and the thyroid cornu of the hyoid bone. Posteriorly, it is attached to the first rib and the cariniform cartilage of the sternum. The =deep layer= (prevertebral fascia) covers the ventral surface of the longus colli, and incloses the trachea and œsophagus. Anteriorly, it forms, with the corresponding layer of the opposite side, a septum between the guttural pouches; posteriorly, it becomes continuous with the endothoracic fascia. A =fascia propria= forms a tubular sheath around the trachea, inclosing also the recurrent nerves.

VENTRAL MUSCLES

This group consists of eleven pairs of muscles which lie almost entirely ventral to the vertebræ.

1. =Panniculus carnosus.=—The =cervical panniculus= (platysma myoides of man) has a fleshy origin on the cariniform cartilage (manubrium) of the sternum. it passes forward, outward, and upward, crossing over the sterno-cephalicus and jugular furrow obliquely. On reaching the surface of the mastoido-humeralis it adheres closely to this muscle, and soon thins out, to be continued over the splenius and trapezius by an aponeurosis which is difficult to remove from the latter muscle. Scattered bundles may be traced on the ventral surface of the neck to the facial portion. The right and left muscles meet at a ventral median raphé in pennate fashion.

[Illustration:

FIG. 177.—ANTERO-LATERAL VIEW OF MUSCLES AND SKELETON OF HORSE.

_a_, Trapezius; _c_, mastoido-humeralis; _d_, sterno-cephalicus; _f_, long head of triceps; _f′_, external head of triceps; _g_, anterior superficial pectoral muscle; _g′_, posterior superficial pectoral; _h′_, anterior deep pectoral; _v_, cervical panniculus; _z_, supraspinatus; _29_, omo-hyoideus; _30_, sterno-thyro-hyoideus; _31_, jugular vein; _32_, cephalic vein; _1_, scapula; _1′_, cartilage of scapula; _2_, spine of scapula; _4_, shaft of humerus; _4′_, external epicondyle; _5_, external tuberosity of humerus; _6_, deltoid tuberosity; _14_, ventral border ("keel") of sternum; _14′_, cariniform cartilage; I.R., first rib. (After Ellenberger-Baum, Anat. für Künstler.)]

2. =Mastoido-humeralis.=—This is described on p. 252.

3. =Sterno-cephalicus= (Sterno-maxillaris s.-mandibularis).[42]—This is a long, narrow muscle, extending along the ventral and lateral aspects of the trachea from the sternum to the angle of the jaw. It forms the ventral boundary of the jugular furrow.

Origin.—The cariniform cartilage of the sternum.

Insertion.—The posterior border of the lower jaw.

Action.—Acting together, to flex the head and neck; acting singly, to incline the head and neck to the side of the muscle contracting.

Structure.—The two muscles are fused at their origin, which is fleshy. Near the middle of the neck they separate, and, becoming thinner, each muscle passes under the parotid gland and terminates in a flat tendon.

Relations.—Superficially, the cervical panniculus; deeply, the sterno-thyro-hyoideus and omo-hyoideus muscles. The upper edge of the muscle is related to the jugular vein, which lies in the jugular furrow. The carotid artery, the vagus, sympathetic, and recurrent nerves also lie along the upper edge at the root of the neck. The tendon passes under the submaxillary vein and the parotid gland, having the submaxillary gland and stylo-maxillaris muscle on its inner side.

Blood-supply.—Carotid artery.

Nerve-supply.—Ventral branches of the spinal accessory and first cervical nerves.

4. =Sterno-thyro-hyoideus= (Sterno-thyroideus et sterno-hyoideus).—This is a long, slender, digastric muscle, applied to the ventral surface of the trachea and its fellow of the opposite side.

Origin.—The cariniform cartilage of the sternum.

Insertion.—(1) The external surface of the thyroid cartilage of the larynx; (2) the body of the hyoid bone.

Action.—To depress and retract the hyoid bone, the base of the tongue, and the larynx, as in deglutition. It may also fix the hyoid bone when the depressors of the tongue are acting, as in suction.

Structure.—The origin of the muscle is fleshy, and as far as the middle of the neck it blends with its fellow. The common belly is then interrupted by a tendon, or sometimes two tendons, from which arise three or four fleshy bands. The lateral bands diverge to reach their insertion into the thyroid cartilage; while the inner bands, closely applied to each other and blending with the omo-hyoideus, pass straight forward to reach the ventral surface of the hyoid bone.

Relations.—At the root of the neck the common belly has the sterno-cephalicus below, and the carotid arteries and recurrent nerves above. Further forward the trachea becomes the upper relation, and near the head the skin and fascia, the lower one.

Blood-supply.—Carotid artery.

Nerve-supply.—Ventral branch of the first cervical nerve.

5. =Omo-hyoideus= (Subscapulo-hyoideus).—This is a thin, ribbon-like muscle, almost entirely fleshy, which crosses the trachea very obliquely under cover of the mastoido-humeralis.

Origin.—The subscapular fascia close to the shoulder joint.

Insertion.—The body of the hyoid bone, in common with the hyoid branch of the preceding muscle.

Action.—To depress the hyoid bone.

Structure.—The muscle is composed of parallel fleshy fibers, except at its origin, where it has a thin tendon.

Relations.—In the first part of its course the muscle passes forward between the supraspinatus, anterior deep pectoral, mastoido-humeralis (outwardly), and the scalenus (inwardly). It is intimately adherent to the mastoido-humeralis. In the middle of the neck it is related superficially to the mastoido-humeralis, sterno-cephalicus, and the jugular vein; deeply, to the rectus capitis anterior major, the carotid artery, the vagus, sympathetic, and recurrent nerves, the trachea, and, on the left side, the œsophagus. In its anterior part the muscle blends with the hyoid part of the sterno-thyro-hyoideus, the two covering the thyroid portion of the latter muscle, the thyroid gland, and the ventral face of the larynx.

Blood-supply.—Carotid and inferior cervical arteries.

Nerve-supply.—Ventral branches of the cervical nerves.

6. =Scalenus= (M. scalenus primæ costæ).—This muscle is deeply situated on the side of the posterior half of the neck. It is composed of two parts, between which the roots of the brachial plexus of nerves emerge.

Origin.—The anterior border and outer surface of the first rib.

Insertion.—(1) The dorsal (smaller) portion is attached to the transverse process of the seventh cervical vertebra; (2) the ventral portion is attached to the transverse processes of the sixth, fifth, and fourth cervical vertebræ.

Action.—The neck is flexed or inclined laterally, according as the muscles act together or singly. If the neck be the fixed point, the muscle may have a respiratory action by pulling forward or fixing the first rib.

Structure.—The dorsal portion is composed of three or four fleshy bundles.[43] The ventral portion, which is much larger, is almost entirely fleshy, and not so divided.

Relations.—Superficially, the anterior deep pectoral, mastoido-humeralis, and omo-hyoideus muscles, the phrenic nerve, and the other branches of the brachial plexus; deeply, the vertebræ, the longus colli and intertransversales muscles, the œsophagus (on the left side), the trachea (on the right side), the vertebral vessels, the vagus, sympathetic, and recurrent nerves. The roots of the brachial plexus form a flat anastomosis, which lies between the two portions of the muscle. The brachial vessels cross the ventral edge close to the first rib.

Blood-supply.—Carotid, vertebral, and inferior cervical arteries.

Nerve-supply.—Ventral branches of the cervical nerves.

7. =Rectus capitis anterior major= (M. longus capitis).—This is the largest of the three special flexors of the head, and lies along the ventro-lateral surface of the anterior cervical vertebræ and the base of the cranium.

Origin.—The transverse processes of the fifth, fourth, and third cervical vertebræ.

Insertion.—The tubercles at the junction of the basilar process of the occipital bone with the body of the sphenoid.

Action.—Acting together, to flex the head; acting singly, to incline it to the same side also.

Structure.—The origin of the muscle is by fleshy digitations. The belly increases in size by the union of these digitations, reaching its maximum at the axis. It then diminishes, passes toward the median plane, and terminates on a rounded tendon.

Relations.—Superficially, the mastoido-humeralis, omo-hyoideus, and rectus capitis anticus minor, the submaxillary gland, the carotid artery (which lies along the lower border), the occipital and internal carotid arteries, and the tenth, eleventh, and sympathetic nerves; deeply, the vertebræ, the longus colli, intertransversales, and the small straight muscle. The terminal part of the muscle lies in contact with its fellow above the pharynx and between the guttural pouches.

Blood-supply.—Carotid, vertebral, and occipital arteries.

Nerve-supply.—Ventral branches of the cervical nerves.

8. =Rectus capitis anterior minor= (M. rectus capitis ventralis).—This is a small muscle which lies under cover of the preceding one.

Origin.—The ventral arch of the atlas.

Insertion.—The basilar process, close to the preceding muscle.

Action.—To flex the occipito-atlantal articulation.

Structure.—Fleshy.

Relations.—Below, to the preceding muscle; above, to the atlas, occipito-atlantal articulation, and the basilar process; externally, to the rectus capitis lateralis and the guttural pouch.

Blood-supply.—Occipital artery.

Nerve-supply.—Ventral branch of the first cervical nerve.

9. =Rectus capitis lateralis.=—This is a still smaller, entirely fleshy muscle, which lies for the most part under the small oblique muscle.

Origin.—The atlas, external to the preceding muscle.

Insertion.—The paramastoid or styloid process of the occipital bone.

Action.—The same as the preceding muscle.

Structure.—Fleshy.

Relations.—Superficially, the small oblique muscle, the occipital vessels, and the ventral branch of the first cervical nerve.

Blood-supply.—Occipital artery.

Nerve-supply.—Ventral branch of the first cervical nerve.

10. =Longus colli.=—This muscle covers the ventral surface of the vertebræ, from the sixth thoracic to the atlas, and is united with its fellow. It consists of two portions, thoracic and cervical.

Origin.—(1) Thoracic portion, the bodies of the first six thoracic vertebræ; (2) cervical portion, the transverse processes of the cervical vertebræ.

Insertion.—(1) Thoracic portion, the bodies and transverse processes of the last two cervical vertebræ; (2) cervical portion, the bodies of the cervical vertebræ and the tubercle on the ventral surface of the atlas.

Action.—To flex the neck.

Structure.—The muscle is composed of a succession of bundles. The largest of these constitute the thoracic part of the muscle, which has a strong tendon inserted into the last two cervical vertebræ. A bursa is interposed between the tendon and the spine at the first costo-vertebral articulation. The cervical portion consists of a number of smaller bundles, each of which passes from its origin on the transverse process of one vertebra forward and inward to its insertion into a vertebra further forward. The most anterior bundle is inserted by a strong tendon into the ventral tubercle of the atlas.

Relations.—The principal relations of the two muscles in the thorax are: ventrally, the pleura, and, further forward, the trachea and œsophagus; dorsally, the vertebræ and the costo-vertebral joints; laterally, the dorsal, superior cervical, and vertebral vessels, the sympathetic nerve, and the thoracic roots of the brachial plexus. In the neck, important relations are: ventrally, the trachea and œsophagus, the carotid artery, the vagus, sympathetic and recurrent nerves; dorsally, the vertebræ and, in the middle third of the neck, the intertransversales muscles; laterally, the scalenus, the rectus capitis anticus major, and the intertransversales (in the anterior third). The terminal part of the muscle is separated from the trachea by the œsophagus, which is here median in position.

Blood-supply.—Subcostal and vertebral arteries.

Nerve-supply.—Ventral branches of the spinal nerves.

11. =Intertransversales colli= (Mm. intertransversarii cervicis).—These are six fasciculi which occupy the spaces between the lateral aspects of the vertebræ and the transverse and articular processes. There is thus a bundle for each intervertebral articulation except the first. Each bundle consists of a dorsal and ventral portion.

Attachments.—The dorsal bundles pass from transverse process to articular process; the ventral bundles extend between adjacent transverse processes.

Action.—To bend the neck laterally.

Structure.—They contain strong tendinous intersections.

Relations.—Superficially, the mastoido-humeralis, rectus capitis anterior major, complexus, trachelo-mastoideus, splenius, scalenus, and longissimus muscles; deeply, the vertebræ, the longus colli muscle, and the vertebral vessels. The muscles are perforated by branches of these vessels and by the primary branches of the cervical nerves.

Blood-supply.—Vertebral artery.

Nerve-supply.—The cervical nerves.

LATERAL MUSCLES

This group consists of twelve pairs of muscles arranged in layers.

FIRST LAYER

1. =Trapezius cervicalis.=—Described on p. 250.

SECOND LAYER

2. =Rhomboideus cervicalis.=—Described on p. 251.

3. =Serratus magnus= (M. serratus cervicis).—Described with the thoracic part on p. 254.

THIRD LAYER

4. =Splenius.=—This is an extensive, flat, triangular muscle, partly covered by the preceding three muscles.

Origin.—The second, third, and fourth thoracic spines by means of the dorso-scapular ligament, and the funicular portion of the ligamentum nuchæ.

Insertion.—The occipital crest, the mastoid process, the wing of the atlas, and the transverse processes of the third, fourth, and fifth cervical vertebræ.

Action.—Acting together, to elevate the head and neck; acting singly, to incline the head and neck to the side of the muscle acting.

Structure.—The muscle arises in the withers from the anterior part of the dorso-scapular ligament, which also affords attachment to the rhomboideus, serratus anticus, and complexus muscles. The fibers pass upward and forward toward the head and the first cervical vertebra. The insertion on the occipital bone and the mastoid process is by means of a thin aponeurosis common to the

splenius, trachelo-mastoideus, and mastoido-humeralis. The atlantal insertion is by a strong, flat tendon, also in common with these muscles. The remaining insertions are fleshy digitations.

Relations.—Superficially, the skin and fascia, the trapezius rhomboideus, cervicalis, serratus magnus, and posterior auricular muscles; deeply, the complexus, trachelo-mastoideus, and longissimus muscles.

Blood-supply.—Deep cervical and dorsal arteries.

Nerve-supply.—Dorsal branches of the last six cervical nerves.

FOURTH LAYER

5. =Trachelo-mastoideus= (M. longissimus capitis et atlantis).—This muscle consists of two parallel, fusiform portions. It lies between the deep face of the splenius and the ventral part of the complexus.

Origin.—(1) The transverse processes of the first two thoracic vertebræ; (2) the articular processes of the cervical vertebræ.

Insertion.—(1) The mastoid process; (2) the wing of the atlas.

[Illustration:

FIG. 178.—SUPERFICIAL MUSCLES OF HORSE.

The panniculus, except the cervical part, has been removed. _a_, Trapezius cervicalis; _a′_, trapezius thoracalis; _c_, _c′_, mastoido-humeralis; _d_, sterno-cephalicus; _e_, deltoid; _f_, long head of triceps; _f′_, external head of triceps; _g_, anterior superficial pectoral; _h_, posterior deep pectoral; _h′_, anterior deep pectoral; _i_, serratus thoracis; _i′_, serratus cervicis; _k_, latissimus dorsi; _l_, obliquus abdominis externus; _l′_, aponeurosis of _l_; _m_, serratus posticus; _m′_, lumbo-dorsal fascia; _o_, tensor fasciæ latæ; _o′_, fascia lata; _o″_, gluteus superficialis; _q_, _q′_, _q″_, biceps femoris; _r_, semitendinosus; _s_, sacro-coccygeus superior; _t_, sacro-coccygeus lateralis; _u_, coccygeus; _v_, cervical panniculus; _w_, splenius; _x_, rhomboideus; _y_, tendon of trachelo-mastoideus and mastoido-humeralis; _z_, suprasinatus; _X_, wing of atlas; _2_, spine of scapula; _4′_, external epicondyle of humerus; _6_, deltoid tuberosity; _8_, olecranon; _16_, external angle of ilium; _20_, patella; _21′_, external condyle of tibia. (After Ellenberger-Baum, Anat. für Künstler.)]

Action.—Acting together, to extend the head and neck; acting singly, to flex the head and neck laterally or to rotate the atlas.

Structure.—The origin from the thoracic vertebræ is by aponeurotic slips which blend with the complexus. The succeeding fleshy portion, in passing along the neck, receives fasciculi from each of the cervical vertebræ except the first two. The dorsal division of the muscle is inserted into the mastoid process by a flat tendon which fuses with that of the splenius; the ventral division is inserted into the wing of the atlas by a ribbon-like tendon in common with the splenius and mastoido-humeralis.

Relations.—Superficially, the splenius muscle and dorsal branches of the cervical nerves; deeply, the complexus, the spinalis colli, and the oblique muscles of the head. The superior cervical vessels cross the deep face of the muscle obliquely at the level of the sixth and seventh cervical vertebræ.

Blood-supply.—Vertebral and superior cervical arteries.

Nerve-supply.—Dorsal branches of the last six cervical nerves.

6. =Complexus= (M. semispinalis capitis).—This is a large triangular muscle which lies chiefly on the ligamentum nuchæ, under cover of the splenius and trachelo-mastoideus muscles.

Origin.—(1) The second, third, and fourth thoracic spines, in common with the splenius and serratus anticus; (2) the transverse processes of the first six or seven thoracic vertebræ; (3) the articular processes of the cervical vertebræ.

Insertion.—The posterior surface of the occipital bone, external to the funicular portion of the ligamentum nuchæ.

Action.—It is the chief extensor of the head and neck. Acting singly, the muscle inclines the head to the same side.

Structure.—The origin of the muscle at the withers is aponeurotic. In the neck the bundles arising from the articular processes run obliquely upward and forward, giving the lower part of the muscle a distinct pennate character. The upper part of the belly is

crossed obliquely by four or five tendinous intersections. The insertion is by a strong tendon.

Relations.—Superficially, the rhomboideus, serratus magnus, splenius, and trachelo-mastoideus muscles; deeply, the ligamentum nuchæ, the multifidus cervicis, longissimus, and the oblique and posterior straight muscles of the head, the deep or superior cervical vessels, and the dorsal cutaneous branches of the cervical nerves.

Blood-supply.—Deep cervical, vertebral, and occipital arteries.

Nerve-supply.—Dorsal branches of the last six cervical nerves.

7. =Multifidus cervicis= (M. semispinalis colli; transverse spinous muscle of neck).—This muscle lies on the arches of the last five cervical vertebræ. It consists of five or six segments.

Origin.—The articular processes of the last five (or four) cervical and the first thoracic vertebræ.

Insertion.—The spinous processes of the cervical vertebræ.

[Illustration:

FIG. 179.—DEEPER MUSCLES OF HORSE.

_f_, Long head of triceps; _f′_, external head of triceps; _g_, anterior superficial pectoral; _h_, posterior deep pectoral; _h′_, anterior deep pectoral; _i_, serratus thoracis; _i′_, serratus cervicis; _l_, obliquus abdominis externus, and _l′_, its aponeurosis, the posterior part of which has been removed; _m_, serratus posticus; _p_, gluteus medius; _r_, semitendinosus; _s_, sacro-coccygeus superior; _t_, sacro-coccygeus lateralis; _u_, coccygeus; _v′_, biceps brachii; _x_, rhomboideus; _y_, _y′_, trachelo-mastoideus; _z_, supraspinatus; _z′_, infraspinatus; _1_, cartilage of scapula; _2_, spine of scapula; _5_, external tuberosity of humerus; _6_, deltoid tuberosity; _8_, olecranon; _16_, external angle of ilium; _19_, trochanter major; _20_, patella; _21′_, external condyle of tibia; _26_, articular processes of cervical vertebræ; _27_, parotido-auricularis; _28_, vastus externus; _28′_, rectus femoris; _28″_, trochanter tertius; _29_, semimembranosus; _30_, gastrocnemius; _31_, sacro-sciatic ligament; _32_, omo-hyoideus; _33_, complexus; _34_, rectus capitis anterior major; _35_, spinalis dorsi; _36_, longissimus dorsi; _37_, transversalis costarum; _38_, teres minor; _39_, brachialis; _40_, external intercostal; _41_, obliquus abdominis internus; _42_, iliacus; _43_, transversus abdominis. (After Ellenberger-Baum, Anat. für Künstler.)]

Action.—Acting together, to extend the neck; acting singly, to flex and rotate the neck to the opposite side.

Structure.—The muscle is composed of two sets of bundles. The superficial bundles are directed obliquely forward and inward, each passing from an articular process to the spine of the preceding vertebra. The deep bundles are shorter and run straight from an articular process to that of the preceding vertebra.

Relations.—Superficially, the complexus, longissimus, trachelo-mastoideus, and great oblique muscles; deeply, the spinalis muscle, the ligamentum nuchæ, and the arches of the vertebræ.

Blood-supply.—Deep cervical and vertebral arteries.

Nerve-supply.—Dorsal branches of the last six cervical nerves.

8. =Spinalis.=—Described with the longissimus on p. 237.

9. =Obliquus capitis posterior= (s. caudalis) (great oblique muscle of the head).—This is a strong, quadrilateral muscle, which covers the dorso-lateral aspect of the atlas and axis.

Origin.—The side of the spine and the posterior articular process of the axis.

Insertion.—The dorsal surface of the wing of the atlas.

Action.—Chiefly to rotate the atlas, and with it the head, to the same side; also to assist in extending and fixing the atlanto-axial joint.

Structure.—The muscle is composed almost entirely of parallel fleshy fibers directed obliquely forward and outward.

Relations.—Superficially, the skin, the splenius, complexus, trachelo-mastoideus, and mastoido-humeralis muscles; deeply, the arch and spine of the axis, the wing of the atlas, the atlanto-axial joint, the multifidus cervicis, the posterior straight muscles, the occipital and vertebral vessels, and the first and second cervical nerves. The terminal part of the vertebral artery joins the posterior branch of the occipital artery under cover of the muscle.

Blood-supply.—Occipital and vertebral arteries.

Nerve-supply.—Dorsal branch of the second cervical nerve.

10. =Obliquus capitis anterior= (s. cranialis) (small oblique muscle of the head).—A short, thick, quadrilateral muscle which lies on the side of the occipito-atlantal articulation.

Origin.—The anterior edge of the wing of the atlas and the fossa atlantis.

Insertion.—The styloid process and crest of the occipital bone, and the mastoid process.

Action.—Acting together, to extend the head on the atlas; acting singly, to flex the head laterally.

Structure.—The muscle contains a good deal of tendinous tissue. The direction of its fibers is forward, upward, and inward.

Relations.—Superficially, the posterior auricular muscles, artery, and nerve, the aponeurosis of the splenius, trachelo-mastoideus and mastoido-humeralis, and the parotid gland; deeply, the straight muscles, the complexus, the occipito-hyoideus, the occipito-atlantal articulation, branches of the occipital artery, and a branch of the occipital nerve.

Blood-supply.—Occipital artery.

Nerve-supply.—Dorsal branch of the first cervical nerve.

11. =Rectus capitis posterior major= (s. dorsalis major) (great posterior straight muscle of the head).—This muscle extends from the axis to the occipital bone, in contact with the ligamentum nuchæ.

Origin.—The edge of the spinous process of the axis.

Insertion.—The occipital bone, below and external to the complexus and ligamentum nuchæ.

Action.—To extend the head.

[Illustration:

FIG. 180.—DEEPEST LAYER OF MUSCLES OF NECK OF HORSE.

_a_, Obliquus capitis anterior; _b_, obliquus capitis posterior; _c_, rectus capitis lateralis; _d_, rectus capitis anterior minor; _e_, rectus capitis anterior major; _f_, longus colli; _g_, _g′_, scalenus; _h_, transversalis costarum; _i_, longissimus dorsi; _k_, spinalis et semispinalis; _l_, multifidus dorsi; _m_, multifidus cervicis; _n_, intertransversales; _o_, _o′_, rectus capitis posterior major; _p_, rectus capitis posterior minor; _q_, tendon of insertion of complexus; _1_, lamellar part, _1′_, funicular part of ligamentum nuchæ; _2_, occipital crest; _3_, paramastoid process; _4_, edge of wing of atlas; _5_, transverse, and _6_, articular, processes of cervical vertebræ; _7_, nerves of brachial plexus (cut); _8_, first rib. (Ellenberger-Baum, Anat. d. Haustiere.)]

Structure.—The muscle is fleshy and may be divided into two parallel portions, superficial and deep. The former blends somewhat with the terminal part of the complexus. The deep portion may be termed the rectus capitis posterior medius.

Relations.—Superficially, the anterior oblique, splenius, and complexus; internally, the ligamentum nuchæ; deeply, the atlas, the occipito-atlantal articulation, and the rectus capitis posterior minor. The dorsal branch of the first cervical nerve appears between this muscle and the small oblique.

Blood-supply.—Occipital artery.

Nerve-supply.—Dorsal branch of the first cervical nerve.

12. =Rectus capitis posterior minor= (s. dorsalis minor) (small posterior straight muscle of the head).—This small muscle lies under cover of the preceding.

Origin.—The dorsal surface of the atlas.

Insertion.—The occipital bone beneath the preceding muscle.

Action.—To assist the preceding muscle.

Structure.—It is fleshy and varies a good deal in volume, being sometimes small and difficult to recognize.[44] On the other hand, it is sometimes double.

Relations.—Superficially, the preceding muscle and the small oblique; deeply, the atlas and the occipito-atlantal articulation.

Blood-supply.—Occipital artery.

Nerve-supply.—Dorsal branch of the first cervical nerve.

THE FASCIÆ AND MUSCLES OF THE BACK AND LOINS

The =superficial fascia= presents no special features. The =lumbo-dorsal fascia= (Fascia lumbo-dorsalis) closely invests the muscles, but is easily stripped off the longissimus. It is attached medially to the supraspinous ligament and the spinous processes of the vertebræ; laterally, it divides into two layers. The superficial layer is practically the aponeurosis of the latissimus dorsi. The deep layer gives origin to the serratus anticus and posticus, the lumbar part of the obliquus externus abdominis, the transversus abdominis, and the retractor costæ. Its lateral edge curves under the longissimus and is attached to the ribs and lumbar transverse processes. Posteriorly, it is continuous with the gluteal fascia. At the withers it forms an important structure, the =dorso-scapular ligament=. This is a strong tendinous sheet, attached to the third, fourth, and fifth thoracic spines. Its upper part is very thick and gives origin by its superficial surface to the rhomboideus dorsi, by its anterior part to the splenius. The lower part is thin and elastic, and furnishes numerous lamellæ which intersect the scapular part of the serratus and are attached with it to the scapula. Three lamellæ are detached from the deep face of the ligament. The deepest of these passes between the longissimus and spinalis and is attached to the transverse processes of the first seven thoracic vertebræ; it gives attachment to the complexus. The middle one dips in between the longissimus and transversalis costarum. The superficial one gives origin to the serratus anticus. A strong fascial layer, the ilio-lumbar ligament, extends from the last rib to the external angle of the ilium.

There are nine pairs of muscles in this region, arranged in four layers.

FIRST LAYER

1. =Trapezius thoracalis.=

2. =Latissimus dorsi.=

SECOND LAYER

3. =Rhomboideus thoracalis.=

The foregoing are described with the other muscles which attach the thoracic limb to the trunk (p. 251).

4. =Serratus anticus= (M. serratus dorsalis inspiratorius).—This is a thin quadrilateral muscle, named from its toothed ventral border. It lies beneath the rhomboideus, serratus magnus, and latissimus dorsi.

Origin.—The lumbo-dorsal fascia and dorso-scapular ligament.

Insertion.—The external surfaces of the fifth to the eleventh or twelfth ribs inclusive.

Action.—To draw the ribs on which it is inserted forward and outward, thus assisting in inspiration.

Structure.—The muscle arises by means of a thin aponeurosis which blends with the lumbo-dorsal fascia and the aponeurosis of the latissimus dorsi. The muscle-fibers pass downward and backward to be attached to the ribs by seven or eight digitations below the outer edge of the transversalis costarum.

Relations.—Superficially, the rhomboideus, serratus magnus, latissimus dorsi, and serratus posticus; deeply, the longissimus dorsi, transversalis costarum, external intercostal muscles, and the ribs.

Blood-supply.—Intercostal arteries.

Nerve-supply.—Thoracic nerves.

5. =Serratus posticus= (M. serratus dorsalis exspiratorius).—This muscle resembles the preceding one, which it partly covers.

Origin.—The lumbo-dorsal fascia.

Insertion.—The outer surfaces of the last seven or eight ribs.

Action.—To draw the ribs backward, thus assisting in expiration.

Structure.—Similar to the preceding muscle. The fibers are directed downward and forward and terminate in seven or eight digitations, one or two of which cover the posterior teeth of the anticus. The aponeurosis blends with that of the latissimus dorsi.

Relations.—Superficially, the latissimus dorsi and external oblique; deeply, the longissimus dorsi, transversalis costarum, external intercostals, serratus anticus, and the ribs.

Blood-supply.—Intercostal and lumbar arteries.

Nerve-supply.—Thoracic nerves.

THIRD LAYER

6. =Transversalis costarum= (M. ilio-costalis).—This long, segmental muscle extends, as its name indicates, across the series of ribs, in contact with the outer edge of the longissimus dorsi.

Origin.—(1) The transverse processes of the second and third lumbar vertebræ and the deep layer of the lumbo-dorsal fascia. (2) The anterior borders and external surface of the last fifteen ribs.[45]

Insertion.—The posterior borders of the ribs and the transverse processes of the last two or three cervical vertebræ.

Action.—Chiefly to depress and retract the ribs and so help in expiration. Acting together, they may assist in extending this spine, acting singly in inclining it laterally.

Structure.—This muscle presents a distinct segmental arrangement. It is composed of a series of bundles, the fibers of which are directed forward and a little downward and outward. From these are detached two sets of tendons. The superficial tendons spring from the outer edge of the muscle. They are flat and are about half an inch in width. Each crosses two or three intercostal spaces, to be inserted on the posterior border of a rib. The deep tendons are detached from the dorsal part of the deep face of the muscle. Each passes backward across one or two intercostal spaces to its origin on the anterior border or outer surface of a rib. Small bursæ may be found between the ribs and tendons.

Relations.—Superficially, the dorsal serrati and the complexus; deeply, the external intercostals and the ribs. The lumbar origin is covered by the longissimus. The superior (deep) cervical and dorsal vessels cross the surface of the muscle at the first and second intercostal spaces respectively, and branches of the intercostal vessels and nerves emerge between the transversalis and longissimus; here a fascial layer dips in between the two.

Blood-supply.—Intercostal arteries.

Nerve-supply.—Dorsal branches of the thoracic nerves.

7. =Longissimus.=[46]—This is the largest and longest muscle in the body. It extends from the sacrum and ilium to the neck, filling up the space between the spinous processes medially and the lumbar transverse processes and the upper ends of the ribs below; consequently it has the form of a three-sided prism.

Origin.—(1) The internal angle, crest, and adjacent part of the ventral surface of the ilium; (2) the first three sacral spines; (3) the lumbar and thoracic spines and the supraspinous ligament.

Insertion.—(1) The lumbar transverse and articular processes; (2) the thoracic transverse processes; (3) the spinous and transverse processes of the last four cervical vertebræ; (4) the outer surfaces of the ribs, except the first.

Action.—Acting with its fellow, it is the most powerful extensor of the back and loins; by its cervical attachment it assists in extending the neck. By its costal attachment it may also assist in expiration. Acting singly, it flexes the spine laterally.

[Illustration:

FIG. 181.—RIGHT PORTION OF CROSS-SECTION OF BACK OF HORSE. SECTION IS CUT THROUGH SEVENTH THORACIC VERTEBRA.

_a_, Ligamentum nuchæ; _b_, trapezius muscle; _c_, cartilage of scapula; _d_, latissimus dorsi; _e_, panniculus carnosus; _f_, rhomboideus dorsi; _g_, serratus magnus; _h_, serratus anticus; _h′_, lumbo-dorsal fascia, which divides below into three layers; _i_, transversalis costarum; _k_, levator costæ; _k′_, internal intercostal muscle; _l_, longissimus dorsi; _m_, _m′_, seventh thoracic vertebra; _n_, head of eighth thoracic vertebra; _o_, head of eighth rib; _p_, seventh rib; _r_, intercostal artery and nerve; _s_, skin. The fasciæ are indicated by dotted lines. (After Ellenberger, in Leisering's Atlas.)]

Structure.—This is quite complex. The posterior part of the muscle is greatly developed and constitutes the common mass of the loins. This is covered by a strong aponeurosis which blends with the supraspinous and sacro-iliac ligaments, and is attached to the crest and inner (sacral) angle of the ilium and the first and second sacral spines; it furnishes origin to the lumbar portion of the middle gluteus. In its course further forward the muscle receives fasciculi from the lumbar and thoracic spines, but diminishes somewhat in volume. At the withers it divides into two parts. The dorsal division (spinalis et semispinalis), reinforced by bundles from the first four thoracic spines, passes forward under the complexus to be inserted into the spines of the last four cervical vertebræ. The ventral division passes forward and downward underneath the serratus magnus to be inserted into the ribs and the transverse processes of the last four cervical vertebræ. Three sets of fasciculi may be distinguished, viz.: (1) spinal, which are superficial and internal; (2) transverse, attached to the transverse and articular processes, which are internal and deep; (3) costal, which are external.

Relations.—Superficially, the middle gluteus, the lumbo-dorsal fascia, the latissimus dorsi, dorsal serrati, serratus magnus, and complexus; deeply, the multifidus, intertransversales, external intercostals, levatores costarum, the ligamentum nuchæ, and its fellow of the opposite side (in the neck).

Blood-supply.—Dorsal, superior cervical, intercostal, and lumbar arteries.

Nerve-supply.—Dorsal branches of the thoracic and lumbar nerves.

8. =Multifidus dorsi= (semispinalis of the back and loins).—This is a long segmental muscle which covers the sides of the spinous processes of the vertebræ from the sacrum to the neck.

Origin.—(1) The lateral portion of the sacrum; (2) the articular processes of the lumbar vertebræ; (3) the transverse processes of the thoracic vertebræ.

Insertion.—The spinous processes of the first two sacral, the lumbar, thoracic, and last cervical vertebræ.

Action.—Acting with its fellow, it is an extensor of the spine; acting singly, it flexes it laterally.

Structure.—It is composed of a series of bundles which are directed obliquely forward and upward. Each fasciculus passes over several vertebræ to its insertion. In the posterior part of the series the bundles cross two or three vertebræ and are inserted into the summits of the spines. Anteriorly, the bundles have a more horizontal direction, cross three to five vertebræ, and are inserted into the sides of the spines considerably below their summits. A further complication consists in the fusion of several bundles into a common insertion.

Relations.—Superficially, the longissimus; deeply, the vertebral spines.

Blood-supply.—Intercostal and lumbar arteries.

Nerve-supply.—Dorsal branches of the thoracic and lumbar nerves.

9. =Intertransversales lumborum.=—These are very thin muscular and tendinous strata, which occupy the spaces between the transverse processes of the lumbar vertebræ except the fifth and sixth.

Action.—To assist in flexing the loins laterally.

Relations.—Superficially, the longissimus; deeply, the quadratus lumborum.

Blood-supply.—Lumbar arteries.

Nerve-supply.—Lumbar nerves.

THE FASCIA AND MUSCLES OF THE TAIL

The muscles of the tail are inclosed in the strong =coccygeal fascia=, which is continuous in front with the gluteal fascia and blends with the lateral sacro-iliac ligament. At the root of the tail it is loosely attached to the subjacent muscles, but further back it is intimately adherent to them. From its deep face are detached septa which pass between the muscles to become attached to the vertebræ.

1. =Coccygeus= (Compressor coccygis; ischio-coccygeus).—This is a flat, triangular muscle which lies chiefly between the sacro-sciatic ligament and the rectum.

Origin.—The pelvic surface of the sacro-sciatic ligament near the ischiatic spine.

Insertion.—The first four coccygeal vertebræ and the coccygeal fascia.

Action.—Acting together, to depress (flex) the tail, compressing it over the perineum; acting singly, to depress and incline it to the same side.

Structure.—The origin of the muscle is aponeurotic. Becoming fleshy, its fibers pass upward and backward and divide into two layers. The outer layer is attached to the vertebræ, the inner to the fascia; included between the two lie the intertransversales. When the tail is raised, the ventral edges of the muscles produce a distinct ridge at either side of the anus.

Relations.—Outwardly, the sacro-sciatic ligament and the semimembranosus; inwardly, the rectum and the sacro-coccygeus ventralis muscle. The internal pudic artery crosses the outer face of the origin of the muscle.

2. =Sacro-coccygeus superior= (M. sacro-coccygeus dorsalis medialis; erector s. extensor coccygis).—This muscle lies along the dorso-median aspect of the tail, in contact with its fellow.

Origin.—The last three sacral spines and some of the coccygeal spines.

Insertion.—The dorsal surface of the coccygeal vertebræ.

Action.—Acting together, to elevate (extend) the tail; acting singly, to elevate and incline it laterally.

Structure.—The muscle has a strong rounded belly. It is inserted by means of short tendons which fuse with those of the next muscle.

Relations.—Superficially, the coccygeal fascia; internally, its fellow; laterally, the sacro-coccygeus lateralis; deeply, the vertebræ.

3. =Sacro-coccygeus lateralis= (M. sacro-coccygeus dorsalis lateralis; curvator coccygis).—This muscle lies immediately lateral to the preceding.

[Illustration:

FIG. 182.—CROSS-SECTION OF TAIL OF HORSE CLOSE TO ANUS.

_34_, Coccygeal vertebra; _35_, sacro-coccygeus superior; _36_, intertransversalis; _37_, sacro-coccygeus inferior; _38_, coccygeus; _39_, recto-coccygeus; _40_, coccygeal fascia. (After Ellenberger-Baum, Anat. für Künstler.)]

[Illustration:

FIG. 183.—MUSCLES OF PERINEUM OF HORSE.

_a_, Coccygeus; _b_, retractor ani; _c_, _c′_, sphincter and externus; _d_, recto-coccygeus; _e_, sacro-coccygeus inferior lateralis; _f_, retractor penis; _g_, bulbo-cavernosus; _h_, ischio-cavernosus; _i_, internal pudic artery; _k_, anus; _l_, penis. (After Ellenberger-Baum, Top. Anat. d. Pferdes.)]

Origin.—The sides of the sacral spines, with the multifidus, and the transverse processes of the sacral and coccygeal vertebræ.

Insertion.—The lateral surface of the coccygeal vertebræ, except the first four.

Action.—Acting with its fellow, to assist the preceding muscle in elevating the tail; acting singly, to incline it to the same side.

Structure.—This muscle appears to be a direct continuation of the multifidus dorsi. The belly is fusiform and receives reinforcing fasciculi from the transverse processes of the sacrum. This is succeeded by bundles of tendons, as many as four lying alongside of each other.

Relations.—Superficially, the lateral sacro-iliac ligament and the coccygeal fascia; dorsally, the sacro-coccygeus superior; ventrally, the intertransversales; deeply, the vertebræ and a branch of the lateral coccygeal artery and accompanying vein and nerve.

4. =Intertransversales caudæ= (Mm. intertransversarii caudæ).—These consist of muscular bundles which lie on the lateral aspect of the tail, between the preceding muscle and the sacro-coccygeus inferior. They begin on the lateral edge of the sacrum and occupy the spaces between the transverse processes, to which they are attached. They are, however, not arranged in a strict segmental manner.

Action.—Acting together, to fix the coccygeal vertebræ; acting singly, to assist in lateral flexion.

5. =Sacro-coccygeus inferior= (Mm. sacro-coccygei ventrales; depressor coccygis).—This muscle lies on the ventral aspect of the sacrum and coccyx. It is composed of two portions, described by Bourgelat and the German anatomists as separate muscles.

(_a_) The =outer portion= (M. coccygeus ventralis lateralis) is much the larger of the two. It arises from the outer part of the ventral surface of the sacrum, about as far forward as the third foramen, and is inserted into the transverse processes and ventral surface of the coccygeal vertebræ.

(_b_) The =inner portion= (M. sacro-coccygeus ventralis medialis) arises from the ventral surface of the sacrum internal to the preceding muscle and the first eight coccygeal vertebræ, and is inserted into the ventral surfaces of the coccygeal vertebræ.

Action.—Acting together, to depress (flex) the tail; acting singly, to incline it laterally also.

Structure.—The outer portion has a somewhat compressed belly, and receives bundles from the transverse processes of the coccygeal vertebræ. The inner portion is much smaller and shorter, reaching only about to the middle of the tail.

Relations.—Ventrally, the pelvic and coccygeal fasciæ; dorsally, the sacrum, coccygeal vertebræ, and the intertransversales; laterally, the sacro-sciatic ligament, the coccygeus, and the coccygeal fascia; medially, its fellow, the recto-coccygeus, and the middle coccygeal vessels. Branches of the lateral coccygeal vessels and nerves lie between the outer division of the muscle and the intertransversales.

Blood-supply.—Middle and lateral coccygeal arteries.

Nerve-supply.—Coccygeal nerves.

THE MUSCLES OF THE THORAX

These consist of seven muscles or sets of muscles, which are attached to the thoracic vertebræ, to the ribs and their cartilages, and to the sternum. Functionally, they are muscles of respiration.

1. =Levatores costarum.=—These constitute a series of small muscles which occupy and overlie the upper ends of the intercostal spaces.

Origin.—The transverse processes of the thoracic vertebræ.

Insertion.—The external surfaces of the upper ends of the ribs posterior to the vertebral origin.

Action.—To draw the ribs forward in inspiration.

Structure.—Arising by tendinous fibers, each muscle passes backward and outward and expands at its insertion. Some fibers pass over one rib and are inserted on a succeeding one. At the first and last spaces the muscle cannot be distinguished from the

external intercostal, of which it is in reality only a specially developed part.

Relations.—Superficially, the longissimus dorsi; deeply, the ribs, internal intercostal muscles, and the intercostal vessels and nerves.

Blood-supply.—Intercostal arteries.

Nerve-supply.—Intercostal nerves.

2. =External intercostals= (Mm. intercostales externi).—Each of these occupies an intercostal space, from the levatores to the sternal extremity of the rib. They do not occupy the intercartilaginous spaces.

Origin.—The posterior borders of the ribs.

Insertion.—The anterior borders and external surfaces of the succeeding ribs.

Action.—To draw the ribs forward in inspiration.

Structure.—The fibers are directed downward and backward. There is a considerable admixture of tendinous tissue. The thickness of the muscles gradually diminishes toward the lower ends of the spaces.

[Illustration:

FIG. 184.—DORSAL AND LUMBAR REGIONS OF HORSE, DORSAL VIEW. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

Relations.—Superficially, the serratus magnus, latissimus dorsi, serratus anticus and posticus, longissimus dorsi, transversalis costarum, rectus thoracis, deep pectorals, obliquus abdominis externus, and panniculus; deeply, the internal intercostals and (in the upper part of the spaces) the intercostal vessels and nerves.

Blood-supply.—Intercostal and internal thoracic arteries.

Nerve-supply.—Intercostal nerves.

3. =Internal intercostals= (Mm. intercostales interni).—These occupy the entire length of the intercostal spaces, including their interchondral portion.

Origin.—The anterior borders of the ribs and their cartilages.

Insertion.—The posterior borders of the preceding ribs and cartilages.

Action.—To draw the ribs backward in expiration. It seems probable, however, that the intercartilaginous portion is inspiratory.[47]

Structure.—The direction of the fibers is oblique downward and forward. There is a smaller amount of tendinous tissue than in the external set, and the thickness diminishes from below upward. In the upper part of the spaces fibers sometimes cross a rib in a fashion similar to the subcostals of man. A thin aponeurosis separates the internal from the external intercostal muscle in each space.

Relations.—Superficially, the levatores costarum and the external intercostals; deeply, the endothoracic fascia and pleura, the transversus thoracis, diaphragm, transversus abdominis, and the internal thoracic and asternal vessels. In the upper part of the intercostal spaces the intercostal vessels and nerves lie between the internal and external intercostal muscle, but below they lie chiefly on the deep face of the inner muscle.

Blood-supply.—Intercostal and internal thoracic arteries.

Nerve-supply.—Intercostal nerves.

4. =Retractor costæ.=—This is a small triangular muscle which lies behind the last rib, chiefly under cover of the serratus posticus.

Origin.—The transverse processes of the first three or four lumbar vertebræ by means of the lumbar fascia.

Insertion.—The posterior border of the last rib.

Action.—To retract the last rib.

Structure.—The muscle arises by a thin aponeurosis. Its fibers are parallel to those of the adjacent internal oblique.

Relations.—Superficially, the serratus posticus and external oblique; deeply, the transversus abdominis.

Blood-supply.—Lumbar arteries.

Nerve-supply.—Lumbar nerves.

5. =Rectus thoracis= (M. transversus costarum; lateralis sterni).—This is a thin muscle which lies under cover of the deep pectoral muscles. It is directed obliquely backward and downward, and crosses the lower part of the first three intercostal spaces.

Origin.—The outer surface of the first rib, below the scalenus.

Insertion.—The cartilage of the third or fourth rib. The aponeurosis usually joins the rectus abdominis. It may reach the sternum.

Action.—It may assist in inspiration or concur with the rectus abdominis.

Relations.—Superficially, the deep pectoral muscles; deeply, the intercostal muscles and the ribs.

6. =Transversus thoracis= (Triangularis sterni).—This is a flat muscle situated on the thoracic surface of the sternum and the cartilages of the sternal ribs.

Origin.—The sternal ligament.

Insertion.—The cartilages of the ribs, from the second to the eighth inclusive.

Action.—It draws the costal cartilages inward and backward, thus assisting in expiration.

Structure.—Each muscle has the form of a scalene triangle, of which the base is the strongly serrated external border. The muscle contains a good deal of tendinous tissue. The anterior bundles are directed forward and outward; the posterior backward and outward.

Relations.—Superiorly, the endothoracic fascia and pleura; inferiorly, the costal cartilages, the internal intercostal muscles, and the internal thoracic vessels.

Blood-supply.—Internal thoracic artery.

Nerve-supply.—The intercostal nerves.

7. =Diaphragm.=—This is a broad, unpaired muscle which forms a partition between the thoracic and abdominal cavities.[48] In outline it has some resemblance to a palm-leaf fan. In form it is dome-shaped, compressed laterally. On a median section it is seen to have a general direction downward and forward from the lumbar vertebræ to the xiphoid cartilage. The thoracic surface is strongly convex, and is covered by the pleura. The abdominal surface is deeply concave, and is covered for the most part by the peritoneum. The muscle consists of a peripheral fleshy portion, two muscular crura, and a tendinous center.

Attachments.—(1) =Costal part=: The cartilages of the ninth to the fifteenth ribs, and the last three ribs at an increasing distance from their sternal ends.

(2) =Sternal part=: The upper surface of the xiphoid cartilage.

(3) =Lumbar part=: (_a_) The =right crus= is attached to the inferior common ligament, and by this means to the first four or five lumbar vertebræ. (_b_) The =left crus= is attached in a similar fashion to the first and second lumbar vertebræ.

Action.—It is the principal muscle of inspiration and increases the longitudinal diameter of the chest. The contraction produces a general lessening of the curvature of the diaphragm. In the expiratory phase the costal part and crura lie directly on the body walls, so that the bases of the lungs are in contact with the tendinous center and sternal portion only. In ordinary inspiration the fleshy rim recedes from the chest-wall, so that the bases of the lungs move backward to a line about parallel with the curve formed by the cartilages of the asternal ribs, and about four or five inches (ca. 10 to 12 cm.) therefrom. It is stated that the inspiratory movement affects the tendinous center much less than the fleshy part, since the posterior vena cava is firmly attached to the former. It should

be noted, however, that the direction of the thoracic part of the vena cava in the expiratory phase is oblique upward and backward. Thus it would seem that there is no anatomical reason why the diaphragm should not move as a whole in ordinary inspiration at least.

Structure.—The =costal part= (Pars costalis) consists of a series of digitations which meet, or are separated by a very narrow interval from, the transversus abdominis; between the two are the asternal vessels. From the tenth rib backward the attachments are to the ribs at an increasing distance above the costo-chondral junctions. Thus at the last rib the attachment is four to five inches (10 to 12 cm.) from the lower end. Anteriorly, the origin extends along the ninth costal cartilage to the xiphoid cartilage. From these points of origin the fibers curve inward and forward to join the tendinous center. The =right crus= (Crus dextrum) is about twice as thick as the left one and is also longer. It arises by a strong tendon from the lumbar vertebræ (by means of the inferior common ligament). The tendon is succeeded by a rounded belly which leaves the vertebral column, at the last thoracic vertebra. Passing downward and forward, its fibers spread out and join the tendinous center. The =left crus= (Crus sinistrum) arises by a thin tendon from the inferior common ligament at the first and second lumbar vertebræ. This is succeeded by a triangular belly which joins the central tendon. Between the crura and the attachment to the last rib the edge of the muscle crosses the ventral surface of the psoas muscles without attachment, forming the so-called lumbo-costal arch; here the thoracic and abdominal cavities are separated only by the serous membranes and some areolar tissue. The =tendinous center= (Centrum tendineum) resembles the periphery in outline, but is more elongated. It is partially divided into right and left halves by the descent of the crura into it. It is composed largely of radiating fibers, but many interlace in various directions; this is specially evident around the foramen venæ cavæ, which is encircled by fibers. A strong tendinous layer extends across below the hiatus œsophageus.

[Illustration:

FIG. 185.—DIAPHRAGM OF HORSE, ABDOMINAL SURFACE.

_1_, Inferior common ligament; _2_, _2′_, tendons of crura; _3_, lumbar sympathetic trunks; _4_, external spermatic nerve; _5_, _5′_, great splanchnic nerves; _6_, cisterna chyli (opened); _7_, _7′_, œsophageal continuations of vagus nerves; _8_, lymph gland; _9_, coronary ligament of liver (cut); _10_, right lateral ligament of liver (cut); _11_, left lateral ligament of liver (cut); _12_, falciform ligament of liver (cut); _A.l._, lumbo-costal arch; _N.i._, intercostal nerve; _C.d._, right crus; _C.s._, left crus; _A_, aorta; _Ca_, cœliac artery; _Oe._, œsophagus; _V.c._, posterior vena cava; _V.p._, phrenic veins. (After Schmaltz, Atlas d. Anat. d. Pferdes.)]

The diaphragm is pierced by three foramina. (1) The =hiatus aorticus= is an interval between the two crura and below the last thoracic vertebra. It contains the posterior aorta, vena azygos, and cisterna chyli. (2) The =hiatus œsophageus= (or foramen sinistrum) perforates the right crus near its junction with the tendinous center. It is situated a little to the left of the median plane and two or three inches below the thirteenth thoracic vertebra (in expiration). It transmits the œsophagus, the vagus nerves, and the œsophageal branch of the gastric artery. (3) The =foramen venæ cavæ= (s. dextrum) pierces the tendinous center about an inch to the right of the median plane, and about six inches below the twelfth thoracic vertebra (in expiration). The vena cava is firmly attached to the margin of the opening.[49]

Relations.—The thoracic surface is related to the endothoracic fascia, pleuræ, pericardium, the bases of the lungs, and the ribs in part. The abdominal surface is in great part covered by the peritoneum, and is related chiefly to the liver, stomach, spleen, pancreas, kidneys and adrenals, and the anterior flexures of the colon. The sympathetic and splanchnic nerves pass between the crus and the psoas muscles on each side. The asternal vessels perforate the edge of the muscle at the ninth costo-chondral joint.

Blood-supply.—Phrenic and asternal arteries.

Nerve-supply.—Phrenic nerves (from the fifth, sixth, and seventh cervical nerves).

THE ABDOMINAL MUSCLES

The =superficial fascia= covering the lateral and ventral walls of the abdomen is continuous dorsally with the lumbo-dorsal fascia, in front with the thoracic fascia, and behind with the gluteal fascia. In the inguinal region it forms part of the fascia of the penis or of the mammary glands. At the lower part of the flank it forms a fold which is continuous with the fascia of the thigh near the stifle joint. In this fold are the precrural lymph glands. Medially it blends with the linea alba. It contains the abdominal portion of the panniculus carnosus.

The =abdominal panniculus= (M. cutaneus maximus) covers a large part of the lateral surface of the abdomen and thorax. The general direction of its fibers is longitudinal. Its posterior extremity forms the basis of the fold of the flank. Its anterior extremity is inserted by a thin tendon into the internal tuberosity of the humerus, with the posterior deep pectoral muscle. Its dorsal edge may be indicated by a line drawn from the upper end of the thirteenth rib to the fold of the flank. Its ventral limit corresponds to a line drawn from the fold to a point about a handbreadth external to the umbilicus, and from here to a point a little above the level of the elbow. Behind the shoulder the fibers become oblique and blend with the scapular portion. The aponeurosis extends ventrally to the linea alba, dorsally to the supraspinous ligament. The muscle is intimately adherent to the skin, so that special care is necessary in removing the latter. Its deep face, on the other hand, is loosely attached to the underlying structures by a quantity of areolar tissue which is more or less loaded with fat (panniculus adiposus) in animals in good condition. The large external thoracic ("spur") vein is partially embedded in the lower part of the muscle. Its action is to twitch the skin.

The =deep fascia= is represented chiefly by the =abdominal= tunic (Tunica flava abdominis). This is a sheet of elastic tissue which assists the muscles in supporting the great weight of the abdominal viscera. It is practically coextensive with the obliquus externus, which it covers. Ventrally it is thick, and is intimately adherent to the aponeurosis of the muscle. Laterally it becomes thinner and is more easily separated, although fibers from it dip in between the muscle-bundles. It is continued for some distance upon the intercostals and serratus magnus. Traced forward, it passes as a thin layer beneath the posterior deep pectoral muscle. Posteriorly it is attached to the external angle of the ilium. In the inguinal region it forms the deep fascia of the prepuce or of the mammary glands.

The =linea alba= is a median fibrous raphé which extends from the xiphoid cartilage to the symphysis pubis. It is formed chiefly by the junction of the aponeuroses of the oblique and transverse muscles, but partly by longitudinal fibers. A little behind its middle is a cicatrix which indicates the position of the umbilical opening of the fœtus.

1. =Obliquus abdominis externus= (great oblique; external oblique of the abdomen).—This is the most extensive of the abdominal muscles. It is a broad sheet, irregularly triangular in shape, widest behind. Its fibers are directed chiefly downward and backward.

Origin.—(1) The outer surfaces of the last fourteen ribs, and the fascia over the external intercostal muscles; (2) the lumbo-dorsal fascia.

Insertion.—(1) The linea alba and the prepubic tendon; (2) the external angle and shaft of the ilium; (3) the internal femoral fascia.

Action.—(1) To compress the abdominal viscera, as in defecation, micturition, parturition, and expiration; (2) to flex the trunk (arch the back); (3) acting singly, to flex the trunk laterally.

Structure.—The muscle is composed of a fleshy portion and an aponeurosis. The =muscular portion= lies on the lateral wall of the thorax and abdomen. It arises by a series of digitations, the anterior four of which alternate with those of the serratus magnus. The origin may be indicated by a slightly curved line (concave above) drawn from the lower part of the fifth rib to the external angle of the ilium. The fibers are directed downward and backward and terminate on the aponeurosis, except in the flank, where they are almost horizontal in direction. The line of junction is a curve (concave above) extending from the upper edge of the posterior deep pectoral muscle toward the external angle of the ilium. The =aponeurosis= is intimately attached to the abdominal tunic, and its fibers are largely interwoven ventrally with those of the aponeurosis of the internal oblique. By this fusion is formed the outer sheath of the rectus abdominis, which blends at the linea alba with that of the opposite side. In the inguinal region the aponeurosis divides into two chief layers; one of these curves upward and backward and is inserted into the external angle of the ilium and the prepubic tendon. Between these points the aponeurosis is much strengthened and is called the =inguinal= (Poupart's) =ligament= (Ligamentum inguinale). This curves upward and somewhat forward, becomes thin, and blends with the iliac fascia. It forms the posterior wall of the inguinal canal. About an inch (ca. 2 to 3 cm.) in front of the pubis and about two inches (ca. 4 to 5 cm.) from the median plane the aponeurosis is pierced by a slit-like opening,[50] the =external inguinal ring= (Annulus inguinalis subcutaneus). This is the external orifice of the inguinal canal. Its long axis is directed outward and forward, and is about four inches (ca. 10 cm.) in length. The inner angle is rounded and is well defined by the junction of the inguinal ligament with the prepubic tendon, but the outer angle is not so sharply defined. The borders or pillars are constituted by arciform fibers of the aponeurosis of the external oblique (Crus mediale, laterale). The =femoral layer= of the aponeurosis (Lamina femoralis) passes on to the inner surface of the thigh, where it blends with the femoral fascia. A thin =iliac layer= (Lamina iliaca) passes over the outer margin of the iliacus to the external border of the ilium.

Relations.—Superficially, the skin, the panniculus carnosus, the abdominal tunic, and the posterior deep pectoral muscle; deeply, the ribs and their cartilages, the intercostal muscles, the internal oblique, the contents of the inguinal canal, and the sartorius and gracilis.

Blood-supply.—Intercostal and lumbar arteries.

Nerve-supply.—Intercostal and lumbar nerves.

2. =Obliquus abdominis internus= (small oblique; internal oblique of the abdomen).—This muscle is situated under the preceding one. Its fibers are directed downward, forward, and inward. It forms a triangular curved sheet with the base behind.

[Illustration:

FIG. 186.—VENTRAL MUSCLES OF HORSE, AFTER REMOVAL OF GREATER PART OF PANNICULUS CARNOSUS AND ABDOMINAL TUNIC. SARTORIUS AND GRACILIS REMOVED FROM RIGHT THIGH.

_c_, Mastoido-humeralis; _g_, anterior superficial pectoral; _g′_, posterior superficial pectoral; _h_, posterior deep pectoral; _l′_, aponeurosis of obliquus abdominis externus; _t_, pectineus; _u_, ilio-psoas; _v_, semimembranosus; _w_, gracilis; _x_, sartorius; _y_, vastus internus; _z_, _z′_, adductor; _14_, sternum; _14′_, cariniform cartilage. (After Ellenberger-Baum, Anat. f. Künstler.)]

Origin.—The external angle of the ilium and the adjacent part of the inguinal (Poupart's) ligament.

Insertion.—(1) The cartilages of the last four or five ribs; (2) the linea alba and the prepubic tendon.

Action.—Similar to that of the preceding muscle.

Structure.—Like the external oblique, it is composed of a fleshy portion and an aponeurosis. The fleshy portion is fan-shaped, and is situated chiefly in the flank. At its iliac origin it is covered by a glistening aponeurosis. Traced inward and downward along the abdominal surface of the inguinal ligament, the muscular origin is found to become much thinner, and also becomes loosely attached to the ligament. About four or five inches (ca. 10 to 12 cm.) from the linea alba the muscle separates from the ligament and forms the anterior wall of the inguinal canal. The abdominal orifice of the canal, the =internal inguinal ring=[51] (Annulus inguinalis abdominalis), is found here. It is normally a narrow slit, bounded in front by the edge of the internal oblique, and behind by the inguinal ligament. The =aponeurosis= is to a great extent blended with that of the external oblique, being, indeed, considerably interwoven with it ventrally. Where it covers the rectus abdominis it is attached to the tendinous inscriptions of that muscle.

Relations.—Superficially, the external oblique; deeply, the rectus abdominis, transversus abdominis, and the peritoneum.

Blood-supply.—Circumflex iliac, lumbar, and intercostal arteries.

Nerve-supply.—Ventral branches of the lumbar nerves.

3. =Rectus Abdominis.=—This muscle is confined to the ventral part of the abdominal wall; it extends from the lower part of the chest-wall to the pubis.

Origin.—The cartilages of the fifth to the ninth ribs inclusive, and the adjacent surface of the sternum.

Insertion.—The pubis, by means of the prepubic tendon.

Action.—Similar to that of the oblique muscles. It is specially adapted to flex the lumbo-sacral joints and the lumbar and thoracic parts of the spine.

Structure.—The fibers of the muscle are directed longitudinally. Nine to eleven transverse bands of fibrous tissue extend in an irregular manner across the muscle. These are termed =inscriptiones tendineæ=. They strengthen the muscle and serve to prevent separation of its fibers. The width of the muscle is greatest about its middle.

Relations.—Superficially, the aponeuroses of the oblique muscles (which constitute the external rectus sheath), and the posterior deep pectoral; deeply, the transversus, intercostals, the cartilages of the ribs, and the sternum. The posterior abdominal artery runs along the outer edge of the muscle posteriorly, and the anterior abdominal artery on or in its anterior part.

Blood-supply.—Anterior and posterior abdominal arteries.

Nerve-supply.—Intercostal and lumbar nerves.

4. =Transversus abdominis.=—This muscle, named from the general direction of its fibers, is a triangular curved sheet. Its lateral part is muscular, its ventral aponeurotic.

Origin.—(1) The inner surfaces of the distal ends or the cartilages of the asternal ribs, meeting the costal attachment of the diaphragm; (2) the transverse processes of the lumbar vertebræ, by means of the deep layer of the lumbo-dorsal fascia.

Insertion.—The xiphoid cartilage and the linea alba.

Action.—Similar to that of the oblique muscles.

Structure.—The =muscular part= is a sheet of parallel bundles of fibers, directed downward and inward. It is thickest over the cartilages of the ribs, and from here it thins out greatly toward the aponeurosis and the lumbar region. The fibers of the =aponeurosis= directly continue those of the fleshy part. Posteriorly it becomes extremely thin and blends with the aponeuroses of the oblique muscles. It covers the deep face of the rectus, so forming the internal rectus sheath.

Relations.—Superficially, the oblique and straight muscles, the retractor costæ, the cartilages of the asternal ribs, and the internal intercostal muscles; deeply, the transversalis fascia and the peritoneum. The =transversalis fascia= is little developed in the horse, and is very thin in emaciated subjects, but in animals in good condition it contains a good deal of fat. It blends with the iliac fascia and descends into the inguinal canal. The asternal artery runs along the interval between the origin of the transversus and the costal part of the diaphragm. The intercostal nerves pass down over the external surface of the muscle, to which they give branches. Branches of the first three lumbar nerves are similarly disposed further back.

Blood-supply.—Intercostal, lumbar, and asternal arteries.

Nerve-supply.—Intercostal and lumbar nerves.

5. =Cremaster externus.=—This small muscle may be regarded as a detached portion of the internal oblique, with which it blends at its origin (Figs. 272, 450).

Origin.—The iliac fascia, near the origin of the sartorius.

Insertion.—The tunica vaginalis communis.

Action.—To raise the tunica vaginalis, and with it the testicle.

Structure.—The muscle arises by a thin aponeurosis which is succeeded by a flat muscular belly about one and a half to two inches (ca. 4 to 5 cm.) in width.[52] It passes down the inguinal canal on the postero-external surface of the tunica vaginalis, to which it is rather loosely attached. On reaching the point where the tunic is reflected on to the tail of the epididymis, the muscle is firmly attached to the outer surface of the tunic by short tendinous fibers.

Relations.—The muscle lies between the peritoneum and the fascia transversalis in front and the iliac fascia and inguinal ligament behind. On reaching the internal ring it descends the inguinal canal on the postero-external surface of the tunica vaginalis communis.

Blood-supply.—External spermatic or cremasteric artery.

Nerve-supply.—External spermatic nerve.

=The Inguinal Canal.=—This term (Canalis inguinalis) is applied to an oblique passage through the posterior part of the abdominal wall.[53] It begins at the internal inguinal or abdominal ring, and extends obliquely downward, inward, and somewhat forward, to end at the external inguinal or subcutaneous ring. Its anterior wall is formed by the fleshy posterior part of the internal oblique muscle, and the posterior wall by the strong tendinous inguinal (Poupart's) ligament. The average length of the canal, measured along the spermatic cord, is about four inches (ca. 10 cm.). The =internal inguinal ring= (Annulus inguinalis abdominalis) is bounded in front by the thin margin of the internal oblique muscle, and behind by the inguinal ligament. It is directed approximately from the edge of the prepubic tendon toward the external angle of the ilium. Its length is about four or five inches (ca. 10 to 12 cm.). The edge of the muscle is attached to the surface of the ligament here by delicate connective tissue, except where structures

intervene between the walls of the canal. Consequently the limits of the ring are not very clearly defined. The =external inguinal ring= (Annulus inguinalis subcutaneus) is a well defined slit in the aponeurosis of the external oblique muscle, situated lateral to the prepubic tendon. Its long axis is directed from the edge of the prepubic tendon outward and forward, and its average length is about four inches (ca. 10 cm.). The canal contains in the male the spermatic cord, the tunica vaginalis, the external cremaster muscle, the external pudic artery and a small satellite vein, and the inguinal lymph vessels and nerves. In the female it contains the mammary vessels and nerves; in the bitch it also lodges the round ligament of the uterus, inclosed in a tubular process of peritoneum.

The two rings do not correspond in direction, so that the length of the canal varies greatly when measured at different points. The inner angle of the internal ring lies almost immediately above that of the external ring, but the outer angle is situated five to six inches (ca. 12 to 15 cm.) from that of the external ring. The inner angles of the external rings are well defined and distinctly palpable in the living subject; they are about three to four inches (ca. 8 to 10 cm.) apart.

=The Prepubic Tendon.=—The =prepubic tendon= is essentially the tendon of insertion of the two recti abdominis, but also furnishes attachment to the obliqui, the graciles, and the pectinei. It is attached to the anterior borders of the pubic bones, including the ilio-pectineal eminences. It has the form of a very strong thick band, with concave lateral borders which form the inner boundaries of the external inguinal rings. Its direction is oblique upward and backward.[54] Its structure is somewhat complex. Most of the fibers of the posterior part extend from one ilio-pectineal eminence to the other. The fibers which belong to the recti curve in to the median line. The aponeuroses of the internal oblique muscles are inserted into its abdominal surface, and the inguinal ligaments are attached to and continue across it in arciform fashion. The anterior part of the tendon of origin of the gracilis is fused with it ventrally, and many of the fibers of the pectineus arise from it. It gives off on either side a strong round band, the so-called =pubo-femoral= or =accessory ligament=, which is inserted into the fossa of the head of the femur with the round ligament (_vide_ hip joint).

MUSCLES OF THE THORACIC LIMB

I. THE MUSCLES OF THE SHOULDER GIRDLE (Figs. 177, 178, 179, 186)

This group consists of those muscles which connect the thoracic limb with the head, neck, and trunk. The group naturally falls into two divisions—dorsal and ventral.[55]

A. DORSAL DIVISION

This division consists of two layers which overlie the proper muscles of the neck and back.

FIRST LAYER

1. =Trapezius.=—This is a flat, triangular muscle, the base of the triangle corresponding with the spine. It is divided by an aponeurotic portion into two divisions:

(=a=) =Trapezius cervicalis.=—_Origin._—The funicular portion of the ligamentum nuchæ, from the second cervical to the third thoracic vertebra.

Insertion.—The spine of the scapula and the fascia of the shoulder and arm.

(=b=) =Trapezius thoracalis s. dorsalis.=—_Origin._—The supraspinous ligament, from the third to the tenth thoracic vertebra.

Insertion.—The tubercle of the spine of the scapula.

Action.—Acting as a whole, to elevate the shoulder; the cervical portion draws the scapula forward and upward and the thoracic portion draws it backward and upward.

Structure.—The muscle arises by a short, thin aponeurosis, from which the fibers of the flat fleshy portion converge to the spine of the scapula and the aponeurosis which separates the two portions. The cervical fascia joins the ventral edge of the cervical portion to the mastoido-humeralis, or the two muscles may unite here.

Relations.—Superficially, the skin and fascia; deeply, the rhomboideus, latissimus dorsi, supraspinatus, infraspinatus, deltoid, splenius, serratus magnus, and anterior deep pectoral muscles, and the cartilage of the scapula.

Blood-supply.—Deep cervical and intercostal arteries.

Nerve-supply.—Spinal accessory nerve.

SECOND LAYER

This consists of two muscles—the rhomboideus and the latissimus dorsi.

2. =Rhomboideus.=—This consists of two portions:

(=a=) =Rhomboideus cervicalis s. cervicis.=—_Origin._—The funicular portion of the ligamentum nuchæ, from the second cervical to the second thoracic vertebra.

Insertion.—The internal surface of the cartilage of the scapula.

(=b=) =Rhomboideus thoracalis s. dorsalis.=—_Origin._—The spinous processes of the second to the seventh thoracic vertebra by means of the dorso-scapular ligament.

Insertion.—The inner surface of the cartilage of the scapula.

Action.—To draw the scapula upward and forward. When the limb is fixed the cervical portion will elevate the neck.

Structure.—The cervical portion is narrow, pointed at its anterior extremity, and lies along the funicular part of the ligamentum nuchæ, to which it is attached by short tendon bundles. The fibers are directed for the most part longitudinally. The thoracic portion is quadrilateral in shape, and its fibers are nearly vertical. Its deep face is intimately attached to the dorso-scapular ligament.

Relations.—Superficially, the skin and fascia (over a small area), the trapezius, and the cartilage of the scapula; deeply, the dorso-scapular ligament, the splenius, complexus, longissimus dorsi, and serratus anticus.

Blood-supply.—Dorsal and superior cervical arteries.

Nerve-supply.—Sixth cervical nerve.

3. =Latissimus Dorsi.=—This is a wide muscle which has the form of a right-angled triangle. It lies for the most part under the skin and panniculus, on the lateral wall of the thorax, from the spine to the arm.

Origin.—The lumbo-dorsal fascia—and by this means from the lumbar and thoracic spines as far forward as the highest point of the withers.

Insertion.—The internal tubercle of the humerus, in common with the teres major.

Action.—To draw the humerus upward and backward and flex the shoulder joint. If the limb is advanced and fixed, it draws the trunk forward.

Structure.—The muscle arises by a wide aponeurosis, which fuses with that of the serratus posticus and with the lumbo-dorsal fascia. The muscular portion is at first rather thin, but by the convergence of its fibers becomes thicker as it approaches the arm. The anterior fibers pass almost vertically downward over the dorsal angle of the scapula and its cartilage. The posterior fibers are directed downward and forward. The thick belly formed by the convergence of these passes under the triceps to end on the flat tendon of insertion, which is common to this muscle and the teres major.

Blood-supply.—Subscapular, intercostal, and lumbar arteries.

Nerve-supply.—Brachial plexus (eighth cervical and dorsal roots).

B. VENTRAL DIVISION

1. =Mastoido-humeralis= (M. brachiocephalicus; levator humeri).—This muscle extends along the side of the neck from the head to the arm. It is incompletely divisible into two portions.

Origin.—(1) The mastoid process of the petrous temporal bone and the occipital crest; (2) the wing of the atlas and the transverse processes of the second, third, and fourth cervical vertebræ.

Insertion.—The deltoid tuberosity and the curved rough line which extends from this to the distal extremity of the humerus.

Action.—When the head and neck are fixed, to draw the limb forward, extending the shoulder joint. When the limb is fixed, to extend the head and neck, if the muscles act together; acting separately, to incline the head and neck to the same side.

Structure.—As already mentioned, the muscle is capable of incomplete division into two parts, the line of division being indicated by the emergence of superficial branches of the ventral divisions of the cervical nerves. The mastoid portion (M. cleido-mastoideus) partly overlaps the other portion (M. cleido-transversarius), which lies dorsal to it. The former is attached to the mastoid process and the occipital bone by a broad tendon which fuses with that of the splenius and trachelo-mastoideus; it is also attached to the tendon of insertion of the sterno-cephalicus by aponeurosis. The dorsal portion is attached to the transverse processes by four fleshy digitations. The belly of the muscle is adherent superficially to the cervical fascia and the panniculus, and deeply to the subscapulo-hyoideus. In front of the shoulder its deep face is marked by a tendinous intersection of variable development.[56] Here the muscle becomes wider, covers the shoulder joint, passes between the brachialis and biceps, and is inserted by means of a wide tendon which it shares with the superficial pectoral muscle.

Relations.—Superficially, the skin, cervical fascia, the parotid gland, the panniculus, brachialis, and branches of the cervical nerves; deeply, the splenius, trachelo-mastoideus, rectus capitis anterior major, omo-hyoideus, serratus magnus, anterior deep pectoral and biceps muscles, the inferior cervical artery, the prescapular lymph glands, and branches of the cervical nerves. The ventral edge of the muscle forms the dorsal boundary of the jugular furrow. The dorsal border may be in contact with the cervical trapezius, or separated from it by a variable interval.

Blood-supply.—Inferior cervical, carotid, and vertebral arteries.

Nerve-supply.—Spinal accessory and cervical nerves.

The =pectoral fascia= is a thin membrane covering the surface of the pectoral muscles, to which it is, for the most part, pretty intimately attached. It detaches a layer which passes between the superficial and deep pectorals. At the posterior edge of the triceps another layer is given off, which passes on the outer surface of this muscle to blend with the scapular fascia; the deeper layer becomes continuous with the subscapular and cervical fasciæ.

The =pectoral muscles= form a large fleshy mass which occupies the space between the ventral part of the chest-wall and the shoulder and arm. They are clearly divisible into a superficial and a deep layer. The superficial layer may be subdivided into two portions by careful dissection; the deep layer is clearly made up of two muscles.

2. =Superficial pectoral= (M. pectoralis superficialis).

(=a=) =Anterior superficial pectoral= (portio clavicularis s. descendens; pectoralis anticus).—This is a short, thick, somewhat rounded muscle, which extends between the anterior part of the sternum and the front of the arm. It forms a distinct prominence on the front of the breast, which is easily recognized in the living animal.

Origin.—The cariniform cartilage of the sternum.

Insertion.—(1) The curved line of the humerus with the mastoido-humeralis; (2) the fascia of the arm.

Action.—To adduct and advance the limb.

Structure.—The belly of the muscle is convex on its superficial face, but deeply it is flattened where it overlaps the posterior superficial pectoral. Here the two muscles are usually pretty intimately attached to each other, and care must be exercised in making the separation. The tendon of insertion blends with that of the mastoido-humeralis and with the fascia of the arm. At the middle line of the breast a furrow occurs between the two muscles; laterally, another furrow, containing the cephalic vein, lies between the muscle and the mastoido-humeralis.

Relations.—Superficially, the skin, fascia, and panniculus; deeply, the posterior division, the deep pectoral, and the biceps. The cephalic vein lies in the groove between this muscle and the mastoido-humeralis.

(=b=) =Posterior superficial pectoral= (portio sternocostalis; pectoralis transversus).—This is a wide muscular sheet which extends from the ventral edge of the sternum to the fascia on the inner surface of the forearm.

Origin.—(1) The ventral edge of the sternum as far back as the sixth cartilage; (2) a fibrous raphé common to the two muscles.

Insertion.—(1) The fascia on the proximal third of the forearm; (2) the curved line of the humerus with the preceding muscle.

Action.—To adduct the limb and to tense the fascia of the forearm.

Structure.—It is thin and pale, and mixed with a good deal of fibrous tissue. The right and left muscles fuse at a median fibrous raphé. The tendon of insertion unites with the fascia on the inner side of the forearm for the most part; only a small part in front, about an inch in width, is attached to the humerus.

Relations.—Superficially, the skin, fascia, and the preceding muscle; deeply, the deep pectoral, the biceps, and the brachialis; at the elbow, the posterior radial vessels, the median nerve, and the inner and middle flexors of the carpus.

3. =Deep pectoral= (M. pectoralis profundus).—This muscle is much thicker and more extensive in the horse than the superficial pectoral. It consists of two distinct portions.

(=a=) =Anterior deep pectoral= (portio prescapularis; pectoralis parvus).—This division is prismatic and extends from the anterior part of the lateral surface of the sternum to the cervical angle of the scapula.

Origin.—The anterior half of the lateral surface of the sternum and the cartilages of the first four ribs.

Insertion.—The aponeurosis which covers the supraspinatus at its dorsal end, and the scapular fascia.

Action.—To adduct and retract the limb; when the limb is advanced and fixed, to draw the trunk forward.

Structure.—The muscle is almost entirely fleshy. It describes a curve (convex anteriorly), passing at first forward, then upward over the front of the shoulder, a little to its inner side, and finally upward and backward along the anterior border of the supraspinatus. It is loosely attached to the latter muscle, and terminates in a pointed end which becomes more firmly attached near the cervical angle of the scapula.

Relations.—Superficially, the skin and fascia, the panniculus, superficial pectoral, trapezius, and mastoido-humeralis muscles, the cephalic vein, and the inferior cervical artery; deeply, the posterior deep pectoral, biceps, supraspinatus, omo-hyoideus, and serratus magnus muscles, the brachial vessels, and the branches of the brachial plexus of nerves.

(=b=) =Posterior deep pectoral= (portio humeralis s. ascendens; pectoralis magnus).—This is much the largest of the pectoral group in the horse. It is somewhat triangular or fan-shaped.

Origin.—(1) The abdominal tunic; (2) the xiphoid cartilage and ventral aspect of the sternum; (3) the cartilages of the fourth to the ninth ribs.

Insertion.—(1) The internal tuberosity of the humerus; (2) the external lip of the bicipital groove; (3) the tendon of origin of the coraco-brachialis.

Action.—To adduct and retract the limb; if the limb is advanced and fixed, to draw the trunk forward.

Structure.—This muscle is also almost entirely fleshy. Its posterior part is wide and thin, but as the muscle is traced forward, it becomes narrower and much thicker. It passes forward and slightly upward in a gentle curve to its insertion. The humeral insertion is just below that of the inner division of the supraspinatus. Part of the fibers are inserted by means of a tendinous band which binds down the tendon of the biceps and is attached to the external lip of the bicipital groove, and a small part is attached to the tendon of origin of the coraco-brachialis.

Relations.—Superficially, the skin, panniculus, and superficial pectoral; deeply, the abdominal tunic, the external oblique, the rectus abdominis et thoracis, the brachial vessels, and branches of the brachial plexus of nerves. The external thoracic vein lies along the outer or upper border.

Blood-supply.—Internal and external thoracic, inferior cervical, anterior circumflex, and intercostal arteries.

Nerve-supply.—Pectoral (or thoracic) nerves, from the brachial plexus.

4. =Serratus magnus= (M. serratus ventralis).—This is a large, fan-shaped muscle, situated on the lateral surface of the neck and thorax. It derives its name from the serrated ventral edge of its thoracic portion. It consists of a cervical and a thoracic portion.

(=a=) =Cervical part= (M. serratus cervicis; levator scapulæ hominis).

Origin.—The transverse processes of the last four or five cervical vertebræ.

Insertion.—The anterior triangular area on the costal surface of the scapula and the adjacent part of the cartilage.

(=b=) =Thoracic part= (M. serratus thoracis; serratus anterior hominis).

Origin.—The external surfaces of the first eight or nine ribs.

Insertion.—The posterior triangular area on the costal surface of the scapula and the adjacent part of the cartilage.

Action.—The two muscles form a sort of sling in which the trunk is suspended. Contracting together, they raise the thorax; contracting singly, the weight is shifted to the limb on the side of the muscle acting. The two parts can contract separately and are antagonistic in their action on the scapula. The cervical part draws the base of the scapula toward the neck, while the thoracic part has the opposite action; these effects concur in the backward and forward swing of the limb respectively. With the limb fixed, the cervical part extends (raises) the neck or inclines it laterally. The thoracic part may act as a muscle of forced inspiration.

Structure.—In the domesticated animals there is no such clear division of the muscle as is found in man and the apes. On account of the difference in action, however, it seems desirable to distinguish the two portions. The cervical part is thick and almost entirely fleshy. The thoracic part has on its superficial face a thick, tendinous layer which may sustain the weight of the trunk when the muscle substance relaxes. The ventral edge presents distinct digitations, the last four of which alternate with those of the obliquus externus abdominis, and are covered by the abdominal tunic. The fourth, fifth, and sixth digitations extend nearly to the distal ends of the ribs. The last digitation is small and may be absent. Exceptionally additional digitations may be attached to the tenth or eleventh rib or to the fascia over the intercostal muscles. The fibers converge to the insertion, which is thick and is intersected by elastic lamellæ derived from the dorso-scapular ligament.

Relations.—Superficially, the mastoido-humeralis, trapezius, deep pectoral, subscapularis, teres major, latissimus dorsi, panniculus carnosus, the abdominal tunic, the brachial vessels, and the long thoracic nerve; deeply, the splenius, complexus, longissimus, transversalis costarum, the ribs and external intercostal muscles, and branches of the superior cervical and dorsal arteries.

Blood-supply.—Superior cervical, dorsal, vertebral, and intercostal arteries.

Nerve-supply.—Brachial plexus.

II. THE MUSCLES OF THE SHOULDER

Under this head will be described those muscles which arise on the scapula and end on the arm; they may be divided into two groups—one covering the dorsum, the other the venter of the scapula.

The =superficial fascia= of the shoulder and arm contains the panniculus carnosus of this region, and may be considered to be continued on the inner side of the limb by the subscapular fascia.

The =thoracic= or =scapulo-humeral portion= of the =panniculus= (M. cutaneus scapulæ et humeri) arises by a thin aponeurosis from the ligamentum nuchæ at the withers. The fleshy portion begins over the upper part of the scapula and extends to the elbow. Its fibers have in general a dorso-ventral direction. It is continuous behind with the abdominal portion.

The =deep fascia= of the shoulder and arm (Fascia omobrachialis) is much more developed and important. It is strong and tendinous, and is intimately adherent to the muscles on the outer surface of the scapula, between which it detaches =intermuscular septa=, which are attached to the spine and borders of the scapula. The brachial portion is, for the most part, only loosely attached to the underlying muscles, for which it forms sheaths; it is attached to the humerus, especially to the lips of the bicipital groove and the deltoid tuberosity. It blends distally with the tendon of insertion of the biceps, and is continued by the antibrachial fascia.

A. EXTERNAL GROUP (Figs. 178, 179)

1. =Deltoid= (M. deltoideus; long abductor of the arm; scapular portion of the deltoid of man).—This lies partly on the triceps in the angle between the scapula and humerus, partly on the infraspinatus and teres minor.

Origin.—(1) The upper part of the posterior border of the scapula; (2) the spine of the scapula, by means of the strong aponeurosis which covers the infraspinatus.

Insertion.—The deltoid tuberosity of the humerus.

Action.—To flex the shoulder joint and abduct the arm.

Structure.—The origin of the muscle is partly aponeurotic, partly fleshy. The aponeurosis fuses with that of the infraspinatus; the posterior part is attached to the scapula immediately in front of the origin of the long head of the triceps. The belly of the muscle lies for the most part in a cavity formed in the triceps. It is widest about its middle.

Relations.—Superficially, the skin, fascia, panniculus, and mastoido-humeralis; deeply, the infraspinatus, teres minor, triceps, and brachialis muscles, and branches of the posterior circumflex artery and axillary nerve.

Blood-supply.—Subscapular artery (chiefly through the posterior circumflex).

Nerve-supply.—Suprascapular and axillary nerves.

2. =Supraspinatus.=—This muscle occupies the supraspinous fossa, which it fills, and beyond which it extends, thus coming in contact with the subscapularis.

Origin.—The supraspinous fossa, the spine, and the lower part of the cartilage of the scapula.

Insertion.—The inner and outer lips of the bicipital groove.

Action.—To extend the shoulder joint. It also assists in preventing dislocation.

Structure.—The surface of the muscle is covered by a strong aponeurosis, from the deep face of which many fibers arise. The muscle is thin at its origin from the cartilage, but becomes considerably thicker below. At the neck of the scapula it divides into two branches, between which the tendon of origin of the biceps emerges. These branches, fleshy superficially, tendinous deeply, are inserted into the lips of the bicipital groove. They are united by a fibrous membrane already mentioned in connection with the deep pectoral muscle; some fibers are attached to this membrane and the capsule of the shoulder joint.

Relations.—Superficially, the skin, fascia, panniculus, trapezius, and mastoido-humeralis; deeply, the scapula and its cartilage, the subscapularis muscle, and the suprascapular vessels and nerve; in front, the anterior deep pectoral muscle; behind, the spine of the scapula and infraspinatus muscle.

Blood-supply.—Suprascapular and posterior circumflex arteries.

Nerve-supply.—Suprascapular nerve.

3. =Infraspinatus.=—This muscle occupies the greater part of the infraspinous fossa.

Origin.—The infraspinous fossa and the scapular cartilage.

Insertion.—(1) The outer tuberosity of the humerus, distal to the outer insertion of the supraspinatus; (2) the posterior eminence of the outer tuberosity.

Action.—To abduct the arm and rotate it outward.[57] It also plays the part of a lateral ligament.

Structure.—This muscle is also covered by a strong aponeurosis, from which many fibers arise, and by means of which the deltoid is attached to the spine of the scapula. A thick tendinous layer partially divides the muscle into two strata, and, coming to the surface at the shoulder joint, constitutes the chief means of insertion. This tendon, an inch or more (3 cm.) in width, passes over the posterior eminence of the external tuberosity of the humerus; it is bound down by a fibrous sheet, and a =synovial bursa= is interposed between the tendon and the bone. When the long insertion is cut and reflected, the short insertion, partly tendinous, partly fleshy, is exposed.

Relations.—Superficially, the skin, fascia, panniculus, trapezius, and deltoid; deeply, the scapula and its cartilage, the shoulder joint and capsule, the long head of the triceps, the teres minor, and the nutrient artery of the scapula.

Blood-supply.—Subscapular artery.

Nerve-supply.—Suprascapular and axillary nerves.

4. =Teres minor.=—This is a much smaller muscle than the foregoing. It lies chiefly on the triceps, under cover of the deltoid and infraspinatus.

Origin.—(1) The rough lines on the distal and posterior part of the infraspinous fossa; (2) a small part of the posterior border of the scapula, about its middle; (3) a tubercle near the rim of the glenoid artery.

Insertion.—The deltoid tuberosity and a small area just above it.

Action.—To flex the shoulder joint and to abduct the arm; also to assist in outward rotation.

Structure.—The muscle is not rounded in the horse and ox, but flat and triangular. Its origin from the posterior border of the scapula is by means of an aponeurosis which also gives origin to fibers of the infraspinatus and triceps. A =bursa= is commonly found between the terminal part of the muscle and the capsule of the shoulder joint, and is often continuous with that of the infraspinatus.

Relations.—Superficially, the deltoid and infraspinatus muscles; deeply, the scapula, the shoulder joint, and the triceps muscle.

Blood-supply.—Subscapular artery (circumflex branches).

Nerve-supply.—Axillary nerve.

B. INTERNAL GROUP

1. =Subscapularis.=—This muscle occupies the subscapular fossa, beyond which, however, it extends both before and behind.

Origin.—The subscapular fossa.

Insertion.—The posterior eminence of the internal tuberosity of the humerus.

Action.—To adduct the humerus.

[Illustration:

FIG. 187.—MUSCLES OF THORACIC LIMB OF HORSE, INTERNAL VIEW.

_3_, _4_, Rhomboideus; _5_, latissimus dorsi; _8_, posterior deep pectoral; _9_, anterior deep pectoral; _11_, supraspinatus; _15_, subscapularis; _16_, teres major; _20_, long head of triceps; _22a_, _22b_, tensor fasciæ antibrachii; _23_, internal head of triceps. (After Ellenberger, in Leisering's Atlas.)]

Structure.—The muscle is flat and triangular, with the base upward. The latter is thin and interdigitates with the scapular attachments of the serratus. Below this the belly thickens and becomes narrower. It is covered by an aponeurosis, and contains a considerable amount of tendinous tissue. The tendon of insertion is crossed by the tendon of origin of the coraco-brachialis; it is intimately adherent to the capsule of the shoulder joint, and may be regarded as replacing the internal ligament of the latter. A small bursa may occur here.

Relations.—Superficially, the scapula and shoulder joint, the supraspinatus, triceps, and teres major muscles; deeply, the serratus magnus muscle, the brachial vessels, and the chief branches of the brachial plexus. The subscapular vessels run along or near the posterior edge of the muscle.

Blood-supply.—Subscapular artery.

Nerve-supply.—Subscapular nerves (from the brachial plexus).

2. =Teres major= (Teres internus; adductor of the arm).—This muscle is flat, widest about its middle, and lies chiefly on the deep face of the triceps.

Origin.—The dorsal angle and the adjacent part of the posterior border of the scapula.

Insertion.—The tubercle on the inner surface of the shaft of the humerus, in common with the latissimus dorsi.

Action.—To flex the shoulder joint and adduct the arm.

Structure.—It is for the most part fleshy, but the origin consists of an aponeurosis which blends with that of the tensor fasciæ antibrachii. The insertion is by a flat tendon which fuses with that of the latissimus dorsi.

Relations.—Superficially, the triceps, infraspinatus, and deltoid muscles; deeply, the serratus magnus muscle. The subscapular vessels lie in a groove between the anterior edge of this muscle and the posterior border of the subscapularis; near the shoulder joint the posterior circumflex artery and the axillary nerve emerge between the two muscles. The deep face of the muscle is crossed by the thoracic branches of the brachial plexus, and by the branch of the subscapular artery which supplies the latissimus dorsi.

Blood-supply.—Subscapular artery.

Nerve-supply.—Axillary nerve.

3. =Coraco-brachialis= (Coraco-humeralis).—This muscle lies on the inner surface of the shoulder joint and the arm.

Origin.—The coracoid process of the scapula.

Insertion.—(1) A small area above the internal tubercle of the humerus; (2) the middle third of the anterior surface of the humerus.

Action.—To adduct the arm and to flex the shoulder joint.

Structure.—The long tendon of origin emerges between the subscapularis and the inner branch of the supraspinatus. It passes over the terminal part of the subscapularis and is provided with a =synovial sheath=. The muscular part spreads out and divides into two portions. The smaller and shorter portion is inserted into the proximal third of the shaft of the humerus, close to the origin of the lateral head of the triceps; the larger and longer portion is inserted into the middle third of the humerus, in front of the internal tubercle and the inner head of the triceps.

Relations.—Externally, the subscapularis muscle and the humerus; internally, the deep pectoral and brachialis muscles. The anterior circumflex artery and the nerve to the biceps usually emerge between the two insertions, and the brachial vessels lie along the posterior border of the muscle.

Blood-supply.—Anterior circumflex artery.

Nerve-supply.—Musculo-cutaneous nerve.

4. =Capsularis= (Scapulo-humeralis posticus s. gracilis).—This is a very small muscle, which lies on the back of the capsule of the shoulder joint.

Origin.—The scapula, close to the rim of the glenoid cavity.

Insertion.—The posterior surface of the shaft of the humerus, a short distance below the head.

Action.—It may perhaps tense the capsule of the shoulder joint and prevent its being pinched during flexion.

Structure.—It is fleshy and usually about the breadth of a finger. It may, however, consist of only a few bundles of fibers; sometimes it is double. Its attachment to the joint capsule is slight. It passes through the brachialis muscle to reach its insertion.

Relations.—Superficially, the teres minor and triceps muscles; deeply, the teres major and subscapularis muscles, and the capsule of the joint.

Blood-supply.—Posterior circumflex artery.

Nerve-supply.—Axillary nerve.

III. THE MUSCLES OF THE ARM

This group consists of five muscles which are grouped around the humerus. They arise from the scapula and the humerus, and are inserted into the forearm. They act on the elbow joint and the fascia of the forearm.

[Illustration:

FIG. 188.—BICEPS AND BRACHIALIS MUSCLES OF HORSE. (After Ellenberger-Baum, Anat. für Künstler.)]

1. =Biceps brachii= (Coraco-radialis; flexor brachii).—This is a strong, somewhat rounded muscle, which lies on the anterior surface of the humerus.

Origin.—The tuberosity of the scapula.

Insertion.—(1) The bicipital tuberosity of the radius; (2) the internal lateral ligament of the elbow joint; (3) the fascia of the forearm and the tendon of the extensor carpi radialis.

Action.—To flex the elbow joint, to fix the shoulder, elbow, and carpus in standing, and to tense the fascia of the forearm.

Structure.—The muscle is inclosed in a double sheath of fascia, which is attached to the lips of the bicipital groove and the deltoid ridge of the humerus. The tendon of origin is moulded on the bicipital groove; it is very strong and dense and is partly cartilaginous. Its play over the groove is facilitated by the large =bicipital bursa= (Bursa intertubercularis). The synovial membrane covers not only the deep face of the tendon, but extends somewhat over the edges to the superficial face. A well-marked tendinous intersection runs through the belly of the muscle and divides distally into two portions. Of these, the short, thick one is inserted into the bicipital tuberosity and detaches fibers to the internal lateral ligament. The long tendon (Lacertus fibrosus) is thinner, blends with the fascia of the forearm, and ends by fusing with the tendon of the extensor carpi radialis.

Relations.—Externally, the mastoido-humeralis and brachialis muscles; internally, the posterior deep pectoral and the superficial pectoral muscles; in front, the anterior deep pectoral muscle; behind, the humerus, the coraco-brachialis muscle, the anterior circumflex and anterior radial vessels, and the musculo-cutaneous nerve.

Blood-supply.—Branches of the brachial and anterior radial arteries.

Nerve-supply.—Musculo-cutaneous nerve.

2. =Brachialis= (Humeralis obliquus s. externus; brachialis anticus).—This muscle occupies the musculo-spiral groove of the humerus.

Origin.—The proximal third of the posterior surface of the humerus.

Insertion.—The inner surface of the neck of the radius (under cover of the lateral ligament) and the arciform ligament.

Action.—To flex the elbow joint.

Structure.—The peculiar spiral course of this muscle gave rise to the name often applied to it—humeralis obliquus. Beginning on the posterior surface of the shaft, close to the head of the humerus, it winds over the lateral surface, crosses the biceps very obliquely, and finally reaches the inner side of the forearm by passing between the biceps and the extensor carpi. It is entirely fleshy, with the exception of its relatively slender tendon of insertion.

Relations.—Externally the skin and fascia, the teres minor, deltoid, triceps (lateral head), biceps, and mastoido-humeralis muscles. The anterior radial artery crosses the deep face of the muscle in its distal third, and the radial nerve accompanies the muscle in the distal half of the musculo-spiral groove.

Blood-supply.—Brachial artery.

Nerve-supply.—Radial nerve.

3. =Tensor fasciæ antibrachii= (Fig. 187)[58] (Scapulo-ulnaris; long extensor of the forearm; accessory anconeus of the latissimus dorsi).—This is a thin muscle which lies on the inner surface of the triceps.

Origin.—The tendon of insertion of the latissimus dorsi and the posterior border of the scapula.

Insertion.—(1) The fascia of the forearm; (2) a small eminence on the posterior border of the olecranon.

Action.—(1) To tense the fascia of the forearm and to extend the elbow joint.

Structure.—The origin consists of a very thin aponeurosis which blends with those of the caput longum and the latissimus dorsi. The muscular portion is quite thin in its anterior part, somewhat thicker behind, and is narrower than the aponeurotic origin. It is succeeded by an aponeurotic insertion, which ends chiefly by blending with the fascia of the forearm a little below the elbow. There is, however, a small but constant tendinous attachment to the olecranon.

Relations.—Externally, the panniculus, triceps (long and internal heads), the inner and middle flexors of the carpus, and the ulnar vessels and nerve; internally, the latissimus dorsi, serratus magnus, and posterior pectoral muscles.

Blood-supply.—Subscapular, ulnar, and deep brachial arteries.

Nerve-supply.—Radial nerve.

4. =Triceps brachii= (Figs. 178, 179, 187) (Brachial triceps; triceps extensor cubiti).—This, together with the preceding muscle, constitutes the large muscular mass which fills the angle between the posterior border of the scapula and the humerus. It is clearly divisible into three heads, as described below.

(=a=) =Long head= (Caput longum tricipitis; anconeus longus; caput magnum).—This, the largest and longest of the three heads, is a powerful, thick, triangular muscle, which extends from the posterior border of the scapula to the olecranon.

Origin.—The posterior border of the scapula.

Insertion.—The outer and posterior part of the summit of the olecranon.

Action.—(1) To extend the elbow joint; (2) to flex the shoulder joint.

Structure.—The muscle arises by a wide, strong aponeurosis from the posterior border of the scapula. From this the bundles of the fleshy portion converge to the short, strong tendon of insertion. A careful examination will show that the muscle is penetrated by a tendinous intersection from which many fibers take origin obliquely. The superficial face is covered by an aponeurosis which is specially developed at its distal part. A small =bursa= occurs under the tendon of insertion.

Relations.—Externally, the panniculus, deltoid, infraspinatus, teres minor, and the external head; internally, the tensor fasciæ antibrachii, teres major, latissimus dorsi, and posterior deep pectoral muscles, and the subscapular vessels; in front, the brachialis, and the inner head, the deep brachial and posterior circumflex vessels, and the axillary and radial nerves; behind, the skin and fascia.

Blood-supply.—Subscapular and deep brachial arteries.

Nerve-supply.—Radial nerve.

(=b=) =External head= (Caput laterale tricipitis s. anconeus lateralis s. externus; caput medium).—This is a strong, quadrilateral muscle, which lies on the outer surface of the arm. Its proximal third is covered by the deltoid and teres minor muscles; the remainder only by the thin panniculus and the skin.

Origin.—The deltoid tuberosity and the curved rough line which extends from it to the neck of the humerus.

Insertion.—(1) A small prominent area on the outer surface of the olecranon; (2) the tendon of the long head.

Action.—To extend the elbow joint.

Structure.—The origin consists of short tendinous fibers. The belly is thick, and is composed of parallel bundles which are directed obliquely downward and backward. They are inserted partly into the tendon of the long head and partly into the olecranon below and in front of that tendon.

Relations.—Externally, the deltoid, teres minor, and panniculus muscles; internally, the long and inner heads and the brachialis muscle. Branches of the circumflex vessels and axillary nerve emerge between the posterior edge of the muscle and the long head. The deep face of the muscle is related to the branches of the deep brachial artery and of the radial nerve.

Blood-supply.—Posterior circumflex and deep brachial arteries.

Nerve-supply.—Radial nerve.

(=c=) =Internal head= (Fig. 193) (Caput mediale tricipitis; anconeus medialis s. internus; caput parvum).—This is much the smallest of the three heads. It is situated on the inner surface of the arm, and extends from the middle third of the humerus to the olecranon.

Origin.—The middle third of the inner surface of the shaft of the humerus, behind and below the internal tubercle.

Insertion.—The inner and fore part of the summit of the olecranon, between the insertion of the long head and the origin of the ulnar head of the flexor perforans.

Action.—To extend the elbow joint.

Structure.—The muscle is fleshy except at its insertion, where it has a flat tendon, under which a small bursa may be found.

Relations.—Externally, the humerus, brachialis, anconeus, and the external head; internally, the posterior deep pectoral, coraco-brachialis, teres major, latissimus dorsi, and tensor fasciæ antibrachii muscles, the brachial and deep brachial vessels, and the median and ulnar nerves; behind, the long head, branches of the deep brachial vessels, and the radial nerve.

Blood-supply.—Deep brachial and ulnar arteries.

Nerve-supply.—Radial nerve.

5. =Anconeus= (M. anconeus parvus s. subanconeus).—This is a small fleshy muscle which covers the olecranon fossa and is covered by the triceps. It is somewhat difficult to separate from the outer head.

Origin.—The distal third of the posterior surface of the humerus.

Insertion.—The outer surface of the olecranon.

Action.—To extend the elbow joint, and to raise the capsule of the joint and prevent its being pinched during extension.

Structure.—It is almost entirely fleshy, and is adherent by its deep face to the joint capsule.

Relations.—Superficially, the triceps muscle; deeply, the humerus and the elbow joint.

Blood-supply.—Deep brachial artery.

Nerve-supply.—Radial nerve.

[Illustration:

FIG. 189.—DIGIT OF HORSE, POSTERIOR VIEW.

_14_, Deep flexor tendon; _15_, superficial flexor tendon; _16_, posterior annular ligament of fetlock; _17_, proximal annular or vaginal ligament of digit; _11_, lateral cartilage; _24_, plantar cushion. (After Ellenberger-Baum, Anat. für Künstler.)]

IV. FASCIÆ AND MUSCLES OF THE FOREARM AND MANUS

The forearm is covered on three sides by the muscles of this group, leaving the inner surface of the radius for the most part subcutaneous. The extensors of the carpus and digit lie on the anterior (dorsal) and external part of the region, while the flexors occupy the posterior (volar) surface.

The =fascia= of the =forearm= (Fascia antibrachii) forms a very strong and complete investment for all the muscles of the region. The =superficial fascia= is thin, and disappears at the carpus by fusing with the deep fascia. The =deep fascia= is very strong and tendinous in character. It furnishes insertion at its upper and inner part to the tensor fasciæ antibrachii and posterior superficial pectoral muscles; at its upper anterior and outer part, to aponeuroses from the mastoido-humeralis and biceps. It is attached at the elbow by its deep face to the outer tuberosities of the humerus and radius, to the ulna, and to the lateral ligaments. On the inner surface of the forearm it blends with the periosteum on the subcutaneous surface of the radius. It is closely adherent to the surface of the extensor muscles, but is rather loosely attached to the flexors. From its deep face are detached =intermuscular septa=, which form sheaths for the muscles and are attached to the underlying bones. The principal septa are: (_a_) One which passes between the common extensor (in front) and the lateral extensor and flexor carpi externus (behind); (_b_) one between the common extensor and the extensor carpi radialis; (_c_) one between the inner and middle flexors of the carpus.

The =carpal fascia= (Fascia carpi) is a direct continuation of that of the forearm. It is attached chiefly to the tuberosities at the distal end of the radius, to the accessory carpal (pisiform) bone, and to the lateral ligaments. In front it forms the so-called =anterior annular ligament= (Ligamentum carpi dorsale), bridging over the grooves and binding down the extensor tendons and their synovial sheaths. Behind it is greatly thickened and forms the =posterior annular= or =transverse ligament= of the carpus (Ligamentum carpi transversum). This stretches across from the accessory carpal bone to the internal lateral ligament and the proximal extremity of the inner metacarpal bone. It thus completes the carpal canal, in which lie the flexor tendons, their synovial sheath, and the principal vessels and nerves of the region.

The =fascia= of the =metacarpus= and =digit= (Fascia metacarpea et digitalis) is, in general, thinner than the preceding. It is attached to the tendons, ligaments, and the exposed bony prominences—especially to the small metacarpal bones. On the flexion surface of the fetlock joint it is much thickened by fibers passing transversely from one sesamoid bone to the other, forming an =annular ligament= which binds down the flexor tendons in the sesamoid groove or canal. Distal to this is a second thick quadrilateral sheet (Ligamentum vaginale) which covers and is adherent to the tendon of the flexor perforatus. It is attached on either side by two bands to the borders of the first phalanx, thus firmly binding down the flexor tendons. A little further down a crescentic =fibro-elastic sheet= covers the terminal expansion of the deep flexor tendon. It is attached on either side by a strong band to the side of the first phalanx about its middle.

A. EXTENSOR DIVISION

1. =Extensor carpi radialis= (M. extensor carpi radialis s. radialis dorsalis; extensor metacarpi magnus; anterior extensor of the metacarpus).—This is the largest muscle of the extensor division, and lies on the anterior (dorsal) surface of the radius.

Origin.—(1) The external condyloid crest of the humerus; (2) the coronoid fossa.

Insertion.—The tuberosity on the anterior (dorsal) surface of the proximal extremity of the large (third) metacarpal bone.

Action.—To extend and fix the carpal joint and to flex the elbow joint.

Structure.—The belly of the muscle is rounded, and runs out to a point at the distal third of the forearm. The tendon, which runs nearly the whole length of the fleshy portion, appears on the surface of the latter about its middle; here the muscle shows a distinctly pennate arrangement. The tendon passes through the middle groove at the distal extremity of the radius and over the capsule of the carpal joint, bound down by the anterior annular ligament and invested with a =synovial sheath=. The latter begins three to four inches (ca. 8 to 10 cm.) above the carpus and extends almost to the insertion of the tendon. In the lower half of the forearm the deep fascia blends with the tendon, and here the latter is joined by the long tendon of the biceps.

Relations.—Superficially, the skin, fascia, and the oblique extensor; deeply, the capsule of the elbow joint, the biceps tendon, the radius, the carpal joint capsule, the anterior radial artery, and the radial nerve; externally, the anterior or common extensor; internally, at the elbow, the brachialis and biceps.

Blood-supply.—Anterior radial artery.

Nerve-supply.—Radial nerve.

2. =Anterior= or =common digital extensor= (M. extensor digitalis communis; anterior extensor of the phalanges; extensor pedis).—This muscle lies external to the foregoing, which it resembles in general form, although less bulky.

Origin.—(1) The front of the distal extremity of the humerus, just external to the coronoid fossa; (2) the external tuberosity on the proximal extremity of the radius, the external lateral ligament of the elbow, and the external border of the radius at the junction of its proximal and middle thirds; (3) the external surface of the shaft of the ulna; (4) the fascia of the forearm.

[Illustration:

FIG. 190.—MUSCLES OF LEFT THORACIC LIMB OF HORSE, FROM ELBOW DOWNWARD, ANTERIOR VIEW.

_a_, Extensor carpi radialis; _g′_, superficial pectoral muscle. (After Ellenberger-Baum, Anat. für Künstler.)]

Insertion.—(1) The extensor (or pyramidal) process of the third phalanx; (2) the anterior surface of the proximal extremities of the first and second phalanges.

Action.—To extend the digital and carpal joints, and to flex the elbow joint.

Structure.—The muscle is a compound one, representing the common extensor, together with vestiges of the proper extensors of the digits. Usually at least =two heads= may be distinguished. The principal or humeral head (Caput humerale) arises from the front of the extensor epicondyle of the humerus in common with the extensor carpi. Its belly is fusiform, and terminates in a point near the distal third of the radius. The tendon appears on the surface of the muscle about the middle of the belly, the arrangement being pennate. The tendon passes downward through the outer of the two large grooves on the front of the distal end of the radius, and over the capsule of the carpal joint. Passing down over the front of the metacarpus, it inclines gradually inward, reaching the middle line of the limb near the fetlock. A little below the middle of the first phalanx it is joined by the branches of the suspensory ligament, and the tendon thus becomes much wider. Two =synovial membranes= facilitate the play of the tendon. The proximal one is a =sheath= which begins about three inches (ca. 7 to 8 cm.) above the carpus, and terminates at the proximal end of the metacarpus. At the fetlock a =bursa= occurs between the tendon and the joint capsule, but otherwise the two are adherent. The smaller head, arising chiefly from the radius and ulna, is often divisible into two parts (Fig. 443). The larger of these (Caput radiale, muscle of Phillips)[59] arises from the outer tuberosity and outer border of the radius, and from the lateral ligament of the elbow joint. The flat belly is succeeded by a delicate tendon, which accompanies the principal tendon over the carpus (included in the same sheath), and then passes outward to fuse with the tendon of the lateral extensor. Usually a slip is detached which is inserted on the proximal extremity of the first phalanx, or ends in the fascia here. The smaller and deeper division (Caput ulnare, muscle of Thiernesse)[60] is usually somewhat difficult to isolate. It arises from the ulna close to the interosseous space. It has a small rounded belly and is provided with a delicate tendon which may fuse with the principal tendon or may be inserted into the capsule and the fascia in front of the fetlock joint.

Relations.—The chief relations of the belly of the muscle are: superficially, the skin and fascia; deeply, the elbow joint, the radius and ulna, the extensor carpi obliquus, and the anterior radial vessels and radial nerve; in front and internally, the extensor carpi radialis; behind, the lateral extensor and the interosseous vessels.

Blood-supply.—Radial and interosseous arteries.

Nerve-supply.—Radial nerve.

3. =Lateral digital extensor= (M. extensor digitalis lateralis s. digiti quinti proprius; lateral extensor of the phalanges; extensor suffraginis).—This muscle is much smaller than the preceding, behind which it is situated.

Origin.—The external tuberosity of the radius and the lateral ligament of the elbow joint, the shaft of the ulna, the outer border of the radius, and the intermuscular septum.

Insertion.—An eminence on the front of the proximal extremity of the first phalanx.

Action.—To extend the digit and carpus.

Structure.—The muscle is pennate, and is inclosed in a sheath formed by the deep fascia, from which many fibers arise. The belly is thin and fusiform and terminates at the lower third of the forearm. From here the tendon (at first small and round) passes downward through the groove on the outer tuberosity of the distal end of the radius, then over the carpus, and, gradually inclining toward the front, but not reaching the middle line of the limb, it passes over the metacarpus and fetlock to its insertion. Two =synovial membranes= occur in connection with the tendon. A =sheath= envelops the tendon, beginning about three inches (ca. 6 to 8 cm.) above the carpus, and reaching to the proximal end of the metacarpus. At the fetlock a small bursa lies between the tendon and the joint capsule, but otherwise the tendon is adherent to the capsule. The tendon becomes flat and much larger below the carpus, having received the tendon of the radial head of the anterior extensor and a strong band from the accessory carpal bone.

[Illustration:

FIG. 191.—MUSCLES OF LEFT THORACIC LIMB OF HORSE FROM ELBOW DOWNWARD; EXTERNAL VIEW.

_a_, Extensor carpi radialis; _g_, brachialis; _g′_, anterior superficial pectoral; _c_, anterior or common digital extensor; _e_, flexor carpi externus. (After Ellenberger-Baum, Anat. für Künstler.)]

Relations.—Superficially, the skin and fascia; deeply, the outer face of the radius and ulna; in front, the common extensor, the oblique extensor, and the interosseous artery; behind, the external flexor of the carpus and the deep flexor of the digit.

Blood-supply.—Interosseous artery.

Nerve-supply.—Radial nerve.

4. =Extensor carpi obliquus= (M. abductor pollicis longus et extensor pollicis brevis; oblique extensor of the metacarpus; extensor metacarpi obliquus).—This is a small muscle which curves obliquely over the distal half of the radius and the carpus.

Origin.—The external border and adjacent part of the anterior surface of the radius (the attachment area beginning at a point above the middle of the bone and extending down to its lower fourth).

Insertion.—The head of the inner (second) metacarpal bone.

Action.—To extend the carpal joint.

Structure.—The muscle is pennate and has a flat belly which curves downward, forward, and inward over the distal part of the radius. The tendon continues the direction of the muscle, crossing obliquely over the tendon of the extensor carpi radialis; it then occupies the oblique groove at the distal end of the radius, and crosses the inner face of the carpus. It is provided with a =synovial sheath=.

[Illustration:

FIG. 192.—CROSS-SECTION OF MIDDLE OF RIGHT FOREARM OF HORSE.

_a_, Accessory cephalic vein; _b_, cutaneous branch of median nerve; _c_, extensor carpi obliquus; _d_, posterior radial artery; _e_, satellite vein; _f_, median nerve; _g_, _g′_, ulnar vessels; _h_, ulnar nerve; _i_, cephalic vein; _k_, tendon of ulnar head of deep flexor; _l_, interosseous artery; _m_, extensor carpi radialis; _n_, anterior digital extensor; _o_, lateral digital extensor; _p_, flexor carpi externus; _q_, _q_, _q_, humeral heads of deep digital flexor; _r_, radial head of same; _s_, superficial digital flexor; _t_, flexor carpi medius; _u_, flexor carpi internus; _v_, radius; _w_, skin; _x_, anterior radial artery. (After Ellenberger, in Leisering's Atlas.)]

Relations.—Superficially, the skin and fascia, the lateral extensor, and the common extensor; deeply, the radius, the extensor carpi radialis, the carpal capsule, and the internal lateral ligament.

Blood-supply.—Interosseous and anterior radial arteries.

Nerve-supply.—Radial nerve.

B. FLEXOR DIVISION

1. =Flexor carpi internus= (M. flexor carpi radialis s. radialis volaris; internal flexor of the metacarpus).—This muscle lies on the inner surface of the forearm, immediately behind the inner border of the radius.

Origin.—The flexor (internal) epicondyle of the humerus, below and behind the lateral ligament.

Insertion.—The proximal end of the internal (second) metacarpal bone.

Action.—To flex the carpal joint and to extend the elbow.

Structure.—The muscle has a short tendon of origin, which is succeeded by a somewhat flattened, fusiform belly. The tendon of insertion begins near the distal fourth of the radius. It is provided with a synovial sheath which begins two or three inches (ca. 5 to 8 cm.) above the carpus and extends almost to the insertion of the tendon.

Relations.—Superficially, the skin and fascia, the posterior superficial pectoral and the tensor fasciæ antibrachii; deeply, the elbow joint, the radius, the deep flexor, the flexor carpi medius, the posterior radial vessels, and the median nerve. At the elbow the artery and nerve lie in front of the muscle, but below they dip beneath it.

Blood-supply.—Posterior radial artery.

Nerve-supply.—Median nerve.

On removing the deep fascia on the inner surface of the elbow the student may notice a small muscle lying along the lateral ligament. This is the =pronator teres=, which is usually not present or a mere vestige in the horse. It arises by a small, flat tendon from the flexor epicondyle of the humerus, and is inserted into the internal lateral ligament of the elbow. On account of its small size and the fact that the forearm is fixed in the position of pronation, the muscle can have no appreciable function. It is usually represented by the long portion of the internal lateral ligament.

2. =Flexor carpi medius= (M. flexor carpi ulnaris s. ulnaris medialis; oblique or middle flexor of the metacarpus).—This muscle lies on the inner and posterior aspect of the forearm partly under, partly behind, the preceding muscle. It arises by two heads—humeral and ulnar.

Origin.—(1) The flexor (internal) epicondyle of the humerus just behind the preceding muscle; (2) the inner surface and posterior border of the olecranon.

Insertion.—The upper edge of the accessory carpal (pisiform) bone.

Action.—To flex the carpal joint, and to extend the elbow.

Structure.—The humeral head is much the larger, constituting, in fact, the bulk of the muscle. It is flattened, curved, and tapers at both ends. The ulnar head, much smaller and very thin, is covered by an aponeurosis from which many of its fibers arise. It joins the large head a little above the middle of the forearm. The tendon of insertion is short and strong; it blends with the posterior annular ligament of the carpus.

Relations.—Superficially, the tensor fasciæ antibrachii, superficial pectoral, and flexor carpi internus, the skin and fascia, and cutaneous branches of the ulnar nerve; deeply, the superficial and deep flexors of the digit. In the distal half of the forearm the ulnar vessels and nerve lie between the outer edge of this muscle and the external flexor of the carpus.

Blood-supply.—Ulnar and posterior radial arteries.

Nerve-supply.—Ulnar and median nerves.

[Illustration:

FIG. 193.—DEEPER MUSCLES OF FOREARM OF HORSE, INTERNAL VIEW.

_23_, Internal head of triceps; _30_, flexor carpi medius; _31_, flexor carpi internus; _31′_, tendon of _31_; _32_, superficial digital flexor; _32′_, radial check ligament; _32″_, tendon of superficial flexor; _33a_, _33b_, _33c_, humeral heads of deep flexor; _33′_, deep flexor tendon; _33″_, subcarpal check ligament; _34_, ulnar head of deep flexor; _35_, radial head of deep flexor; _36_, suspensory ligament. (After Ellenberger, in Leisering's Atlas.)]

3. =Flexor carpi externus= (M. extensor carpi ulnaris[61] s. ulnaris lateralis; external flexor of the metacarpus).—This muscle lies on the outer face of the forearm, behind the lateral extensor of the digit.

Origin.—The extensor (external) epicondyle of the humerus, behind and below the lateral ligament.

Insertion.—(1) The outer surface and upper edge of the accessory carpal bone; (2) the proximal extremity of the outer (fourth) metacarpal bone.

Action.—To flex the carpal joint and to extend the elbow.

Structure.—The belly of the muscle is flattened and is intersected by a good deal of tendinous tissue. There are two tendons of insertion. The short tendon is inserted into the accessory carpal bone. The long tendon is detached just above the carpus; it is smaller and rounded; it passes downward and a little forward through a groove on the outer surface of the accessory carpal bone, enveloped by a =synovial sheath=, to reach its insertion on the outer metacarpal bone. A synovial pouch lies under the origin of the muscle at the elbow joint, with the cavity of which it communicates.

[Illustration:

FIG. 194.—CROSS-SECTION OF PROXIMAL PART OF LEFT CARPUS OF HORSE.

The tendons have been removed to show the canals in which they lie. The joint cavity is black. By an oversight the carpal canal for the two flexor tendons behind the posterior ligament of the carpus is not marked. _Cr_, Radial, _Ci_, intermediate, _Cu_, ulnar, _Ca_, accessory carpal bones.]

Relations.—Superficially, the skin, fascia, and cutaneous branches of the ulnar nerve; deeply, the elbow joint, the ulna, and the flexors of the digit; in front, the lateral extensor of the digit; behind, the middle flexor of the carpus, the ulnar head of the deep flexor, and the ulnar vessels and nerve.

Blood-supply.—Interosseous, ulnar, and median arteries.

Nerve-supply.—Radial nerve.

4. =Superficial digital flexor= or =flexor perforatus= (M. flexor digitalis sublimis; superficial flexor of the phalanges).—This muscle is situated in the middle of the flexor group, chiefly under cover of the middle flexor of the carpus.

Origin.—(1) The flexor epicondyle of the humerus, between the flexor carpi internus and the deep flexor of the digit; (2) a ridge on the posterior surface of the radius, below its middle and near the internal border.

Insertion.—(1) The eminences on the proximal extremity of the second phalanx behind the lateral ligaments; (2) the distal extremity of the first phalanx, also behind the lateral ligaments.

Action.—To flex the digit and carpus, and to extend the elbow.

[Illustration:

FIG. 195.—SYNOVIAL SHEATHS AND BURSÆ OF LOWER PART OF RIGHT FORE LIMB OF HORSE, INTERNAL VIEW.

_a_, Sheath of extensor carpi obliquus; _b_, sheath of flexor carpi internus; _c_, carpal sheath; _d_, _d′_ _d″_, _d■_, digital sheath; _e_, bursa under anterior extensor tendon; _f_, capsule of fetlock joint; _1_, extensor carpi radialis; _2_, tendon of extensor carpi obliquus; _3_, flexor carpi internus; _4_, flexor carpi medius; _5_, superficial flexor tendon; _6_, deep flexor tendon; _7_, suspensory ligament; _8_, small metacarpal bone; _9_, large metacarpal bone; _10_, posterior annular ligament of fetlock; _11_, proximal digital annular ligament; _12_, radius; _13_, radio-carpal joint; _14_, fetlock joint; _15_, lateral cartilage; _16_, band from first phalanx to lateral cartilage. (After Ellenberger, in Leisering's Atlas.)

The synovial sheaths (colored yellow) and the joint capsules (colored pink) are injected.]

[Illustration:

FIG. 196.—SYNOVIAL SHEATHS AND BURSÆ OF LOWER PART OF RIGHT FORE LIMB OF HORSE, EXTERNAL VIEW.

_a_, Sheath of extensor carpi radialis; _b_, sheath of anterior extensor; _c_, sheath of lateral extensor; _d_, sheath of outer tendon of flexor carpi externus; _e_, _e′_, carpal sheath; _f_, _f′_ _f″_, digital sheath; _g_, bursa under anterior extensor tendon; _h_, bursa under lateral extensor tendon; _i_, capsule of fetlock joint; _1_, extensor carpi radialis; _2_, anterior digital extensor; _3_, lateral digital extensor; _4_, flexor carpi externus; _4′_ _4″_, tendons of _4_; _5_, superficial flexor tendon; _6_, deep flexor tendon; _7_, suspensory ligament; _8_, external metacarpal bone; _9_, large metacarpal bone; _10_, posterior annular ligament of fetlock; _11_, digital annular ligament; _12_, fetlock joint; _13_, lateral cartilage; _14_, band from first phalanx to lateral cartilage. (After Ellenberger, in Leisering's Atlas.)]

Structure.—The fleshy portion of the muscle or =humeral head= takes origin from the humerus. The =radial head= (Caput tendineum) consists of a strong fibrous band, usually termed the =radial= or =superior check ligament=, which fuses with the tendon near the carpus. The belly of the muscle is intersected by tendinous strands, and fuses more or less with that of the deep flexor. Near the carpus it is succeeded by a strong, thick tendon which passes down through the carpal canal, formed by the posterior ligament of the carpus, the accessory carpal bone, and the posterior annular ligament (Ligamentum carpi transversum). Here it is enveloped by a synovial sheath, in common with the deep flexor. This =carpal sheath= (Vagina carpea) begins three or four inches (8 to 10 cm.) above the carpus, and extends downward nearly to the middle of the metacarpus. Below the carpus the tendon becomes flattened and broader. Near the fetlock it forms a ring through which the tendon of the deep flexor passes (Fig. 150). Here the two tendons are bound down in the sesamoid groove by the posterior annular ligament, which fuses more or less with the superficial flexor tendon. At the distal end of the first phalanx the tendon divides into two branches which diverge to reach

their points of insertion, and between these branches the tendon of the deep flexor emerges (Fig. 189). A second =synovial sheath=, the =digital= or =sesamoidean= (Vagina digitalis), begins at the distal third of the metacarpus, three to four inches (8 to 10 cm.) above the fetlock, and extends to the middle of the second phalanx.

[Illustration:

FIG. 197.—CROSS-SECTION OF DISTAL PART OF LEFT METACARPUS OF HORSE, JUST ABOVE SESAMOIDS.]

Relations.—The belly of the muscle is related superficially to the ulnar head of the deep flexor, the flexor carpi medius, and, at its origin, to the ulnar vessels and nerve; deeply to the humeral head of the deep flexor. The tendon is related superficially to the skin and fascia; deeply to the deep flexor tendon.

Blood-supply.—Posterior radial artery.

Nerve-supply.—Median nerve.

5. =Deep digital flexor= or =flexor perforans= (M. flexor digitalis profundus; deep flexor of the phalanges).—The fleshy part of this muscle lies on the posterior surface of the radius, under cover of the preceding muscles. It is the largest muscle of the flexor group.

Origin.—(1) The flexor (internal) epicondyle of the humerus; (2) the inner surface of the olecranon; (3) the middle of the posterior surface of the radius and a small adjacent area of the ulna.

Insertion.—The semilunar crest of the third phalanx, and the adjacent surface of the lateral cartilage.

Action.—To flex the digit and carpus, and to extend the elbow.

Structure.—This muscle consists of three principal heads. The =humeral head= (Caput humerale) constitutes the bulk of the muscle. It is marked by tendinous intersections, and is separable into three secondary heads. The =ulnar head= (Caput ulnare, ulnaris accessorius) is much smaller, and is at first superficially situated between the outer and middle flexors of the carpus, the =radial head= (Caput radiale, radialis accessorius) is the smallest, and is not always present; it is situated on the distal two-thirds of the posterior surface of the radius, under the humeral head. Each of these heads is provided with a tendon. The principal tendon—that of the humeral head—begins about three or four inches (8 to 10 cm.) above the carpus. It is soon joined by the small tendon of the ulnar head, which begins about the middle of the forearm. The tendon of the radial head fuses with the principal tendon close to the carpus. The conjoined tendon passes downward through the carpal canal, being included in the =carpal synovial sheath= with the superficial flexor tendon, as previously described. Continuing downward, it is joined about the middle of the metacarpus by a strong fibrous band, the so-called =inferior= or =subcarpal check ligament= (Caput tendineum). This is a direct continuation of the posterior ligament of the carpus. Below this the tendon passes through the ring formed by the perforatus, then in succession over the sesamoid groove, the inferior sesamoidean ligaments, and the tendon surface of the third sesamoid, to its insertion (Figs. 150 and 151). Its terminal part is much widened. From the distal third of the metacarpus to the distal end of the second phalanx it is inclosed in the =digital synovial sheath= described in connection with the perforatus. The =navicular bursa= or =bursa podotrochlearis= is found between the tendon and the third sesamoid or navicular bone. The terminal part of the tendon is bound down by the fibrous sheet described with the fascia.

[Illustration:

FIG. 198.—DIGIT OF HORSE, LATERAL VIEW.

_1_, Large metacarpal bone; _2_, distal end of small metacarpal bone; _3_, fetlock joint; _5_, first phalanx; _6_, pastern joint; _7_, second phalanx; _8_, coffin joint; _9_, third phalanx; _11_, lateral cartilage; _11′_, upper (subcutaneous) border of cartilage; _12_, suspensory ligament; _13_, branch of _12_ to extensor tendon; _14_, deep flexor tendon; _15_, superficial flexor tendon; _15′_, branch of _15_; _16_, posterior annular ligament of fetlock; _17_, proximal annular or vaginal ligament of digit; _18_, distal annular ligament or reinforcing sheath of deep flexor tendon; _19_, lateral ligament of coffin joint; _21_, tendon of common or anterior extensor; _22_, tendon of lateral extensor; _23_, digital vein. (After Ellenberger-Baum, Anat. für Künstler.)]

Relations.—The belly of the muscle is related posteriorly to the perforatus and the middle flexor of the carpus; internally, to the internal carpal flexor, the radial check ligament, and the posterior radial vessels and median nerve; externally, to the external flexor of the carpus; anteriorly, to the radius and ulna and branches of the posterior radial artery and median nerve. Below the carpus the tendon is accompanied by the vessels and nerves of the digit. It may also be noted that the muscle is not entirely covered by the

other flexors; it comes in contact with the skin and fascia on the postero-external aspect of the proximal half of the forearm, and also on the outer aspect of the distal fourth.

Blood-supply.—Posterior radial and ulnar arteries.

Nerve-supply.—Median and ulnar nerves.

METACARPAL MUSCLES

The five muscles of this group are either reduced to vestiges or modified greatly in structure.

1, 2. =Lumbricales= (internus et externus).—These are two small muscles which lie on either side of the flexor tendons above the fetlock. They arise from the deep flexor tendon, and are lost in the fibrous tissue which lies under the nodule of horn or ergot at the fetlock (Fig. 447). Their action is inappreciable. The size of these muscles is subject to much variation. Often very little muscular tissue can be found, but the small tendon is constantly present.

Blood-supply.—Metacarpal arteries.

Nerve-supply.—Median and ulnar nerves.

3, 4, 5. =Interossei.=—These are three in number in the horse, and are situated chiefly in the metacarpal groove. Two, the =internus= and =externus=, are very small muscles, each of which arises from the corresponding small metacarpal bone near its proximal extremity, and is provided with a delicate tendon which is usually lost in the fascia at the fetlock (Fig. 150). They have no appreciable action. Their blood- and nerve-supply is the same as that of the preceding muscles.

The =interosseus medius= is so much modified that it is usually termed the =suspensory=, or =superior sesamoidean ligament=. It contains little muscular tissue, being transformed very largely into a strong tendinous band, bifurcate below, and having for its chief function the supporting of the fetlock. It has been described, in deference to common usage, with the ligaments.

FASCIÆ AND MUSCLES OF THE PELVIC LIMB

THE FASCIÆ

The =iliac fascia= (Fascia iliaca) covers the ventral surface of the iliacus and psoas muscles, over which it is tightly stretched (Fig. 450). It is attached internally to the tendon of the psoas minor, externally to the inguinal (Poupart's) ligament and the external angle of the ilium. Its anterior part is thin. Posteriorly, it is in part attached to the ilium, in part becomes continuous with the pelvic fascia. It furnishes surfaces of origin for the sartorius, cremaster externus, and transversus abdominis muscles.

The =pelvic fascia= (Fascia pelvis) lines the cavity (parietal layer) and is reflected on the viscera at the pelvic outlet (visceral layer). Laminæ are detached from it to strengthen the various peritoneal folds.

The =superficial fascia= of the =gluteal region= is continuous with the aponeurosis of the panniculus. It covers and partly blends with the deep fascia. The =gluteal fascia= (Fascia glutea) covers the superficial muscles of the region, and detaches intermuscular septa, which pass between the muscles. It is attached to the sacral spines, the dorsal sacro-iliac ligament, and the angles of the ilium, and is continuous in front with the lumbo-dorsal fascia, behind with the coccygeal fascia. Its deep face gives origin to fibers of the superficial and middle glutei, the biceps femoris, and the semitendinosus, so that care is necessary in dissecting it off these muscles. The chief =intermuscular septa= are: (1) One which passes between the superficial gluteus and the biceps femoris; (2) one between the biceps and semitendinosus, from which a lamella is detached which passes between the middle and posterior portions of the biceps and is attached to the tuber ischii; (3) one between the semitendinosus and semimembranosus, which is attached to the sacro-sciatic ligament and tuber ischii; it furnishes origin for fibers of the long head of the semimembranosus.

The =fascia lata= is continuous with the preceding, and covers the muscles on the outer surface and front of the thigh. It is tendinous and very strong, and for the most part easily separable from the underlying muscles. It furnishes insertion to the tensor fasciæ latæ and to the biceps femoris (in part), by both of which it is tensed. At the stifle it is attached to the patella and the inner and outer straight ligaments. Internally it is continuous with the internal femoral fascia. It furnishes the following =intermuscular septa=: (1) One which passes between the vastus externus and biceps femoris to be attached to the external trochanter of the femur; (2) two which pass between the three branches of the biceps femoris; (3) a fourth between the biceps femoris and

semitendinosus.

The =internal femoral fascia= (Fascia femoralis medialis) covers the superficial muscles on the inner surface of the thigh. At its upper part it is joined by part of the aponeurosis of the external oblique muscle (Lamina femoralis) (Fig. 450). The posterior part is thin. It is continuous with the fascia lata in front and the crural fascia below. At the stifle it fuses with the tendons of the sartorius and gracilis.

The =crural fascia=, or fascia of the leg (Fascia cruris), consists of three layers. Two of these invest the entire region and may, therefore, be termed the =common fasciæ=. The superficial layer is a continuation of the fasciæ of the thigh, while the second layer may be regarded chiefly as a continuation of the tendons of the superficial muscles of the hip and thigh (biceps femoris, semitendinosus, tensor fasciæ latæ, sartorius, and gracilis). The two layers frequently fuse, and are attached chiefly to the patellar ligaments and the crest and internal surface of the tibia. About the middle of the leg the two layers unite behind the deep flexor of the digit and form a strong band which passes downward in front of the tendons of the gastrocnemius and superficial flexor, to be attached with the latter to the anterior and inner part of the tuber calcis. This may be regarded as an accessory or tarsal tendon of insertion of the biceps femoris and semitendinosus. The third layer forms sheaths for the muscles, furnishing origin in part to their fibers. Two important =intermuscular septa= are detached, viz.: (1) One which passes between the anterior and lateral digital extensors to be attached to the fibula and the external border of the tibia; (2) one between the lateral extensor and the deep flexor.

The =tarsal fascia= (Fascia tarsi) fuses with the ligaments and bony prominences of the region. It is strong and tendinous in front, and joins the tendon of the anterior extensor below the joint. Laterally, it is thin and fuses with the ligaments. Posteriorly, it is very thick and strong, forming an annular ligament which stretches from the internal lateral ligament to the fibular tarsal bone and the plantar ligament. This converts the groove at the back of the hock into a canal, in which are the deep flexor tendon with its synovial sheath and the plantar nerves. In front of the tarsus and above and below it there are three =annular ligaments= (Ligamenta transversa). The proximal one binds down the tendons of the anterior extensor, peroneus tertius, and tibialis anterior on the distal end of the tibia. The middle one stretches from the fibular tarsal bone to the outer tendon of the peroneus tertius, forming a loop around the tendon of the anterior extensor. The distal band stretches across the proximal extremity of the large metatarsal bone and incloses the tendons (and sheaths) of the two extensors of the digit.

The =metatarsal= and =digital fasciæ= do not differ materially from those of the corresponding regions of the thoracic limb.

THE MUSCLES

I. THE SUBLUMBAR MUSCLES (Figs. 450, 456)

The muscles of this group are not confined to the sublumbar region, but extend beyond it both before and behind. Their chief function is to flex the hip joint. Two, however,—the psoas minor and the quadratus lumborum,—have not this action.

1. =Psoas minor= (s. parvus).—This is a fusiform, flattened, pennate muscle, which lies along the ventro-lateral aspect of the bodies of the last three thoracic and the lumbar vertebræ.

Origin.—The bodies of the last three thoracic and first four or five lumbar vertebræ, and the vertebral ends of the sixteenth and seventeenth ribs.

Insertion.—The psoas tubercle on the shaft of the ilium.

Action.—To flex the pelvis on the loins, or to incline it laterally.

Structure.—The muscle arises by a series of digitations which pass backward and outward to be inserted at an acute angle on the tendon. The latter lies along the outer border of the fleshy portion and is flattened. It appears on the surface of the muscle at the third lumbar process and increases gradually in width until it reaches the pelvic inlet, where it becomes narrower.

Relations.—The ventral surface of the thoracic portion of the muscle is related to the pleura, crura of the diaphragm, and sympathetic nerve. In the abdomen, the chief ventral relations are the peritoneum, the vena cava (right side), the aorta and left kidney (left side), the sympathetic nerves, and the ureters. Dorsally, the chief relations are the vertebræ, the psoas major, and lumbar nerves. Near its insertion the tendon is crossed internally by the external iliac artery, and externally by the femoral nerve.

Blood-supply.—Intercostal and lumbar arteries.

Nerve-supply.—Lumbar nerves.

2. =Psoas major= (s. magnus).—This is much larger than the preceding muscle, by which it is partly covered. It is triangular, with the base anterior.

Origin.—The ventral surfaces of the vertebral ends of the last two ribs and the transverse processes of the lumbar vertebræ.

Insertion.—The internal trochanter of the femur, by a common tendon with the iliacus.

Action.—To flex the hip joint and to rotate the thigh outward.

Structure.—The origin of the muscle is fleshy, the belly being in general flattened, thick in its middle, thin at its edges. The thoracic portion is small, the abdominal part much thicker and wider, extending laterally beyond the extremities of the lumbar transverse processes. From the lumbo-sacral articulation it lies in a deep groove formed in the iliacus (with which it is partly united), becomes smaller and rounded, and passes downward and backward to terminate by a strong tendon common to it and the iliacus.[62]

Relations.—Dorsally, the last two ribs and thoracic vertebræ, the lumbar vertebræ, the internal intercostals, quadratus lumborum, longissimus dorsi, and iliacus, and the lumbar vessels and nerves; ventrally, the pleura and peritoneum, the iliac fascia, inguinal ligament, the diaphragm, psoas minor, and sartorius, the kidneys, the spleen, the intestine (duodenum, cæcum, etc.) and the circumflex iliac vessels.

Blood-supply.—Lumbar and circumflex iliac arteries.

Nerve-supply.—Lumbar and femoral nerves.

3. =Iliacus.=—This muscle covers the ventral surface of the ilium external to the sacro-iliac articulation, and extends outward beyond the external border of the bone, underneath the middle gluteus.

Origin.—The ventral surface of the ilium external to the ilio-pectineal line, the ventral sacro-iliac ligament, the wing of the sacrum, and the tendon of the psoas minor.

Insertion.—The internal trochanter of the femur, by a common tendon with the psoas major.

Action.—To flex the hip joint and to rotate the thigh outward.

Structure.—The belly of the muscle is so deeply grooved for the psoas major as to give the appearance of being completely divided into outer and inner portions. When the psoas is removed, it is seen, however, that the two heads are not entirely separated. The outer, larger head arises from the wing of the ilium chiefly; the inner, smaller head arises chiefly from a small area on the shaft of the ilium, between the psoas tubercle and the depression for the inner tendon of the rectus femoris, and from the tendon of the psoas minor. The two portions inclose the psoas major in front of the hip joint.

Relations.—Dorsally, the ilium, sacrum, sacro-iliac articulation, the gluteus medius, the ilio-lumbar and external circumflex vessels; ventrally, the iliac fascia, inguinal ligament, the psoas major, sartorius, and abdominal muscles. At the hip joint the chief relations are: internally, the femoral vessels, the femoral nerve, and the sartorius muscle; externally, the rectus femoris and tensor fasciæ latæ; in front, the abdominal muscles; behind, the hip joint.

Blood-supply.—Lumbar, circumflex iliac, and deep femoral arteries.

Nerve-supply.—Lumbar and femoral nerves.

4. =Quadratus lumborum.=—This thin muscle lies on the outer part of the ventral surfaces of the lumbar transverse processes.

Origin.—The ventral surface of the upper part of the last two ribs and the lumbar transverse processes.

Insertion.—The ventral surface of the wing of the sacrum and the ventral sacro-iliac ligament.

Action.—Acting together, to fix the last two ribs and the lumbar vertebræ; acting singly, to produce lateral flexion of the loins.

Structure.—The muscle is pennate, and is curved with the convexity outward. It is thin, largely mixed with tendinous fibers, and is, in general, little developed in the horse in comparison with some of the other animals (_e. g._, dog, sheep).

Relations.—Ventrally, the psoas major and the last intercostal and first three lumbar nerves; dorsally, the last two ribs, the lumbar transverse processes, and the lateral branches of the lumbar arteries.

Blood-supply.—Lumbar arteries.

Nerve-supply.—Lumbar nerves.

5. =Intertransversales lumborum= (M. intertransversarii lumborum).—These are described with the other spinal muscles. (See p. 238.)

II. THE EXTERNAL MUSCLES OF THE HIP AND THIGH

Under this head will be described the muscles of the outer surface of the pelvis and thigh, and those which form the posterior contour of the latter. They are given in the order in which they may be conveniently examined.

1. =Tensor fasciæ latæ= (Fig. 178).—This is the most anterior muscle of the superficial layer. It is triangular in form, with its apex at the external angle of the ilium.

Origin.—The external angle of the ilium.

Insertion.—The fascia lata, and thus indirectly to the patella, the external straight ligament, and the crest of the tibia.

Action.—To tense the fascia lata, flex the hip joint, and extend the stifle joint.

Structure.—The muscle arises by a rather small head, about two inches (ca. 5 cm.) wide, on the antero-inferior eminence of the external angle of the ilium. Below this the belly spreads out and terminates about midway between the point of the hip and the stifle in the aponeurosis. The belly fuses to a considerable extent with the superficial gluteus. The aponeurosis fuses with the fascia lata, and detaches a lamina which passes with the tendon of insertion of the superficial gluteus to the external border of the femur.

Relations.—Externally, the skin and fascia; internally, the obliquus abdominis externus, the iliacus, superficial gluteus, rectus femoris, and vastus externus, branches of the circumflex iliac, ilio-lumbar, and iliaco-femoral arteries, and the anterior gluteal nerve; anteriorly, the precrural lymph glands. A considerable quantity of connective tissue is found between the deep face of the muscle and the abdominal wall.

Blood-supply.—Circumflex iliac, ilio-lumbar, and iliaco-femoral arteries.

Nerve-supply.—Anterior gluteal nerve.

2. =Gluteus superficialis= (Figs. 178, 199) (Superficial gluteus; gluteus externus).—This muscle lies behind and partly underneath the tensor fasciæ latæ. It is triangular and consists of an anterior and a posterior head united by the gluteal fascia.

Origin.—(1) The external angle and the adjacent part of the external border of the ilium (anterior head); (2) the gluteal fascia (posterior head).

Insertion.—The third (external) trochanter of the femur.

Action.—To abduct the limb, flex the hip joint, and tense the gluteal fascia.

Structure.—The anterior head of the muscle is not completely separable (except artificially) from the tensor fasciæ latæ. The attachment to the border of the ilium is by means of an intermuscular septum, which passes beneath the thick outer border of the gluteus medius. The posterior head arises from the deep face of the gluteal fascia, and so indirectly from the dorsal sacro-iliac ligament. The two heads unite and terminate on a strong flat tendon, which is inserted into the edge of the third trochanter of the femur, beneath the biceps femoris.

Relations.—Superficially, the skin, fascia, and biceps femoris; deeply, the gluteus medius, iliacus, rectus femoris, and branches of the iliaco-femoral artery; in front, the tensor fasciæ latæ; behind, the biceps femoris.

Blood-supply.—Gluteal and iliaco-femoral arteries.

Nerve-supply.—Anterior gluteal nerve.

3. =Gluteus medius= (Figs. 178, 179) (Middle gluteus; gluteus maximus).—This is a very large muscle which covers the dorsal surface of the ilium and the greater part of the lateral wall of the pelvis, and extends forward also on the lumbar part of the longissimus.

Origin.—(1) The aponeurosis of the longissimus, as far forward as the first lumbar vertebra; (2) the gluteal or dorsal surface and internal and external angles of the ilium; (3) the dorsal and lateral sacro-iliac and sacro-sciatic ligaments, and the gluteal fascia.

Insertion.—(1) The summit of the trochanter major of the femur; (2) the crest below the trochanter; (3) the outer aspect of the trochanteric ridge.

Action.—To extend the hip joint and abduct the limb. By its connection with the longissimus a muscular mass is formed which is one of the chief factors in rearing, kicking, and propulsion.

Structure.—The anterior extremity of the muscle is relatively thin, and lies in a depression on the surface of the longissimus, from the strong aponeurosis of which the fibers take origin. The pelvic portion of the muscle is very voluminous, and forms the bulk of the muscular mass which gives the haunch its rounded contour. This part of the muscle is intersected by several tendinous sheets. One of these is particularly distinct, and is attached to the gluteal line on the ilium. This divides the muscle incompletely into superficial and deep strata. The superficial part is inserted by a strong tendon into the summit of the great trochanter, and by a pointed fleshy mass with a tendinous border into the trochanteric ridge. The deep part (Gluteus accessorius) is smaller, and arises entirely from the ilium between the gluteal line and the external angle (Fig. 455). It has a strong flat tendon which passes over the convexity of the trochanter to be inserted into the crest below it. The convexity is covered with cartilage, and the =trochanteric bursa= (Bursa trochanterica) is interposed between the tendon and the cartilage.[63]

Relations.—Superficially, the skin, lumbo-dorsal and gluteal fasciæ, the tensor fasciæ latæ, gluteus superficialis, and biceps femoris; deeply, the longissimus, the ilium, sacro-iliac and sacro-sciatic ligaments, the gluteus profundus, iliacus and rectus femoris, the iliaco-femoral artery, the gluteal and internal pudic vessels and nerves, and the great sciatic nerve.

Blood-supply.—Gluteal, ilio-lumbar, lumbar, and iliaco-femoral arteries.

Nerve-supply.—Gluteal nerves.

4. =Gluteus profundus= (Deep gluteus; gluteus internus; scansorius).—This much smaller, quadrilateral muscle lies under the posterior part of the preceding muscle, and extends over the hip joint, from the superior ischiatic spine to the anterior part of the great trochanter (Fig. 455).

Origin.—The superior ischiatic spine and the adjacent part of the shaft of the ilium.

Insertion.—The edge of the anterior part or convexity of the trochanter major of the femur.

Action.—To abduct the thigh and to rotate it inward.

Structure.—The muscle is short and thick and contains numerous tendinous intersections. The fibers are directed almost transversely outward over the capsule of the hip joint and converge at the convexity of the trochanter.

Relations.—Superficially, the gluteus medius and branches of the gluteal vessels and nerves; deeply, the shaft of the ilium, the hip joint, and the rectus femoris and capsularis.

Blood-supply.—Gluteal artery.

Nerve-supply.—Anterior gluteal nerve.

5. =Biceps femoris= (Gluteo-biceps s. paramero-biceps).—This large muscle lies behind and in part upon the superficial and middle glutei. It extends in a curved direction from the sacral and coccygeal spines to the outer surface of the stifle and leg (Figs. 178, 199, 200, 201, 202).

Origin.—(1) The dorsal sacro-iliac ligament, the gluteal and coccygeal fasciæ, and the intermuscular septum between this muscle and the semitendinosus; (2) the tuber ischii.

Insertion.—(1) A tubercle on the posterior surface of the femur near the external trochanter; (2) the anterior surface and external straight ligament of the patella; (3) the tibial crest; (4) the anterior and internal surface of the tuber calcis.

Action.—The action is somewhat complex, because the muscle is composed of three portions, has several points of insertion, and acts on all the joints of the limb except those of the digit. The general action is to extend the limb, as in propelling the body, rearing or kicking, and to abduct it. The anterior part, by its attachment to the posterior surface of the femur and to the patella, would extend the stifle and hip joints and abduct the limb. The middle part, being inserted chiefly on the tibial crest and the external straight ligament, would extend the hip, and, with the semitendinosus, flex the stifle. The posterior part, by virtue of its attachment to the tuber calcis, assists in extending the hock.

[Illustration:

FIG. 199.—MUSCLES OF PELVIC LIMB OF HORSE, POSTERO-EXTERNAL VIEW.

_17_, Position of tuber ischii; _o′_, superficial gluteus; _q_, _q′_, _q″_, biceps femoris; _r_, semitendinosus; _t_, sacro-coccygeus lateralis; _v_, semimembranosus; _w_, gracilis; _f_, gastrocnemius. (After Ellenberger-Baum, Anat. f. Künstler.)]]

Structure.—The muscle has two heads of origin:[64] The long or vertebral head arises chiefly from the dorsal and lateral sacro-iliac ligaments, the coccygeal fascia, and the intermuscular septum. There is often a large =bursa= between this head and the trochanter major. The short or ischiatic head arises by a strong tendon from the ventral spine on the tuber ischii. They unite, and a short tendon is detached from the deep face of the muscle, to be inserted into the posterior surface of the femur near the third trochanter (Fig. 455), a =bursa= being interposed between the tendon and the bone. The muscle then divides into three portions, which terminate on a strong aponeurosis over the junction of the thigh and leg. The anterior branch is directed toward the patella, the middle toward the tibial crest, while the posterior one assists in the formation of the posterior contour of the limb. The aponeurosis blends with the deep layer of the fascia cruris, as already described. A synovial =bursa= occurs under the patellar insertion.

Relations.—Superficially, the skin and fascia; deeply, the sacro-iliac and sacro-sciatic ligaments, the coccygeal fascia, the femur, the obturator, gemellus, quadratus femoris, adductor, semimembranosus, vastus externus, and gastrocnemius muscles, branches of the lateral sacral, gluteal, obturator, femoral and deep femoral vessels, the great sciatic, tibial, peroneal, and posterior gluteal nerves; in front, the superficial and middle glutei; behind and internally, the semitendinosus.

Blood-supply.—Gluteal, obturator, and femoro-popliteal arteries.

Nerve-supply.—Posterior gluteal and great sciatic nerves.

6. =Semitendinosus= (Biceps rotator tibialis).—This is a long muscle which extends from the first two coccygeal vertebræ to the proximal third of the inner surface of the tibia. It lies at first behind the biceps, then passes downward on the back of the thigh, between that muscle and the semimembranosus (Figs. 178, 179, 199). It has two heads of origin.

Origin.—(1) The transverse processes of the first and second coccygeal vertebræ, the coccygeal fascia, and the intermuscular septum between this muscle and the biceps femoris; (2) the ventral surface of the tuber ischii.

Insertion.—(1) The tibial crest; (2) the crural fascia and the tuber calcis.

Action.—To flex the stifle and rotate the leg inward; also to extend the hip and hock joints, acting with the biceps and semimembranosus in propulsion of the trunk, rearing, etc.

Structure.—The long or vertebral head is small at its origin, but becomes larger by the accession of fibers arising on the intermuscular septum. Below the tuber ischii it is joined by the short head, which arises partly by fleshy fibers, partly by a common tendon with the biceps. The muscle then passes downward on the back of the thigh, and terminates on a wide tendon on the inner surface of the proximal third of the leg. A distinct band passes forward to be inserted on the tibial crest (a =bursa= lying between the tendon and the tibia), part fuses with the fascia of the leg, while the remainder joins the biceps tendon and concurs in the formation of the tendinous band, which, as before described, terminates on the tuber calcis (Fig. 458). A _bursa_ may occur under the long head where it passes over the tuber ischii.

Relations.—Externally, the skin and fascia, the biceps, and the internal head of the gastrocnemius; internally, the coccygeal fascia, the sacro-sciatic ligament, the semimembranosus; anteriorly, the biceps femoris, branches of the femoral artery, and the great sciatic nerve.

Blood-supply.—Posterior gluteal, obturator, and femoro-popliteal arteries.

Nerve-supply.—Posterior gluteal and great sciatic nerves.

7. =Semimembranosus=[65] (Figs. 179, 186, 199, 451).—This muscle lies on the inner surface of the preceding muscle and the gastrocnemius, and has two heads of origin.

Origin.—(1) The posterior border of the sacro-sciatic ligament; (2) the ventral surface of the tuber ischii.

Insertion.—The internal epicondyle of the femur, behind the lateral ligament.

Action.—To extend the hip joint and to adduct the limb.

Structure.—The long head, small and pointed above, extends toward the root of the tail, fusing with the sacro-sciatic ligament. Passing downward, it becomes larger and covers in part the posterior aspect of the tuber ischii. A =bursa= may be found here. Below this it joins the short head, which is much larger. The large belly so formed passes downward and forward, covered in great part by the gracilis, and terminates on a short, flat tendon of insertion at the distal end of the femur.

Relations.—The upper part of the muscle assists in forming the lateral boundary of the pelvic outlet. It is related posteriorly and externally to the skin and fascia and the semitendinosus; internally, to the anus and its muscles, the vulva in the female, and the internal pudic artery and nerve (Figs. 452, 453). Below the pelvis the chief relations are: externally, the semitendinosus, biceps, and gastrocnemius, branches of the obturator, femoral, and femoro-popliteal arteries, and the great sciatic nerve and its chief branches; internally, the crus penis and ischio-cavernosus muscle (in the male), and the gracilis; in front, the adductor and the femoral vessels; behind, the skin and fascia.

Blood-supply.—Obturator and femoral arteries.

Nerve-supply.—Great sciatic nerve.

IV. THE INTERNAL MUSCLES OF THE THIGH

The muscles of this group are arranged in three layers.

FIRST LAYER

1. =Sartorius= (Figs. 180, 202, 203).—This long and rather narrow muscle is the most anterior one of the first layer. It extends from the sublumbar region to the lower and inner part of the stifle.

Origin.—The iliac fascia and the tendon of the psoas minor.

Insertion.—The internal straight ligament of the patella and the adjacent part of the tuberosity of the tibia.

Action.—To flex the hip joint and adduct the limb.

Structure.—The muscle is very thin at its origin, but becomes thicker and narrower as it passes downward and a little backward. It terminates near the stifle joint on an aponeurosis which blends with that of the gracilis and with the fascia of the leg.

Relations.—Superficially, the inguinal (Poupart's) ligament, the abdominal muscles, the skin and fascia, and the saphenous vessels and nerve; deeply, the ilio-psoas, quadriceps femoris, and adductor. It forms the anterior boundary of the femoral canal, in which the femoral artery and vein and the deep inguinal lymph glands are situated (Fig. 451).

Blood-supply.—Femoral artery.

Nerve-supply.—Femoral and saphenous nerves.

2. =Gracilis= (Figs. 186, 199, 202, 203).—This is a wide, flat, quadrilateral muscle, situated behind the sartorius, which it exceeds greatly in extent.

Origin.—The middle third of the pelvic symphysis, the prepubic tendon and pubo-femoral ligament, and the ventral surface of the pubis behind the prepubic tendon.

Insertion.—The internal straight ligament of the patella, the internal surface of the tibia in front of the lateral ligament of the stifle joint, and the fascia of the leg.

Action.—To adduct the limb. It may also rotate it inward.

Structure.—The muscle arises by a strong tendon, chiefly in common with the opposite muscle. Its direct attachment to the ventral surface of the pelvis is not so extensive as a superficial inspection would suggest. The origin of the muscle presents anteriorly a round perforation for the passage of the external pudic vein. The belly is composed of parallel bundles, and is marked by a superficial furrow which, however, does not indicate a muscular division. It terminates on the inner surface of the stifle on a thin wide tendon which blends in front with that of the sartorius, below with the crural fascia.

Relations.—Superficially, the skin and fascia, the penis or mammary gland, and the saphenous vessels and nerve; deeply, the pectineus, adductor, semimembranosus and semitendinosus, and, at the middle of the femur, the femoral vessels; anteriorly, the sartorius. In the upper third of the thigh the sartorius and gracilis are separated by a triangular interval (femoral triangle), in which lie the deep inguinal lymph glands and the femoral vessels.

Blood-supply.—Femoral and deep femoral arteries.

Nerve-supply.—Obturator and saphenous nerves.

SECOND LAYER

1. =Pectineus= (Figs. 180, 451, 456).—This muscle is fusiform and extends from the anterior border of the pubis to the middle of the inner border of the femur.

Origin.—The prepubic tendon, the pubo-femoral ligament, and the anterior border of the pubis.

Insertion.—The middle of the internal border of the femur, near the nutrient foramen.

Action.—To adduct the limb and flex the hip joint.

Structure.—The belly is cylindrical and contains little fibrous tissue. Its origin is perforated by the pubo-femoral ligament, and is thus divided into two unequal parts. The large upper part arises mainly from the prepubic tendon—only a very small part gaining direct attachment to the pubis. The small lower part does not reach the bone. The insertion is pointed and tendinous.

Relations.—Superficially, the gracilis; deeply, the femur, the vastus internus, the terminal tendon of the psoas major and iliacus, and the deep femoral artery; anteriorly, the sartorius, the femoral vessels, the saphenous nerve, and the deep inguinal lymph glands; posteriorly, the adductor, obturator externus, and quadratus femoris, and the obturator nerve (anterior division).

Blood-supply.—Femoral and deep femoral arteries.

Nerve-supply.—Femoral and obturator nerves.

The _femoral canal_ is exposed in the dissection of the preceding muscles (Figs. 200, 451). It is bounded anteriorly by the sartorius, posteriorly by the pectineus, and externally by the iliacus and vastus internus. Its internal wall is formed by the femoral fascia and the gracilis. Its upper or abdominal opening (Lacuna vasorum) lies behind and a little internal to the internal inguinal ring and is bounded anteriorly by the inguinal ligament, posteriorly by the anterior border of the pubis, and externally by the tendon of the psoas minor. The canal terminates below at the insertion of the pectineus. It contains the deep inguinal lymph glands, the femoral artery and vein, and the saphenous nerve.

2. =Adductor=[66] (Figs. 179, 186, 451) (Great and small adductors of the thigh).—This fleshy, prismatic muscle lies behind the pectineus and vastus internus. It extends downward and forward from the ventral surface of the pelvis to the internal condyle of the femur.

Origin.—The ventral surface of the pubis and ischium and the tendon of the gracilis.

Insertion.—(1) The posterior surface of the femur from the level of the external trochanter to the groove for the femoral vessels; (2) the internal epicondyle of the femur and the internal lateral ligament of the stifle joint.

Action.—To adduct the limb and assist in extending the hip joint. It may also rotate the femur outward.

Structure.—It is almost entirely fleshy, and is composed of parallel bundles united rather loosely. It is usually possible to separate from the principal mass a small anterior short portion,[67] which is inserted into the femur behind the pectineus. The principal mass[68] is perforated below its middle by the femoral vessels, and is thus divided into two branches. The outer branch is inserted into the back of the femur with the short portion, while the inner branch is attached to the internal epicondyle and lateral ligament. There is often a superficial slip which reaches the internal straight patellar ligament. Some fibers pass under the lateral ligament and end on the tendon of the semimembranosus.

Relations.—Internally, the gracilis, and branches of the femoral artery and of the obturator nerve; externally, the femur, the obturator externus, quadratus femoris, biceps femoris, and gastrocnemius, and the femoral, deep femoral, and obturator arteries; anteriorly, the pectineus, vastus internus, and a large branch of the obturator nerve; posteriorly, the semimembranosus and the great sciatic nerve.

Blood-supply.—Femoral, deep femoral, and obturator arteries.

Nerve-supply.—Obturator nerve.

3. =Semimembranosus.=—Described on p. 280.

THIRD LAYER

1. =Quadratus femoris= (Ischio-femoralis).—This is a narrow, flat muscle, which lies under cover of the upper part of the adductor (Figs. 455, 456).

Origin.—The ventral surface of the ischium, just in front of the semimembranosus.

Insertion.—An oblique line on the posterior surface of the femur, near the lower part of the internal trochanter.

Action.—To extend the hip joint, and to adduct the thigh and rotate it outward.

Structure.—It is composed of parallel bundles of fibers directed downward, forward, and outward.

Relations.—Internally, the adductor, semimembranosus, and the obturator vessels; externally, the obturator externus and biceps femoris, the deep femoral artery, and the great sciatic nerve.

Blood-supply.—Deep femoral and obturator arteries.

Nerve-supply.—Great sciatic nerve.

2. =Obturator Externus= (Fig. 456).—This is a pyramidal muscle which extends across the back of the hip joint from the obturator foramen to the trochanteric fossa.

Origin.—The ventral surface of the pubis and ischium, and the margin of the obturator foramen.

Insertion.—The trochanteric fossa.

Action.—To adduct the thigh and to rotate it outward.

Structure.—It is almost entirely fleshy, the muscle-bundles being rather loosely connected. The insertion is pointed, flattened, and partly tendinous. The origin is perforated by the obturator vessels and nerve.

Relations.—Internally, the adductor and quadratus femoris and the deep femoral vessels; externally, the gemellus, the tendon of the obturator internus, the biceps femoris, and the great sciatic nerve; anteriorly, the hip joint, the pectineus, and the external pudic vein.

Blood-supply.—Deep femoral and obturator arteries.

Nerve-supply.—Obturator nerve.

3. =Obturator internus= (Fig. 451).—This arises by two heads within the pelvic cavity, the tendon emerging through the lesser sciatic foramen.

Origin.—(1) The pelvic surface of the pubis and ischium around the obturator foramen; (2) the pelvic surface of the shaft of the ilium and the wing of the sacrum.

Insertion.—The trochanteric fossa.

Action.—To rotate the femur outward.

Structure.—The ischio-pubic head lies on the pelvic floor and covers the obturator foramen. It is thin and fan-shaped. The iliac head extends along the lateral wall of the pelvis, and is pennate, with a central tendon throughout. Both terminate on a flat tendon which passes outward through the lesser sciatic foramen to be inserted into the trochanteric fossa. A synovial bursa facilitates the play of the tendon over the external border of the ischium.[69]

Relations.—The pelvic surface is covered by the pelvic fascia and the peritoneum. The obturator vessels and nerve lie between the two heads, and the internal pudic vessels and nerve lie along the dorsal edge of the iliac head.

Blood-supply.—Obturator and internal pudic arteries.

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Minerals in rock sections

Lea McIlvaine Luquer

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MINERALS IN ROCK SECTIONS THE PRACTICAL METHODS OF IDENTIFYING MINERALS IN ROCK SECTIONS WITH THE MICROSCOPE ESPECIALLY ARRANGED FOR STUDENTS IN TECHNICAL AND SCIENTIFIC SCHOOLS

BY

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FOURTH REVISED EDITION

[Illustration: [Logo]]

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PREFACE TO FOURTH REVISED EDITION, 1913.

This edition is practically that of 1908, with necessary minor revisions and corrections, especially the data referring to indices of refraction and strength of double refraction. The values of the refractive indices α and γ are recorded as well as the mean values. References are also given to "The Methods of Petrographic-Microscopic Research," by F. E. Wright, 1912, for exact (quantitative) methods of determining crystal constants.

LEA MCI. LUQUER.

DEPARTMENT OF MINERALOGY, COLUMBIA UNIVERSITY, NEW YORK, May, 1913.

PREFACE TO THIRD REVISED EDITION, 1908.

The 1908 edition is essentially the same as that of 1905; the only changes being in the nature of corrections, and the addition of a brief description of the Schrœder van der Kolk method of determining refractive indices and also an abbreviated diagram for determining triclinic feldspars in sections showing both Carlsbad and Albite twinning. The Naumann symbols for crystal forms have also been omitted.

LEA MCI. LUQUER.

DEPARTMENT OF MINERALOGY, COLUMBIA UNIVERSITY, NEW YORK, April, 1908.

PREFACE TO REVISED EDITION, 1905.

In preparing the revised edition, Chapters I. and IV. have been rewritten and enlarged and the part relating to the determination of the plagioclases has been greatly amplified. Many additions have also been made to Chapter III. and the Becke method, for the determination of the relative indices of refraction of minerals, has been given in detail.

Some new and useful tables have been introduced; as tables of refractive indices (mean) and double refraction (maximum). A diagram has also been added, showing the relation existing between strength of double refraction, interference colors and thickness of section.

Professor E. Weinschenk's admirable text-book, "Die Gesteinsbildenden Mineralien", Freiburg, 1901, has been specially referred to, and the tables of refractive indices and double refraction have been compiled from Weinschenk's new Tables.

Many new cuts have been added, among them being semi-ideal drawings, showing typical outlines of crystal sections, cleavage, optical orientation, etc. In describing the "Usual Appearance in Sections" of a mineral, it is of course only possible to mention the usual crystal form in which the mineral occurs in a rock. The crystal may be cut in any way by the plane of the section; but a general knowledge of the crystal forms will furnish an idea as to the outline, etc., that the mineral may show in the section.

LEA MCI. LUQUER.

DEPARTMENT OF MINERALOGY, COLUMBIA UNIVERSITY, NEW YORK, July, 1905.

PREFACE TO FIRST EDITION, 1898.

The identification of minerals in rock sections with the microscope, including as it does a knowledge of optical mineralogy, is often difficult for beginners. This may be due to the fact that most of the publications on this subject are quite elaborate in their nature and in either French or German. While detailed descriptions are very necessary, and, in fact, indispensable for advanced investigation, they are apt to prove cumbersome and confusing at first. For these reasons this text-book has been prepared by the writer, with a view of putting before the student only those facts which are absolutely necessary for the proper recognition and identification of the common minerals in rock sections. The footnotes refer the student to standard publications, in which are given details of the methods and investigations outlined in the text. An elementary knowledge of crystallography and mineralogy is almost indispensable and is here assumed.

The microscopic and optical characters of the minerals are recorded in the usual order in which they would be observed with a petrographical microscope. Nearly all the rock-forming minerals become transparent in thin sections; but when opaque, attention is called to the fact and the characters are recorded as seen with incident light. White light is assumed to be used, unless otherwise stated. The interference colors recorded in all cases are those given by very thin sections of 0.03 mm. in thickness.

The order followed for the minerals is essentially that of Rosenbusch (based on the symmetry of the crystalline form), with a few exceptions made for convenience, such as placing pyrrhotite after pyrite and zoisite after epidote. The statements regarding the occurrences of minerals in the common rock-types have been taken mainly from Les Minéraux des Roches, by Lévy and Lacroix.

The terms axes and directions of elasticity, used throughout this book, are very commonly employed in petrographical literature of the present time. These axes and directions should probably more correctly be called axes and directions of vibration or extinction. The reasons for or against the elastic condition of the "ether" are of more interest, however, to the physicist than to the petrographer.

An optical scheme is appended, with the minerals grouped according to their common optical characters.

The writer's thanks are due to Dr. A. J. Moses, Professor of Mineralogy, and to Mr. J. F. Kemp, Professor of Geology, for kind suggestions offered during the preparation of this book.

LEA MCI. LUQUER.

DEPARTMENT OF MINERALOGY, COLUMBIA UNIVERSITY, N. Y. CITY, October, 1898.

TABLE OF CONTENTS

PAGE. CONVENTIONS AND ABBREVIATIONS ix

CHAPTER I. INTRODUCTORY OPTICS FOR OPTICAL MINERALOGY. Ordinary Light.—Plane Polarized Light.—Effects Produced by Crystal Sections on Transmitted Light.—Amorphous Bodies.—Isotropic Crystals.—Anisotropic Crystals.—Double Refraction.—Uniaxial Crystals.—Biaxial Crystals.—Principal Vibration Directions.—Axial Angle.—Dispersion. 1

CHAPTER II. PETROGRAPHICAL MICROSCOPE. Reflector.—Polarizer.—Nicol Prism.—Condensing Lens.—Rotating Stage.—Objectives.—Analyzer.—Eye-pieces. 7

CHAPTER III. INVESTIGATION OF MICROSCOPIC AND OPTICAL CHARACTERS OF MINERALS. Opaque Minerals. Transparent Minerals: With transmitted light: _Form_, _Color_, _Index of Refraction and Relief_, _Becke Method_, _van der Kolk Method_, _Cleavage_, _Fracture_, _Inclusions_. With polarized transmitted light: _Pleochroism_. With crossed nicols: _Isotropic Character_, _Anisotropic Character_, _Interference Colors_, _Extinction_ and _Extinction Angles_, _Vibration Directions of Faster and Slower Rays_, _Order of Interference Color_, _Strength of Double Refraction_, _Determination of Minerals and Thickness of Section_, _Structure_. With convergent light: _Uniaxial Interference Figures_ and _Optical Character_, _Biaxial Interference Figures_ and _Optical Character_, _Determination of Axial Angle_, _Distinctions between Orthorhombic, Monoclinic and Triclinic Sections_. Resumé of Uses of Parallel and Convergent Polarized Light. 13

CHAPTER IV. MICROSCOPIC AND OPTICAL CHARACTERS OF MINERALS. Amorphous Minerals.—Isometric Minerals.—Tetragonal Minerals.—Hexagonal Minerals.—Orthorhombic Minerals.—Monoclinic Minerals.—Triclinic Minerals.—Mineral Aggregates. 51

CHAPTER V. METHODS OF PREPARING SECTIONS. Cutting and Grinding Machines.—Saws.—Cutting.—Grinding. Plates or Laps.—Cementing.—Grinding.—Mounting.—Cleaning and Finishing.—Convenient Apparatus for work. 117

CHAPTER VI. CHEMICAL AND MECHANICAL TESTS. Chemical Tests on Crystal in Section: _Carbonates_, _Gelatinizing Silica_.—Etched Figures.—Heating Section to Redness.—Methods of Isolating Crystals or Fragments for Testing: _Specific Gravity Separation_, _Electro-magnetic Separation_, _Chemical Separation_.—Micro-Chemical Reactions: _Borichy's Method_, _Behren's Method_, _Special Tests_. 129

APPENDIX. Brief Scheme of Classification into Systems by Optical Determinations.—Tables of Double Refraction (maximum) and Indices of Refraction (mean).—Diagram, showing relation between strength of double refraction, interference colors and thickness of section.—Order of Consolidation of the Constituent Minerals in Plutonic Rocks.—Optical Scheme with Special Introduction. 141

INDEX. 149

CONVENTIONS AND ABBREVIATIONS.

a = The assumed direction of the ether vibrations of the fastest ray.

b = The assumed direction of the ether vibrations of the ray with intermediate velocity.

c = The assumed direction of the ether vibrations of the slowest ray.

In some American Text-Books (by Iddings, Winchell & Phillips) a = X, b = Y and c = Z.

a′ = The assumed direction of the ether vibrations of the faster ray in the given section.[1]

c′ = The assumed direction of the ether vibrations of the slower ray in the given section.

(+) = Optical character positive.

(−) = Optical character negative.

|| = Parallel to.

($\gamma - \alpha$) = The difference between the indices of refraction of the slowest and fastest rays, respectively, transmitted by the crystal, and indicates in decimals the relative strength of the double refraction.

_n′_ = The mean index of refraction;[2] hence

= $(\alpha + \beta + \gamma)/3$ or $(\varepsilon + 2\omega)/3$.

α = Index of refraction of the fastest ray.

γ = Index of refraction of the slowest ray.

_a_, _b_ and _■_ relate to the crystallographic axes commonly represented by these letters.

2_E_ = the apparent axial angle measured in air, 2_V_ being the true angle.

_Bx_{a·}_ = The acute bisectrix.

_Bx_{c·}_ = The obtuse bisectrix.

_Ax. pl._ = The axial plane, _i. e._, the plane containing the two "optic axes."

ELONGATION relates to the appreciable extension often shown by the crystal section. A crystal of long prismatic habit, cut about parallel to the _■_ axis, would show marked elongation; while a tabular crystal (like mica) would show elongation if cut at right angles to the tabular faces. At times, of course, no elongation is appreciable, as in the case of granular or broken crystals or where the cross-section is essentially square or octagonal. Very often the relation of the cleavage is given to the elongation and also to the directions a′ and c′, which makes it possible to test for a′ and c′ even when no marked elongation can be observed.

MINERALS IN ROCK SECTIONS.

CHAPTER I. INTRODUCTORY OPTICS FOR OPTICAL MINERALOGY.

The object of this introduction is merely to give a practical discussion of elementary optics, as applied to optical mineralogy,[3] and no elaborate discussion of this important subject will be attempted. The explanations will be made as simple as possible, and, in most cases, only the optical phenomena will be described without entering into a theoretical discussion as to the cause of these phenomena.

Light[4] may be regarded as transmitted in straight lines by vibrations of the "ether," taking place at right angles to the direction of transmission.

Ordinary light is light with the ether vibrations in all possible directions, the path described by any particle of ether constantly changing.

Plane polarized light is simply light with the ether vibrations all _parallel_ to one plane passing through the direction of transmission.

By experiment it has been proved that there exists a very close relation between the optical properties of crystals and their other physical properties, such as form, color, transmission of heat, etc. Therefore it is often possible, by a careful optical investigation of a crystal section, to determine important crystallographic facts, even in the absence of any distinct outline.

The Effects Produced by Crystals on Transmitted Light.

Consider that a series of optical tests are made on all possible sections[5] of crystals in the six systems, and the manner in which these crystals affect transmitted light ascertained.

■Isotropic Crystals■: It will be found that all sections of _Isometric_ crystals transmit light with equal velocity in all directions; that is, the crystals are optically equivalent in all directions and, hence, can produce no double refraction.[6] In these crystals any section, however cut, will transmit all the rays of light, incident to the surface at right angles, with no change.[7] The same is true of _Amorphous_ bodies, glass, etc., unless they have been subjected to strains or peculiar conditions during cooling. A _single image_ is seen through these isotropic sections.

[Illustration:

FIG. 1.]

■Anisotropic Crystals■: It will also be found that nearly all sections (the exceptions being given later) of crystals in the remaining five systems, produce quite a different effect on transmitted light. In these crystals the velocity of transmission of light varies with the _vibration direction_ of the light rays. This property, called _double refraction_,[8] seems to result from the power of resolving a ray of ordinary light, with ether vibrations in all directions, into two rays with ether vibrations in planes at right angles to each other; the two resulting rays traversing, usually, divergent paths in passing through the section.

The mineral calcite (Iceland spar) exhibits this property to a marked degree, and in certain sections will show a _double image_, Fig. 1. That the vibration directions of the two doubly refracted rays are in planes at right angles to each other, can be easily proved

by using a nicol prism.[9] In most cases the separation of the two images is so slight as not to be perceived by the eye, and the practical method of testing a crystal section for double refraction will be given later, p. 27.

The crystals that show double refraction are further divided into two groups, _uniaxial_ and _biaxial_:

(1) ■Uniaxial■, or those in which the optical characters are symmetrical to _one_ direction, called an optic axis. This _optic axis_ is the crystallographic vertical axis, _■_; and parallel to this direction there is a single value only for the light velocity and no double refraction takes place.[10] Hence any section parallel to the base (001) being at right angles to the optic axis, acts like a section of an isotropic crystal and transmits all the perpendicularly incident rays of light with no change. In any other section double refraction takes place and it can be proved by using a nicol prism that the two rays have ether vibrations, one in the plane passing through the incident ray and the _■_ axis of the crystal, and the other in a plane at right angles thereto, hence in the basal plane. This latter ray, which has a constant velocity, is called the _ordinary ray O_; and the other ray, with velocity varying with the inclination of the section to _■_, is called the _extraordinary ray E_.[11]

The vibration directions are either parallel or symmetrical to cleavage cracks and crystal outlines. In sections parallel to the optic axis, the two doubly refracted rays have the maximum difference in velocity of transmission, and hence their vibration directions are called _principal vibration directions_[12] and the plane containing them an _optical principal section_. In these sections the refractive index of the ray vibrating parallel to _■_ (extraordinary ray) is denoted by ε, and that of the ray vibrating parallel to the basal plane (ordinary ray) by ω.[13]

To this group belong all _Tetragonal_ and _Hexagonal_ crystals.

(2) ■Biaxial■, or those in which the optical characters are no longer symmetrical to an optic axis but to three planes at right angles to each other (for monochromatic light). These crystals have, however (for light of each wave-length and for each temperature), _two_ directions parallel to which there is a single value only for the light velocity and hence no double refraction. These directions are called "_optic axes_."[14] An investigation of these biaxial crystals shows that of all the rays traversing these crystals there are three rays which advance with maximum, minimum and some intermediate velocity. The vibration directions of these three rays are called the _principal vibration directions_ and are at right angles to each other (being the intersections of the three planes above referred to). The direction of ether vibration of the fastest ray is denoted by a, of the slowest ray by c, and of the ray advancing with intermediate velocity by b.[15] Each of the three planes, containing two principal vibration directions, is called an _optical principal section_. The index of refraction of the a ray is denoted by α, of the b ray by β, and of the c ray by γ.

To this group belong all crystals in the _Orthorhombic_, _Monoclinic_ and _Triclinic_ systems.

In the _Orthorhombic_ system, the principal vibration directions are parallel to the crystallographic axes; hence all pinacoidal sections contain two of these principal vibration directions. In all sections parallel to the three crystallographic axes _■_, _■_ and _■_, the vibration directions are parallel or symmetrical to cleavage cracks, crystal edges, etc.

In the _Monoclinic_ system, one principal vibration direction is parallel to the ortho axis _■_, the other principal vibration directions are in the plane of symmetry, at right angles to _■_, but are not parallel with either the vertical axis _■_ or the clino axis _á_. In clino pinacoid (010) sections the principal vibration directions will make definite angles with crystallographic lines, such as cleavages or crystal outlines. These angles are called _extinction angles_. They will vary, in this system, with reference to the direction of the _■_ axis from a maximum on the clino pinacoid (010) to 0° on the ortho pinacoid (100), when the vibration directions of the two doubly refracted rays will be parallel and at right angles to the plane of symmetry. Hence the vibration directions are parallel or symmetrical to cleavages, edges, etc., _only_ in sections parallel to the ortho axis _■_; but in all other sections are unsymmetrical.

In the _Triclinic_ system, the principal vibration directions are not parallel to the crystallographic axes, and there is no definite relation between these directions and the crystallographic axes; hence in all possible sections there will be extinction angles.

In all biaxial crystals the two _optic axes_ are inclined to each other, making what is called the _axial angle, 2V_, the apparent angle measured in air being _2E_. The optic axes lie in the plane, called the _axial plane_, which contains the principal vibration directions a and c. The axial angles are bisected by these principal vibration directions, the direction bisecting the acute angle being called the _acute bisectrix, Bx_{a}_, and that bisecting the obtuse angle the _obtuse bisectrix, Bx_{o}_. An approximate idea of the value of the axial angle can be obtained by the use of the petrographical microscope, as described later, p. 47. The axial angle is often a convenient distinction between such minerals as muscovite and biotite.

The axial angle will vary with the temperature and with light of different wave-length or color, and this variation is called _dispersion_ of the optic axes. Dispersion of the principal vibration directions also takes place in monoclinic and triclinic crystals, but can be usually disregarded.

In closing it is very important to remember that any section of an anisotropic crystal (not at right angles to an optic axis) will always transmit two rays of light with different velocities and with vibration directions in planes at right angles to each other. Isometric crystals, of course, produce no double refraction of light.

CHAPTER II. THE PETROGRAPHICAL MICROSCOPE.[16]

The _petrographical microscope_ is essentially an ordinary microscope[17] with the following important additional equipment. It must be provided with: 1° a _polarizer_ (a piece of apparatus for giving polarized light) placed below the stage; 2° an _analyzer_ (a piece of apparatus for analyzing the rays of light after they have passed through the polarizer and transparent section) placed between the objective and the eye; 3° a _stage rotating_ about an axis which is the line of sight of the microscope. A convenient type of microscope is that made by Seibert of Wetzlar (No. 11 _a_), Fig. 2.

The reflector _a_ is usually fitted with a plane mirror on one side, and a parabolic mirror on the other. The plane mirror should be used with sunlight, and the parabolic mirror with artificial light, in order to make the rays of light as nearly parallel as possible.

The _polarizer_ is in most cases a nicol prism, set in a suitable frame _b_, and made as follows:

For the _nicol prism_ "a cleavage rhombohedron of calcite (the variety Iceland spar is universally used in consequence of its transparency) is obtained, having four large and two small rhombohedral faces opposite each other. In place of the latter planes, two new surfaces are cut, making angles of 68° (instead of 71°) with the obtuse vertical edges; these then form the terminal faces of the prism. In addition to this, the prism is cut through in the direction HH′, Fig. 3, the parts then polished and cemented together again with Canada balsam. A ray of light, _ab_, entering the prism, is divided into two rays polarized at right angles to each other. One of these, _bc_, on meeting the layer of balsam (whose refractive index is less than that of the ray _bc_), suffers total reflection, and is deflected against the blackened sides of the prism and extinguished. The other, _bd_, passes through and emerges at _e_, a completely polarized ray of light, that is, a ray with vibrations in one direction only, and that the direction of the shorter diagonal of the prism."[18] The vertical plane through the shorter diagonal may be called the _plane_ of _vibration_[19] of the nicol.

[Illustration:

FIG. 2.]

[Illustration:

FIG. 3.]

The polarizer must be below the stage _c_, and is generally adjusted so as to have its plane of vibration parallel to the N. and S. cross-wire in the eye-piece _o_. It is important to know the direction of the plane of vibration of the polarizer or lower nicol, as we can then determine, when absorption of light occurs in a mineral, the direction in this mineral parallel to which the absorbed rays are vibrating. The polarizer slides in an outer shell or frame, and, by means of a lever _d_, can easily be raised or lowered.

A convenient test for the location of this plane of vibration of the polarizer is as follows: Make use of a section of biotite, cut at right angles to the basal plane, hence showing the basal cleavage cracks. Biotite has the property of absorbing to a marked extent the light vibrating parallel to these cleavage cracks. Rotate such a section on the stage of the microscope until the position of maximum darkness is reached and when such is the case the plane of vibration of the polarizer must be parallel to these cleavage cracks.

On the top of the nicol is placed the _condensing lens_ for getting _convergent_ light, and the adjustments are so arranged that when the nicol is up as far as it will go, the condensing lens[20] is brought almost in contact with the lower surface of the transparent section resting on the stage.

The _rotating_ circular _stage e_ is supported on a suitable frame _c_, and arranged so that its axis of rotation coincides with the line of sight of the microscope. The stage is graduated, and, by means of an index fixed to the frame, the angular rotation can always be obtained. It is also provided with two adjusting screws[21] _f_, by means of which the axis of rotation can be accurately centered.

The method of centering is as follows: Bring some prominent mark in the section exactly in coincidence with the intersection of the cross-wires in the eye-piece. Rotate the stage 180°, and correct one half the error by means of the centering screws, and the other half by moving the section on the stage. Check the result by rotating the stage 180° again, and if necessary repeat the corrections in the same way until the adjustment is satisfactory.

The _objective_[22] _g_ screws into the collar _h_, which has a slot _k_, in the upper portion, for the introduction of a sensitive color plate, a one quarter undulation mica plate or a quartz wedge.[23]

The slot _k_ is so arranged that, when the sensitive color plates are introduced, the vibration directions of these plates will make an angle of 45° with the planes of vibration of the crossed nicols, and the interference color will thus be at its maximum intensity.

A revolving _nose-piece_ is sometimes used which can be attached to the collar _h_ and arranged to carry two or three objectives, which can thus be very quickly brought into position for use. This is convenient in passing rapidly from observations with parallel light to observations with convergent light, which must be made with a high power objective. The difficulty is that recentering is generally required. The modern microscopes are provided with a clip for holding the objectives, instead of the screw-thread collar _h_.

The _analyzer_[24] or upper nicol is contained in the frame _l_, which is arranged so as to slide in and out of the tube of the microscope.

The plane of vibration of the analyzer is fixed by the instrument maker so as to be at right angles to the plane of vibration of the polarizer, hence in the Seibert microscope parallel to the E. and W. cross-wire in the eye-piece. Consequently when the frame _l_ is pushed into the tube, the analyzer is introduced in the line of sight between the objective and the observer's eye, with its plane of vibration at right angles to the plane of vibration of the polarizer; that is the nicols are crossed. When the nicols are crossed, if they are properly adjusted, no light can pass through to the eye and the field of view should be dark.[25]

The _eye-piece_[26] _o_ fits into the top of the tube, and, by means of a little projecting piece fitting into a slot in the frame, can always be adjusted so as to have its cross-wires parallel to the planes of vibration of the two nicols.[25]

Some instruments are provided with an additional slot in the tube between the analyzer and the eye-piece for the introduction of a Bertrand lens, which is used to magnify the interference figures produced by convergent light.

The first approximate focusing is made by the screw _m_, and the fine adjustment by the screw _n_.

In focusing always start with the objective very near the section, and move it away until the right focus is obtained. Never move down towards the section in obtaining the focus, as there is danger then of striking the objective against the section.

For cleaning the microscope xylol can be used, as it will not injure the lacquer. To lubricate any of the parts use a small quantity of soft tallow, good clock oil or paraffin oil.

CHAPTER III. INVESTIGATION OF MICROSCOPIC AND OPTICAL CHARACTERS OF MINERALS.

■Characters of Opaque Minerals■, observed by _reflected_ light.

The minerals which remain perfectly opaque in thin rock sections have usually metallic lustre and are very minute in size, as is the case with the iron ores.

When the metallic minerals of a rock specimen are distinctly seen with the unaided eye, it is rarely necessary to make a section for their determination, as this can more easily be done by any of the well known blowpipe methods.

Form, Lustre, Color, Cleavage, etc., are recognized in the same way as in the case of macroscopic specimens. In order to make the observations by reflected light alone, the beam of light from the reflector-mirror must be cut off by holding the hand over the mirror or by moving the mirror.

■Characters of Transparent Minerals■, observed by _transmitted_ light. The petrographical microscope for these observations is supposed to be in the condition of an ordinary microscope, both nicols being out of the field and a strong beam of light coming up through the transparent section from the reflector below.

The characters are considered in the order in which they would most naturally appear to the observer during a complete investigation with the microscope.[27]

[Illustration:

FIG. 4.—Idiomorphic augite crystals in camptonite. The section is about at right angles to the vertical axis _■_, and shows the intersecting cleavages parallel to the prism of 87° 06′. Keene Valley, N. Y.]

[Illustration:

FIG. 5.—Allotriomorphic quartz _q_, showing no "relief," plagioclase _p_ and decomposed feldspar _o_ in granite. As seen with crossed nicols.]

(_a_) ■Form.■[28] _Crystals bounded by planes_, _i. e._, crystals that have formed when conditions were favorable for complete development. Such crystals are often called _idiomorphic_ or _automorphic_, see Fig. 4. Crystals that are large in comparison with other accompanying crystals may be called _Phenocrysts_. Of course crystals, which are not wholly contained within the rock section, will only show the outline of the bounding planes cut by this particular section. In some cases, by a careful study of the outline of several sections of the same mineral and by a measurement of the angles, it is possible to determine the common "crystallographic forms" of the mineral. Very misleading outlines may, however, be observed; as for example the triangular outline of a section of a cube, with the corner truncated. For measuring the angles have the stage accurately centered, then bring the vertex of the angle to be measured to the intersection of the cross-wires in the eye-piece. Bring one of the sides in coincidence with one of the cross-wires. Note the reading of the graduated circle and rotate the section until the other side is in coincidence with the same wire. Take the reading again and the difference will be the angle required.

Crystals without bounding planes, whose surfaces are more or less determined by those of adjacent crystals. Such crystals are frequently called _allotriomorphic_ or _xenomorphic_,[29] see Fig. 5. This allotriomorphic form must not be confounded with the worn or rounded boundaries of the component grains in clastic rocks.

[Illustration:

FIG. 6.—Corroded sanidine crystal in perlite.]

Corroded Crystals,[30] whose fretted outline is undoubtedly due to corrosive action of the magma, see Fig. 6.

Broken or Strained Crystals. In some cases what were formerly larger individuals have been broken or shattered by dynamic action into much smaller fragments, see Fig. 7, showing crushed rim of fragments surrounding feldspar "auge." In other cases an actual bending or distortion of the crystal has taken place, and again sometimes the effect of mechanical stress is only shown by the so-called "wavy" extinction. See p. 31 and Fig. 7, showing a carlsbad twin of feldspar that has been bent and therefore shows marked "wavy" extinction.

[Illustration:

FIG. 7.—Orthoclase "auge" (Carlsbad twin), showing bending and "wavy" extinction, surrounded by crushed rim of mineral fragments. As seen with crossed nicols. "Augen-gneiss," Bedford, N. Y.—B. 13.]

[Illustration:

FIG. 8.—Crystallites and Microlites _a_. Skeleton Forms _b_.]

Crystallites, in general those incipient forms of crystals which have not yet reached a stage of development sufficient to show double refraction, see Fig. 8, _a_. Quite a number of names are used to describe the different forms that occur.

Microlites, more or less completely defined microscopic crystals, which usually show double refraction, but cannot be always specifically determined, see Fig. 8, _a_.

Skeleton Forms, resulting from rapid cooling of the magma occur in some lavas, see Fig. 8, _b_.

(_b_) ■Color.■ It must be remembered that the colors observed are always due to transmitted light and may be called "_absorption tints_." Minerals which in hand specimens are opaque are often colored in sections; and minerals which are commonly colored may appear colorless in sections. At times color may be given to a section simply by the presence of a great number of minute

inclusions.

[Illustration:

FIG. 9.—Olivine crystal in basalt showing “high relief” and cleavage.]

(_c_) ■Index of Refraction.■ _n_ = sin _i_/sin _r_. This can be approximately determined by the appearance of the surface and outline of a mineral, that is by its _relief_. The descriptive terms are of course relative, but in common practice minerals are said to have _medium_ refraction when the refractive index is between that of balsam (1.54) and that of calcite (1.60), _strong_ refraction when higher than 1.60 and _weak_ refraction when lower than 1.54. In the case of uniaxial and biaxial minerals the mean value of the indices of refraction is used.

A mineral which has _strong refraction_ appears to have _high relief_, _i. e._, distinct dark contours and a rough or “shagreened” surface,[31] which has bright illumination and appears to stand out above the surfaces of the surrounding minerals with weaker refraction, see Fig. 9.

A mineral with _medium refraction_ does not show any _relief_, hence has a smooth surface and no dark contours, see Fig. 5.

A mineral with _weak refraction_ may also appear to have a rough surface, but not so marked as in the case of a mineral with very strong refraction, due to the smaller contrast in indices between the mineral and balsam.

The practical way of testing for the approximate index of refraction or the _relief_ of a mineral is to make use of the lens for convergent light, which is placed on top of the lower nicol immediately below the section.

By lowering[32] the lens the character of the relief of a mineral section is made very apparent.

In order to become familiar with the way in which the “relief” or appearance of the surface indicates the strength of the refractive index, the student may use a long glass slide on which are embedded in balsam (1.54) small fragments of different minerals, for example: Sodalite (1.483), orthoclase (1.523), quartz (1.547), topaz (1.620), hornblende (1.631), augite (1.70), epidote (1.751), zircon (1.95) and rutile (2.712).

Determinations of refractive indices in sections by the methods of Chaulnes,[33] Sorby,[34] or total reflection are accompanied by many difficulties and may fail to give satisfactory results. The Becke method, however, often furnishes a convenient means of determining the _relative_ values of the refractive indices of adjoining minerals or of minerals embedded in balsam. This is of especial service when one of the minerals is known and hence its refractive index.

BECKE METHOD.[35]

Suppose two adjoining minerals, in a thin rock section, to be singly refracting and to have their plane of contact vertical, _i. e._, parallel to the optic axis of the microscope.

Let _A_ and _C_, Fig. 10, be two such sections with the plane of contact _OO′_ vertical, _A_ having a lower refractive index than _C_, and consider only the direction of the rays within the section, neglecting the refractive effect of the air, glass and balsam.

A beam of transmitted light contains besides normal rays convergent rays, which pass through the section as indicated in Fig. 10. Consider now the cone of light rays _GBI_. The rays _O′G_ on meeting the plane of contact _OO′_ will be somewhat concentrated and deflected by the higher refractive index of _C_ and will continue as the cone _EF_. Some rays as _O′H_ will, on meeting the contact plane, be totally reflected and will continue as the cone _OE_, while the rest of the rays _HI_ will be dispersed and deflected by the weaker refractive index of _A_, continuing as the cone _OD_. Hence, more light rays will emerge on the side of the contact plane where the substance of higher refractive index lies, and there will be a concentration of illumination on this side producing the so-called “bright line.”

[Illustration:

FIG. 10.]

In practically making the test with a petrographical microscope remove the polarizer, analyzer and condensing lens,[36] and introduce below the section a small light-stop, to reduce in size the cone of incident light.[37] The adapter, holding this light-stop, should be adjustable so that the stop can be lowered sufficiently to produce the best results. The smaller the contrast between the

indices of refraction the smaller the incident cone of light should be, as best results are obtained when this cone is little larger than twice _O′H_, Fig. 10, all the _O′H_ rays being then totally reflected. The more of the _HI_ rays that pass through, the brighter will be the _OD_ cone and the less sharp the contrast in illumination. A high power objective[38] should be used, as those with small aperture and great focal length do not give good results. Focus on the dividing plane and adjust until equal illumination is observed on both sides and the trace of the plane resembles a fine thread, the focal plane being at _MN_. Then _raise_ the _objective_ slightly, thus moving the focal plane to _ST_, when a _bright line_ or band will appear on the side of the _stronger refracting_ substance, the width of the line depending on the contrast between _n_ and _n′_, becoming narrower as _n_ and _n′_ approach each other in value. On raising the objective still further the line broadens and finally disappears. If the objective is lowered instead of raised the reverse phenomenon will take place, the bright line appearing on the side of the weaker refracting substance.[39] When the indices are nearly the same a bright line will appear on both sides and it is important then to make the cone of incident light as small as possible and to select the _brighter_ line.

With doubly refracting minerals, each set of doubly refracted rays would suffer total reflection under somewhat different conditions and there would be no one point _B_ (as in isotropic minerals) where no bright lines would appear. However, if the cone of incident light is small enough in diameter, the test will be practically obtained as described. The Becke test can often be made with a medium power objective[40] without removing the polarizer and condensing lens, provided the condensing lens be lowered sufficiently. It may also prove convenient to turn the reflector a little sideways.

The thinner the section the more distinct will be the phenomenon. The contact plane must be clear and not coated with opaque decomposition products.

When the plane of contact _OO′_ deviates considerably from parallelism with the optic axis of the microscope a disturbance of the phenomenon may be expected and no satisfactory results be obtained. In general under these conditions the “bright line,” both on raising and lowering the objective, will remain on the side of the overlapping substance, without regard to the relative values of the indices.

The refractive index of the cementing material should not be very much lower than that of either of the thin sections, as the result would then be to disperse the emerging rays too much and dim the effect. In the case of distinguishing between minerals of high refractive power, such as augite and garnet, methyliodide is recommended instead of balsam.

In the case of doubly refracting crystals, the lower nicol (polarizer) must be retained, if it is desired to obtain the relative refractive index of one of the two rays, either with respect to the balsam or to a ray in an adjoining crystal with a parallel vibration direction. For determining vibration directions of rays and the faster and slower rays in two adjoining sections see later, pp. 31 and 33.

The method of _Schrœder van der Kolk_[41] can also be employed for the same purpose as the Becke test. The ordinary objective (Seibert No. II) is used, and the method essentially consists of darkening a portion of the field by means of the finger or a plate inserted below the polarizer. The condenser lens must be lowered beyond the sharp focus of the edge of the shadow (on raising the condenser the following phenomena are _reversed_). As the shadow approaches the contact between two minerals a bright line will appear on the edge of the “far” mineral, if its refractive index is the higher, and a dark line on this same edge if its index is lower than that of the “near” mineral. The indices of the two rays in doubly refracting minerals must be determined by the aid of the polarizer.

[Illustration:

FIG. 11.—Biotite, showing perfect cleavage, in rhyolite.]

(_d_) ■Cleavage■,[42] which appears as more or less distinct and regular lines or cracks, see Figs. 11 and 12. These cleavage cracks may be parallel or intersect, depending on the position of the section relative to the cleavage planes of the crystal.

[Illustration:

FIG. 12.—Augite _a_, showing good cleavage, and plagioclase _p_ in diabase. The plagioclase shows “polysynthetic” twinning between crossed nicols.]

[Illustration:

FIG. 13.—Garnet in mica schist, showing fracture. Franconia, N. Y.]

Cleavage is sometimes best observed by slightly lowering the condensing lens under the section.

When sections show intersecting cleavage cracks it is often possible to recognize the mineral by its known cleavage angle, as in the case of amphibole and pyroxene.

(_e_) ■Fracture■, which appears as irregular and non-parallel cracks, see Fig. 13.

[Illustration:

FIG. 14.—Apatite in feldspar _a_. Garnets in quartz, Branchville, Ct., _b_. Liquid inclusions of CO_{2}, some showing gas bubbles, in quartz _c_.]

[Illustration:

FIG. 15.—Enstatite showing “Schiller” Structure.]

(_f_) ■Inclusions■, which may be _solid_ (either distinct crystals or glass), _fluid_ or _gas_, see Fig. 14. These inclusions are distinguished by the fact that the solid inclusions generally have sharp contours, the fluid inclusions distinct dark borders, and the gas inclusions broad dark borders more distinctly marked than those of the fluid inclusions. The fluid inclusions often contain a bubble of gas. The inclusions may have a definite or indefinite position in the crystal in which they occur, and can sometimes be more distinctly seen by using convergent light or a “spot” lens.

(_g_) ■Schiller Structure.■ “Is that in which cavities of definite form and orientation (‘negative crystals’) are developed along certain planes and filled or partially filled by material dissolved out of the enclosing crystal,”[43] see Fig. 15.

Characters Observed by Polarized Light.

The polarized light is obtained by passing the beam of light from the reflector through the polarizer or lower nicol,[44] which must be in place below the stage of the microscope. White light is supposed to be used.

■Pleochroism■, that property which all anisotropic minerals have, to a greater or less extent, of absorbing certain colored rays in certain directions, thereby showing different colors in different directions by transmitted light. Uniaxial minerals are dichroic showing two differences in color, produced by the rays which vibrate parallel to the direction of the vertical axis _■_ and the plane of the basal axes. Biaxial crystals are trichroic showing theoretically three differences of color produced by rays with vibration directions corresponding very nearly to those of the three principal vibration directions.[45] Any given section of a biaxial crystal will, of course, appear only dichroic.

The practical way of testing for _pleochroism_ is as follows: Revolve the stage, carrying the section, when a change in the color of the mineral will be noticed, if it is pleochroic. This pleochroism may appear as an actual change in color or simply as a change in the shade of the same color. At times it may be so weak as hardly to be noticed, when it is best to make the test with the condensing lens in position immediately under the section, or by rotating the lower nicol instead of revolving the stage. The color of the light, vibrating parallel to certain definite crystallographic directions in minerals, is often very characteristic.

In some cases there may be such strong _absorption_ of one of the rays, that, when the vibration direction of this ray is over the plane of vibration of the polarizer, practically no light is transmitted and the section appears dark. Strong absorption is characteristic of certain minerals, such as biotite, amphibole, tourmaline and allanite and takes place parallel to definite directions in these minerals.

Pleochroism may often be noticed with ordinary light in the case of hand specimens.

Characters Observed with both Polarizer and Analyzer[46] in Position, that is with “Crossed Nicols.”

When the nicols are accurately crossed, the field should be quite dark, and if this is not the case the adjustments must be looked to. The condensing lens should be removed for these tests as they are to be made with parallel light, but as a matter of convenience instead of removing the condensing lens, the polarizer with the lens on top may be lowered, when the results will be about the same as with parallel light. White light is supposed to be used.

■Isotropic Character.■ Sections of isotropic crystals are perfectly dark and remain so during a complete rotation of the stage through 360°. The explanation is very simple. Light being transmitted by an isotropic crystal in all directions without double

refraction; it follows that the light from the polarizer, after having passed through the section, comes to the analyzer still vibrating in the plane of vibration of the polarizer. Hence it is entirely cut out by the analyzer.

Amorphous transparent substances act in the same way and remain dark during complete rotation of the stage.

Optical anomalies, _i. e._, double refraction, may occur in isometric crystals and in amorphous substances that have been subjected to strains.

■Anisotropic Character.■ Sections of anisotropic crystals, having the property of _double refraction_, produce in general some _interference_ or _polarization color_, except as mentioned later. The popular explanation is as follows:

[Illustration:

FIG. 16.]

In Fig. 16, let PP′ be the plane of vibration of the polarizer, and A′A the plane of vibration of the analyzer. All the light, after it has passed through the polarizer, is vibrating parallel to PP′ when it reaches the lower side of the transparent crystal, _cdef_, on the stage of the microscope. In this transparent section let _ob_ and _oa_ be the two _directions_ of _vibration_, _i. e._, the only two directions parallel to which rays of light can vibrate in passing through the section.

Let _om_ represent the amplitude of vibration of a ray from the polarizer. When this ray reaches the section it cannot get through it vibrating in the direction _om_, but is doubly refracted and of the two resulting rays, one gets through vibrating in the direction _ob_ and the other vibrating in the direction _oa_. From _m_ draw perpendiculars to _ob_ and _oa_. Then according to the law of the parallelogram of forces _ob_ will represent the amplitude of vibration of the ray passing through the crystal vibrating in the direction _ob_, and _oa_ will represent the amplitude of vibration of the ray passing through the crystal vibrating in the direction _oa_. We will thus have two rays passing through the crystal, polarized at right angles to each other.

[Illustration:

FIG. 17.]

Consider now the general question of the transmission of the doubly refracted rays through a plate. Whatever the angle of the parallel incident rays, each ray as AB, Fig. 17, is resolved, as just described, into two rays BC and BD, polarized at right angles to each other and following (usually) different paths in the plate. On emergence these follow parallel paths. Among the incident rays there are rays EG and FH, such that one component of FH will emerge at D with one of the components of AB, and one component of AB and one component of EG will emerge at C. Hence from every point of the upper surface of the plate there will emerge two rays and these rays will have travelled through different paths in the plate with different velocities and will have their vibrations at right angles to each other.

When these doubly refracted rays come to the analyzer, whose plane of vibration is A′A, they cannot get through vibrating in their present directions, but components of these rays, such as _ot_ and _os_, can get through vibrating parallel to the plane A′A.

Hence we have two series of rays coming to the eye, polarized in the same plane, but one set slightly in advance of the other. These rays will “interfere” and produce some _interference_ or _polarization_ color.[47] In using white light whenever one of two light rays of the same color has suffered a “retardation” of just one wave-length (or even multiple thereof) the color will be extinguished; and when the “retardation” is one half wave-length (or even multiple thereof) the color will be intensified. Therefore, some tints will be extinguished and others intensified, the combination resulting in the production of some definite interference color. Of course in the case of monochromatic light the thickness of the section may be such that “destructive interference” takes place producing no color (darkness).

Now suppose the stage to be rotated until the section _cdef_ takes the position _c′d′e′f′_. The section will be found to be dark and no interference color will be seen. This is due to the fact that the directions of vibration in the section are parallel to the planes of vibration of the crossed nicols, consequently the light passes through the section still vibrating parallel to the plane PP′ of the polarizer and is all cut out by the analyzer. Darkness will occur every 90° and therefore four times during a complete rotation of the stage. The interference color is also observed to vary in intensity, but not in color, and to be at its maximum 45° from the positions of darkness.

Sections of uniaxial crystals at right angles to the optic axis act like isotropic substances and remain dark during a complete rotation of the stage. In the biaxial crystals, a section at right angles to an "optic axis" shows uniform illumination[48] which does not change as the stage is rotated.

The only way to find out whether sections that remain dark are isotropic, or uniaxial at right angles to an optic axis, is to test them with convergent light as described later, see p. 40.

■Interference Colors.■ The interference color shown by any mineral section depends on three factors: 1° the strength of the double refraction (_γ_ − _α_ = the difference between the refractive indices of the slowest and fastest rays); 2° the position of the section in the crystal; 3° the thickness of the crystal section.

To eliminate, so far as possible, the variation due to the optical orientation of the section, care must always be taken to obtain the maximum interference color given by the different sections of the same mineral in the rock section. Sections giving the maximum color are those parallel to the _■_ axis in uniaxial minerals and those parallel to the axial plane in biaxial minerals.[49] Hence such sections in convergent light never show the emergence of an optic axis or a bisectrix; and furthermore, other clues, such as crystal outlines, cleavage, pleochroism, etc., may help to indicate the favorable section.

The influence of the thickness of the section is also important and must be considered. The interference color will rise in the scale (be higher in order) as the section becomes thicker. Methods of obtaining the thickness of a section are given on pp. 35 and 36. When reference is made to definite interference colors the mineral section is supposed to have a thickness of 0.03 mm. and to be such as to give the maximum color; and all mineral sections in a rock section are considered to have a uniform thickness.

With these precautions in mind the _interference colors_ indicate the _strength_ of the _double refraction_ as follows:[50] The colors of minerals with very weak double refraction vary from a bluish-gray to a grayish-white. As the strength of the double refraction increases the colors become the very intense bright tints of the spectrum, yellow, red, blue, green, etc., called the first and second order colors. As the strength of the double refraction still increases the colors pass through the tints of the spectrum in sequence (called orders), becoming paler until finally, when the double refraction is very strong, the colors become the neutral, almost colorless tints of the higher orders. The eye must be trained to appreciate the colors of different orders, and the student is advised to practice with mineral sections, of known strength of double refraction, and compare the resulting interference colors with a color chart,[51] or use the interference color diagram at the end of the book. A convenient test can be made with a one fourth undulation mica plate to distinguish between the white of the 1° order and the practically white very high order tint. Introduce the mica plate in the slot _k_, Fig. 2, and the effect will be to produce a marked change in the color of the 1° order, while no change will be observed in the high order color.

The exact order of the color can be determined by the use of a quartz wedge, as described on p. 35.

Abnormal Interference Colors[52] may be brought about in several ways. In white light strong absorption of part of the light components may not only alter the color of the mineral but also modify the interference color. The double refraction may be nearly zero for light of a particular color so that the mineral is isotropic for that color, resulting in a change in the interference color, as for example the indigo of melilite, which is nearly isotropic for yellow light. In biaxial minerals the axial angle may be zero for light of a particular color, resulting also in a modification of the interference color, as the blue in penninite in sections ■ _Bx_{a}_. When the bisectrices are much dispersed there will be no position of darkness between crossed nicols in white light.

■Extinction and Extinction Angles.■ When the section, see Fig. 16, is in such a position that its directions of vibration are parallel to the planes of vibration of the nicols, no light can pass through the analyzer, and the section is dark. Hence the light is extinguished and this phenomenon is called _extinction_.

Extinction is said to be _parallel_ or _symmetrical_ when the directions of vibration are parallel to any crystallographic lines or directions, or bisect the angles between these lines. The crystallographic lines or directions may be either cleavages or the similar boundaries of idiomorphic crystals.

This kind of _extinction_ is shown by all sections of tetragonal and hexagonal crystals, by all sections parallel to the crystal axes in orthorhombic crystals and also by the sections parallel to the ■ axis in monoclinic crystals.

When the _extinction_ is not symmetrical it is called _oblique_, and is shown by all sections of monoclinic crystals (except those parallel to the ■ axis) and triclinic crystals.

Extinction which does not take place over the whole of the section of a single crystal at the same moment, but passes over the section like a dark wave or shadow, is said to be "_wavy_"; and indicates that the crystal has been subjected to mechanical forces producing a change in the position of the directions of vibration in different parts of the crystal, see Fig. 7.

The angle between a direction of vibration in the section and some known crystallographic direction (as a cleavage or crystal outline) is called an _extinction angle_, and is measured in the following way: Find the positions of the directions of vibration in the section, which must be parallel to the cross-wires when extinction takes place. Note the reading on the graduated circle of the stage, then remove the upper nicol, in order to get a more distinct view of the field, and rotate the stage until you bring some known crystallographic line into parallel position with the cross-wire selected as a reference line. Take the reading of the graduated circle again, and the difference between these two readings will be the _extinction angle_.

It can readily be seen that depending on which way the section is rotated, either a small or a large extinction angle will be obtained, the two angles being complements of each other. The extinction angle generally recorded is that between the nearest direction of vibration and the vertical axis _■_.

In monoclinic minerals the maximum value of the extinction angle (the angle of real value in distinguishing the mineral) can only be obtained from a section parallel to the clino pinacoid (010); but in practice sufficiently accurate results can generally be obtained by measuring the extinction angles of all sections of the same mineral, which seem to be about parallel to the vertical axis _■_, and then taking the maximum value obtained. Amphibole and pyroxene can easily be distinguished in this way.

Extinction is generally tested for by revolving the stage, carrying the section, until darkness is observed. The principal difficulty, however, is caused by the eye failing to appreciate the position of maximum darkness. Hence it is better to revolve the stage until the section just becomes dark (or fades out) and then revolve further until the section just begins to lighten up again. The mean of the readings, in these two positions, will be the one to use.

A gypsum test-plate, so prepared as to give some definite interference color, as red of the 1° order, may be introduced between the two nicols, and the section revolved until this color is exactly matched. This perfect matching of color is only possible when the directions of vibration of the section are exactly parallel to the planes of vibration of the nicols, as otherwise some interference color would be produced by the section and the true color of the test-plate would not appear. The most favorable condition is when the section is colorless and only covers a part of the field of view, as then the rest of the field shows the color of the test-plate and the exact matching of color is an easy matter. This method of testing can be employed to recognize the very weak double refraction of some minerals, whose interference colors are such dark grays as not to be noticed without this test. After the test-plate has been introduced, some slight variation in the color will be observed when the stage carrying the doubly refracting section is rotated. There are other methods[53] for locating these directions of vibration. They depend generally on substituting changes of color for degrees of darkness or on changes in interference figures, and consist in the use of color test-plates or Klein's quartz-plate, or of special oculars prepared by Bertrand, Calderon, etc.

METHOD OF TESTING FOR THE VIBRATION DIRECTIONS OF THE FASTER AND SLOWER RAYS, _A′_ AND _C′_, IN A MINERAL SECTION.

A mica or gypsum plate can be used to make this test, the directions of vibration of the faster and slower rays on these plates being known and marked.[54]

The crystal section to be tested is placed on the rotating stage, between crossed nicols, and turned to the position of extinction, when these directions of vibration will be parallel to the cross-wires in the eye-piece. The section is then turned 45°, when the interference color will be at its maximum, and these directions of vibration will make angles of 45° with the planes of vibration of the nicols and the cross-wires in the eye-piece.

Now introduce[55] the test-plate, between the section and the analyzer, so that its known directions of vibration also make angles of 45° with the cross-wires in the eye-piece.

When the test-plate is introduced a new interference color will be noticed which is either higher or lower in the color scale[56] than the original interference color of the mineral section. When the known directions of vibration of the test-plate are superposed over corresponding directions in the mineral section, the effect is to thicken the section and the interference color rises in the scale.

When the directions of vibration of the test-plate are superposed over directions of vibration in the mineral section which are not corresponding, the effect is to thin the section and the interference color sinks in the scale.

For minerals which have very strong double refraction, as zircons, so that the interference colors are of the higher orders, it is advisable to use the method of testing with a quartz wedge.[57]

If a wedge is inserted between crossed nicols and its _c_ direction inclined at 45° to the planes of vibration of the nicols, then successive interference colors will be seen commencing with the gray of the first order and passing through the colors as shown by a color chart. If now the crystal section lies with its vibration directions also in the diagonal position, the color of any portion of the quartz wedge will be changed where it covers the section, the new color being that of a thicker part of the wedge if the _c_ direction in the section lies under the _c_ direction of the wedge. Also where the wedge overlaps the section the displacement of the color fringes in the section will be towards the thin edge of the wedge. On the other hand the new color will be that of a thinner part of the wedge when the _a_ direction in the section lies under the _c_ direction of the wedge. In this case the displacement of the color fringes will be towards the thick part of the wedge.

This method is very convenient when the crystal section has in any place sloping edges, showing prismatic color fringes. The movement of these fringes (as previously described) is towards the thin edge of the wedge when the vibration directions correspond and away from this edge when they do not correspond.

If the wedge when inserted finally "compensates" the color of the crystal section (_i. e._, practically produces an absence of color, darkness), then the a in this section must lie under the c in the wedge, as the effect of the wedge has been to continually thin the section.

DETERMINATION OF ORDER OF INTERFERENCE COLOR.

This can be determined by use of a quartz wedge or a v. Federow mica wedge.[58] Have the vibration directions of the given section in the diagonal position, then gradually insert the wedge between the crossed nicols so that the corresponding vibration directions in the section and wedge are crossed, that is so that the colors are run down until finally dark gray or black is obtained. Count the number of times the original interference color reappears, if _n_ times, then the color is a red, blue, green, etc., of _n_ + 1 order.[59]

It is often easier to insert the wedge until compensation of the color is obtained; then as the wedge is pulled out the direct count of the recurrence of the original color will give the order of that color.

METHOD OF MEASURING THE STRENGTH OF THE DOUBLE REFRACTION BY VON FEDEROW MICA WEDGE.[60]

"The wedge[61] consists of fifteen superposed quarter undulation mica plates, each about two mm. shorter than the one beneath it and with their directions of vibration parallel. The series is mounted on a strip of glass and covered with a cover-glass.

The wave-length of a middle color may be taken as 560 μμ (millionths of a millimeter); hence each quarter undulation mica plate may be considered to possess a phase difference or retardation of 140 μμ. If, then, between the polarizer and analyzer we insert the mica wedge, so that its direction of vibration of the slower ray, _c_, is at right angles to that of the mineral under examination, we subtract from the phase difference of the mineral an amount equal to _n_ times 140 μμ, in which _n_ represents the number of superposed mica plates in the field. When the mineral appears dark the value evidently corresponds closely to the phase difference of the mineral.[62]

From the expression $\Delta = _eX_$, in which Δ is the phase difference or retardation, _X_ the double refraction, and _e_ the thickness in millionths of millimeters, the thickness can be deduced when the double refraction is known or _vice versa_. If a mineral of known double refraction can be found in the section near the mineral under investigation,[63] the double refraction of the latter can be deduced by measuring the phase difference of the known mineral, whence e results, and this substituted in the above formula yields _X_."

METHOD OF DETERMINING MINERALS AND THICKNESS OF SECTION, BY USE OF TABLE OF DOUBLE REFRACTION (MAXIMUM) AND DIAGRAM.[64]

Select some easily recognized mineral in the rock section and note the maximum interference color given by any of its sections.[65] The strength of the double refraction of this mineral being known, look up on the diagram the diagonal line corresponding to this

double refraction and follow along this line toward the left hand lower corner until the observed interference color is reached, when the horizontal line will indicate the thickness of the section. The thickness is given in hundredths of millimeters. Then in the case of the unknown mineral pick out the section giving the highest interference color and carry along the same horizontal line until this new color is located,[66] then pass up to the right along the diagonal line to the numbers indicating the strength of the double refraction of the unknown mineral. Turn to the table where the minerals will be found having about this strength of double refraction.

Example: In a section of granite (biotite-granite) a grain of quartz was selected, which gave the brightest color. This color was a bright yellowish white and the known double refraction of quartz is 0.009. Following down on this diagonal line until the interference color was reached it was seen that the thickness of the section was about 0.03 mm. (a very thin section). The section of the undetermined mineral, giving the highest order color, showed a bright 2° order purple-blue. Passing along the 0.03 horizontal line until this color was reached and then up along the diagonal line, it was seen that the double refraction of this mineral must be about 0.04. The table gives muscovite and ægerite as having about this double refraction. The mineral was proved to be muscovite by its absence of color and relief and by the characteristic cleavage and parallel extinction.

[Illustration:

FIG. 18.—Sanidine crystal _f_, showing Carlsbad twin (which, as it consists of two parts only, may be called _simple_), and quartz _q_ in rhyolite. Crossed nicols.]

Structure:

(_a_) _Twinning_, generally noticed by the parts of the twin not extinguishing at the same time. It may also be observed, without crossed nicols, just as in the case of macroscopic minerals.

Twinning may be described as: _simple_, Fig. 18; _polysynthetic_, due to repeated twinning after the same law, Fig. 12; and _crossed or "gridiron,"_ due to repeated twinning after two laws, Fig. 19.

[Illustration:

FIG. 19.—Microcline, showing crossed or "gridiron" twinning. Crossed nicols.]

(_b_) _Zonal_ structure, often only made visible by the zones extinguishing at different times. It may, however, be noticed by the zones being of slightly different color, or by the zonal distribution of inclusions. In the case of the feldspars the zonal structure may be caused either by the crystal being formed of zones of different chemical composition (the successive zones in the plagioclases growing more acid towards the exterior), or by ultra-microscopic twinning,[67] Fig. 20.

[Illustration:

FIG. 20.—Zonal feldspar (Carlsbad twin) in trachyte. Crossed nicols.]

(_c_) _Aggregate_ structure, being a confused mass of separate little crystals, scales or grains all extinguishing at different times, Fig. 21.

[Illustration:

FIG. 21.—Sphærulites in felsite. Ground mass shows aggregate structure. Crossed nicols.]

(_d_) _Sphærulitic_ structure, produced by the aggregation, in a radiate form, of crystals or crystallites. It is generally easily perceived by the dark cross, resulting from the extinguishing of the light in those crystals whose directions of vibration are parallel to the planes of vibration of the nicols. When the stage is revolved the arms of the cross do not rotate, Fig. 21.

[Illustration:

FIG. 22.—Olivine decomposed to serpentine. The pseudomorphism has been almost complete, only small portions of the original olivine remaining. The outline of the parent crystal can be quite distinctly seen. Crossed nicols.]

(_e_) _Pseudomorphic_ structure, which may be partial or complete and is noticed by the changed portions producing different optical effects from those of the original mineral. Sometimes, although the pseudomorphism has been almost complete, the form of the original mineral or crystal may still be seen, Fig. 22.

Characters Observed by Convergent Polarized Light.

Convergent light is obtained by passing the rays of polarized light through a strong condensing lens, which generally fits like a cap over the top of the polarizer. By means of a suitable adjustment the condensing lens can be brought very close to the lower surface of the section on the stage. The lens thus sends a cone of light through the section, and used in connection with _crossed nicols_ a series of optical phenomena, called _interference figures_,[68] are produced.

Each direction in which rays are sent is traversed by a minute bundle of parallel rays and these rays extinguish and produce interference colors as already described for parallel light. Hence each direction yields a spot or picture in the field of view and from all these spots combined there results an "interference figure" or picture, depending upon the structure of the section for all the directions traversed by the rays.

A very high power objective[69] must be used, and when the eye-piece is removed, a small image of the interference figure will be seen. In some microscopes an arrangement is made for getting a magnified image of the interference figure, by retaining the eye-piece and using an additional Bertrand lens.

In order to get good results care must be taken to have strong illumination and the condensing lens close up under the section. The tests are best made with monochromatic light, but with white light the effects are substantially the same, the only difference being that the rings and curves are variously colored instead of being simply light and dark.

Isotropic substances show no _interference figures_.

Uniaxial Interference Figures.

(_a_) Sections perpendicular to the optic or vertical axis _■_ show a dark cross, with or without colored rings, Figs. 23 and 24. The figure is symmetrical to the center, as the optical behavior of uniaxial crystals is symmetrical to the optic axis.

[Illustration:

FIG. 23.]

[Illustration:

FIG. 24.]

The arms of the cross are parallel to the planes of vibration of the nicols, and the figure does not move when the stage carrying the section is rotated.[70]

(_b_) Sections oblique to the optic axis show a portion of a dark cross, with or without colored rings, Fig. 25. The centre of the cross is not in the axis of rotation, and as the stage bearing the section is revolved, the centre of the cross describes a circle, the arms always maintaining parallel positions.

If the section is still more oblique to the optic axis the centre of the interference cross may be outside the field of view, and only portions of the dark arms will be seen.

Sections parallel to the optic axis show a vague dark cross, which, on rotating the stage, dissolves into hyperbolic curves (suggesting biaxial figure), which very rapidly disappear in the direction of the optic axis. When the interference figure shows colors, these colors are lower in order in the quadrants containing the optic axis. Knowing thus the position of the optic axis the optical character can be obtained by the method for parallel light, p. 43.

[Illustration:

FIG. 25.]

Sections which are thick and have strong double refraction will show the cross and rings clearly and sharply defined, there being quite a number of rings crowded close together. Sections which are very thin and have weak double refraction show only a broad dark cross and no rings. The interference figures will vary between these extremes, depending on the thickness of the section and the strength of the double refraction.

To obtain the most characteristic figures, observations must be made on sections about perpendicular to the optic axis, that is sections which remain dark or nearly dark during complete rotation between crossed nicols in parallel light.

■Optical Character, Positive or Negative.■ After having obtained an uniaxial interference figure, test it by means of a ¼ undulation mica plate. This plate must be introduced between the objective[71] and the analyzer in such a way that its vibration direction c, marked on the plate, makes an angle of 45° with the planes of vibration of the nicols.

When this is done the interference figure changes, or may more or less disappear, two dark spots or blotches being brought prominently into view. If rings are still seen it will be noticed that they have expanded in the quadrants occupied by the dark spots, and have contracted in the remaining quadrants. This movement of the rings may make it possible to determine the optical character of a section, which is so oblique to the optic axis that the dark spots are not seen after the introduction of the mica plate.

[Illustration:

FIG. 26.]

[Illustration:

FIG. 27.]

If the optical character is _positive_ the line joining these dark spots is perpendicular to the direction c of the mica plate, see Fig. 26.

If _negative_ the line joining the dark spots coincides with the direction c of the mica plate, see Fig. 27.

The (+) and (–) character is easily determined by remembering that the line, joining the dark spots, makes the + and – sign respectively with the direction c of the mica plate. The direction c of the mica plate (represented in the figures by an arrow) is of course not seen, but its position must be borne in mind when making this test. This test can be made with either monochromatic or white light.

If the mica plate does not give satisfactory results, which will be the case when the double refraction of the crystal to be tested is very weak or when the section is very thin, use a selenite plate, cut the proper thickness to give the red color of the first order.

This plate must be introduced with its vibration direction a (previously determined) making an angle of 45° with the planes of vibration of the nicols. Instead of the dark spots being seen there will appear two blue and two red quadrants. The diagonally opposite quadrants being of the same color.

In determining the (+) and (–) character consider the blue quadrants as the equivalent of the dark spots in the preceding case. This test must be made with white light.[72]

Biaxial Interference Figures.

[Illustration:

FIG. 28.]

[Illustration:

FIG. 29.]

(_a_) Sections perpendicular to an optic axis exhibit the interference figures shown in Figs. 28 and 29, the curves being nearly circular and a straight black bar bisecting these curves, whenever the trace of the plane of the optic axes coincides with the vibration direction of either nicol. As the stage, carrying the section, is rotated the bar changes into one arm of a hyperbola and back again into a bar. This arm or bar will rotate in the opposite direction to the motion of the stage.

As previously stated sections of biaxial crystals, perpendicular to an optic axis, do not remain dark during rotation of the stage between crossed nicols in parallel light. On the contrary these sections remain uniformly illuminated.[73]

(_b_) Sections perpendicular to the acute bisectrix (see p. 5), exhibit interference figures like those shown in Figs. 30 and 31.

[Illustration:

FIG. 30.]

[Illustration:

FIG. 31.]

Fig. 30 shows the appearance of the interference figure when the plane of the optic axes is parallel to the plane of vibration of either nicol, and Fig. 31 shows the appearance when this plane is inclined 45° to the planes of vibration of the nicols.

As the stage, carrying the section, is rotated the dark cross seems to dissolve into two branches of a hyperbola, which again unite to form a cross.

In sections perpendicular to a bisectrix, with a large axial angle, the figure will appear, during a rotation of 90° (in the direction of the hands of a watch), as in Fig. 32, top row. When the section is somewhat oblique to an "optic axis," the figure appears as in middle row; and when still more oblique, as in bottom row.

The black centres[74] of the small ellipses and the black hyperbolic curves mark the points of emergence of the optic axes, and therefore indicate approximately the size of the _axial angle_, 2_E_.

Sections in other positions, relative to the optic axes, give interference figures less definite in appearance than those just described; and the same conditions affect the appearance of all figures as in the case of uniaxial crystals. Very thin sections, of weak double refraction, may only show indistinct dark crosses or hyperbolic curves, without any ellipses.

The section perpendicular to the acute bisectrix, which gives the most characteristic interference figure, cannot generally be recognized except by an examination in convergent light. It is never, however, the section giving the maximum interference color. The interference colors in different sections, normal to the optical elements, grade downward in the following order: (1) optic normal, (2) obtuse bisectrix, (3) acute bisectrix, (4) optic axis. Sometimes cleavage may furnish a clue as to the best section to test as in Topaz and Mica, where the acute bisectrix is normal to the cleavage.

[Illustration:

FIG. 32.—Biaxial Interference Figures (from Reinisch). Top row: Almost perpendicular to bisectrix, large axial angle. Middle row: Somewhat oblique to an "optic axis." Bottom row: More oblique to an "optic axis."]

It must be remembered that this uncertainty, in the choice of sections for testing, does not exist in uniaxial crystals; where the best sections are indicated by the fact that they remain dark or nearly so during complete rotation between crossed nicols.

The uniaxial or biaxial character of a mineral section, which only shows an indistinct bar, may be determined as follows: A bar (one arm of the cross) of a uniaxial interference figure moves in the same direction as the rotating stage, and always remains straight, while the biaxial bar rotates in the opposite direction to the stage and becomes curved.

■Optical Character, Positive or Negative.■ When the axial angle is very small, so that the interference figure approaches that of a uniaxial crystal, the methods used for testing uniaxial figures are employed.

When, however, the axial angle is large, the following method can be used:

After having obtained an interference figure, from a section as nearly at right angles to the acute bisectrix[75] as possible, the stage is rotated until the plane of the optic axes (the trace of which on the plane of the section is the line joining the points of emergence of the two optic axes) makes an angle of 45° with the planes of vibration of the crossed nicols or the cross-wires in the eye-piece.

A quartz wedge[76] is now pushed in between the mineral section and the analyzer,[77] so that its axis _■_ = c (previously determined and marked on the wedge) is either at right angles or parallel to the plane of the optic axes of the mineral section.

The optical character of the mineral is _positive_ when the ellipses, surrounding the points of emergence of the two optic axes on the convex sides of the hyperbola, appear to expand or open out towards the centre when the quartz wedge is pushed in with its axis parallel to the plane of the optic axes.

The optical character is _negative_ when the ellipses appear to expand or open out when the wedge is pushed in with its axis at right angles to the plane of the optic axes.

As the ellipses expand they move from the points of emergence of the optic axes towards the centre of the interference figure, and finally open into lemniscates which move outward from the plane of the optic axes.

Even when the section is very thin and the double refraction very weak, only the black hyperbolas without ellipses being seen, the test can be made; and colored ellipses will appear, after the pushing in of the quartz wedge, which will act in the same way as the ellipses of the interference figure.

In a section at right angles to the _obtuse bisectric_ these results are all reversed.

When the section is perpendicular to one optic axis, rotate the section until the plane of its optic axes is 45° to the planes of vibration of the nicols. The interference figure will now have the appearance as shown in Fig. 29, the hyperbola being convex towards the acute bisectrix. Insert the ¼ undulation mica plate, so that its direction c is parallel to the plane of the optic axes. If the optical character is positive the hyperbola will move towards the acute bisectrix and if negative away from it. When the gypsum plate is used the blue color will appear on the convex side for (+) and on the concave side for (–) minerals.

■Determination of the Axial Angle.■[78] This can be approximately determined with a petrographical microscope, if equipped with a micrometer eye-piece. Have the axial plane of the crystal section in the diagonal position, Fig. 31; and measure the distance _d_ from the centre to either hyperbola with a micrometer (or average the distance to both). Then sin _E = d/C_, in which _C_ is a constant for the same combination of lenses and is obtained by using a crystal section (mica cleavage) of known axial angle. For example, in a mica with 2_E_ = 91° 50′ and _d_ = 41.5 divisions on the micrometer scale, _C = d_/sin _E_ = 57.78 for that special combination of lenses. The true axial angle can be obtained from the equation sin _V = d/βC_.

■Optical Distinctions between Orthorhombic, Monoclinic, and Triclinic Crystal Sections (perpendicular to acute and obtuse bisectrices).■ The interference figures are always symmetrical in shape and distribution of color to the planes and axes of symmetry of the crystal system; hence are most symmetrical in the orthorhombic, less so in the monoclinic and still less so in the triclinic system.

Orthorhombic crystals show the figures always in two of the pinacoids and in white light the color distribution will be symmetrical to the trace of the axial plane and the line through the centre at right angles to this trace and also to the central point.

Monoclinic crystals show the figures in the clino pinacoid or in sections at right angles to this. In white light the color distribution is never symmetrical to two lines, but is symmetrical either to the trace of the axial plane (_inclined dispersion_[79]), or to the line through the centre at right angles to this trace (_horizontal dispersion_), or to the central point (_crossed dispersion_).

Triclinic crystals show in white light figures with distribution of color unsymmetrical to any line or point.

In white light the “color fringes” of the hyperbola are due to the “_dispersion_”[79] of the optic axes and bisectrices. That is, for each color (for light of each wave-length) there is a particular interference figure; the overlapping of these superposed figures producing the color fringes.

When the axial angle is larger for red light than for violet, the dispersion is said to be $\rho > \nu$ and the interference figure, in the position of Fig. 31, will show the hyperbolic curves fringed with red towards the centre (inside). In general the color with the larger axial angle is nearer the centre of the field. This is due to the extinguishing of light of each color at the axial points, the resulting colors at these points being produced by white light minus the absorbed color. When the dispersion is $\nu > \rho$ the reverse distribution of color fringes will take place.

By measuring the axial angle in red and blue light, this dispersion of the optic axes can also be obtained.

RESUMÉ OF THE USES OF PARALLEL AND CONVERGENT POLARIZED LIGHT.

Parallel light is used to detect pleochroism, to distinguish between isotropic and anisotropic substances, to study interference colors, to determine the strength of the double refraction, to locate directions of vibration, to measure extinction angles, to find the directions of vibration of the faster and slower rays, to determine the relative value of the indices of refraction of the two rays, and to investigate the crystal structure in general.

Convergent light is used to distinguish between uniaxial and biaxial crystals, to determine whether a section that appears to be isotropic is really so or only perpendicular to an optic axis and to determine the optical character, grade of symmetry (system), axial

angle and dispersion.

CHAPTER IV. THE MICROSCOPIC AND OPTICAL CHARACTERS OF MINERALS.

OPAL.

ISOTROPIC. AMORPHOUS.

COMPOSITION: $SiO_2.nH_2O$, generally soluble in caustic alkalies.

■Usual Appearance in Sections■: Colorless patches, incrustations or veins, also at times with sphærulitic structure (hyalite), showing interference cross, of negative character, between crossed nicols. Often shows anomalous double refraction due to strains. The refractive index is very low (1.46) so that the surface of the opal appears rough.

REMARKS: Found as a secondary mineral in many acid volcanic rocks, rhyolite, trachyte, andesite, etc., and also in basic basalts. H., 5.5 to 6.5. Sp. gr., 2.2.

LIMONITE.

AMORPHOUS.

COMPOSITION: $Fe_2(OH)_6$, Fe_2O_3, frequently quite impure.

■Usual Appearance in Sections■: Brownish and opaque, in very thin sections may be translucent.

REMARKS: Limonite is essentially a decomposition product, often forming pseudomorphs after ferruginous silicates or halos about the iron ores.

PYRITE, Pyrites.

ISOMETRIC. COMPOSITION: FeS_2.

■Usual Appearance in Sections■: Cubes, pyritohedrons, combinations of these forms; or in irregular grains. Outline of cross-sections generally square.

Opaque, and by reflected light, bright yellow, with strong metallic lustre.

Alters very easily to the oxides of iron (rust).

REMARKS: May be present in all kinds of rocks, igneous, metamorphic and sedimentary. Not noticeably acted on by hydrochloric acid. H., 6 to 6.5. Sp. gr., 4.9 to 5.2.

PYRRHOTITE, Magnetic Pyrites.

COMPOSITION: FeS. Distinguished from pyrite by being practically always in irregular masses and not in crystals, and by bronze yellow color with reflected light. Found in basic eruptive rocks, more rarely in schists.

MAGNETITE, Magnetic Iron Ore.

ISOMETRIC.

COMPOSITION: Fe_3O_4, often contains Ti.

■Usual Appearance in Sections■: Grains and crystals (generally octahedra), Fig. 33 B. Skeleton crystals frequent in highly ferruginous eruptive rocks.

Twinning.—Common, according to _Spinel_ law.

[Illustration:

FIG. 33.—_A_, Zircon crystals (isolated from granite) in balsam, showing high relief. _B_, Magnetite crystals. _C_, Ilmenite, showing partial decomposition to _leucoxene_ along crystallographic directions.]

Opaque, and by reflected light, bluish-black, with strong metallic lustre.

■Distinguished from■: HEMATITE, CHROMITE, ILMENITE and GRAPHITE, by being easily separated from powdered rock by weak magnet.

REMARKS: Very widely distributed in eruptive rocks and crystalline schists. In the eruptive rocks magnetite belongs to the oldest secretions from the magma, immediately followed by chrysolite, biotite, hornblende, augite, etc.; hence often appears as inclusions in these and other minerals. Magnetite grains may form with other substances pseudomorphs after hornblende, biotite, hypersthene, etc. Such pseudomorphs appear to be caused by "resorption." Magnetite is strongly magnetic and soluble in hydrochloric acid. H., 5.5 to 6.5. Sp. gr., 4.9 to 5.2.

CHROMITE.

ISOMETRIC.

COMPOSITION: $FeCr_{2}O_{4}$.

■Usual Appearance in Sections■: Octahedral crystals, grains and in the olivine rocks sometimes in dense aggregates. May be surrounded by green, pleochroic halo of chrome ochre.

Opaque, and by reflected light, brownish-black to black, with general absence of metallic lustre. Usually translucent and brownish on the edges (by transmitted light), with a very rough surface due to high index of refraction ($_n_ = 2.1$).

■Distinguished from■:

(_a_) MAGNETITE by brownish-black to black color and general absence of metallic lustre (by reflected light) and by grains being usually translucent and brownish on the edges (by transmitted light).

(_b_) SPINEL (Picotite), see under Spinel.

REMARKS: Common in crystalline rocks, rich in magnesia, and in serpentine. Chromite is not acted on by acids, is non-magnetic and gives chromium bead test. H., 5.5. Sp. gr., 4.3 to 5.6.

SPINEL.

ISOTROPIC. ISOMETRIC.

COMPOSITION: $Mg(AlO_{2})_{2}$. Pleonaste (Fe, Mg spinel), Picotite (Cr spinel).

■Usual Appearance in Sections■: Octahedral crystals and twins (after spinel law), less often in grains. Fracture cracks. Always optically normal and never decomposed in rocks. Usually colorless or dark green (pleonaste) to brown (picotite). The refractive index is high ($_n_ = 1.72$, spinel proper, to 2.00, chrome spinel), hence the _relief_ is marked and the surface rough.

■Distinguished from■:

(_a_) GARNET when colorless by octahedral shape of crystals (garnet forms being 110 and 211), when brown (picotite) from melanite garnet by common zonal coloration of the latter, but may require chemical tests. Furthermore spinel may have green color and is never decomposed.

(_b_) PEROVSKITE by the lower index of refraction and the absence of reaction for Ti.

(_c_) CHROMITE chemically or by density or hardness.

REMARKS: Found in gneiss, granulite, lherzolite and in regions of contact metamorphism and secondary bedding formations (picotite), olivine-basalt and serpentine. Spinels are insoluble in hydrochloric acid. H., 8. Sp. gr., 3.5 to 4.1.

GARNET.

ISOTROPIC. ISOMETRIC.

COMPOSITION: R″_{3}R■_{2}(SiO_{4})_{3}. R″ is Ca, Mg, Fe or Mn; R■ is Al, Fe■, or Cr, rarely Ti.

■Usual Appearance in Sections■: Irregular grains, Fig. 13, or simple crystals, showing forms (110) and (211), alone or in combination, Fig. 14 _b_. Zonal structure not infrequent, especially in the titanium varieties, Fig. 34.

Color.—Colorless, or nearly so, to yellowish, reddish or brownish.

Index of Refraction.—_n_ = 1.750–1.856, hence _relief_ high and surface very rough.

Fracture.—Irregular cracks occur, but no cleavage noticed.

■Crossed Nicols■: As garnets are isotropic, sections remain dark during complete rotation. Optical anomalies may however occur, but are generally confined to, titanium free, lime garnets and manganese garnets. The effect being to divide the crystal symmetrically into different areas, "dodecahedral structure."

[Illustration:

FIG. 34.—Garnet, with zonal structure, in gneiss. (From Cohen.)]

■Alteration■: Garnets are usually fresh, but may be found altered to chlorite or hornblende.

■Distinguished from■: SPINEL and PEROVSKITE.—See under the latter.

REMARKS: Found principally in granulites, metamorphic rocks, contact rocks, crystalline schists, etc. Certain varieties may be found in eruptive rocks or olivine rocks. May form pegmatitic borders with pyroxene, spinel, etc. Garnets are practically insoluble in hydrochloric acid. H., 6.5 to 7.5. Sp. gr., 3.4 to 4.3. The insolubility in acids and the high sp. gr. help in separating garnet from a powdered rock.

LEUCITE.

ISOTROPIC. ISOMETRIC.[80]

COMPOSITION: KAl(SiO_{3})_{2}.

■Usual Appearance in Sections■: Crystals or grains, which vary greatly in size. Cross-sections often nearly round. When very small and free from inclusions may be easily overlooked. Sometimes the grains are surrounded by tangentially arranged needles of different minerals.

[Illustration:

FIG. 35.—Leucite, with radial and tangential inclusions, Vesuvius Lava. (From Cohen.)]

Color.—Colorless.

Index of Refraction.—_n_ = 1.509, hence no _relief_ and generally smooth surface.

Fracture.—May be noticed, but no cleavage observed.

Inclusions.—Common, radially or zonally arranged, consisting of minerals or glass, Fig. 35.

■Crossed Nicols■: The smaller crystals appear isotropic; the larger crystals show characteristic intersecting systems of twin lamellæ, Fig. 36.

[Illustration:

FIG. 36.—Leucite, showing complicated, interpenetration twinning between crossed nicols.]

Double Refraction.—Very weak ($\gamma - \alpha = 0.001$). In thin sections it may be necessary to use a sensitive color plate to prove double refraction.

Interference Colors.—Very low 1st order, dark gray, etc.

■Alteration■: Quite frequent to fibrous or granular zeolites.

■Distinguished from■: ANALCITE—see under analcite.

REMARKS: Almost entirely confined to younger eruptive rocks, phonolite, tephrite and other leucite rocks and their tuffs. Often found with plagioclase, nephelite, augite, etc. It is more or less attacked by hot hydrochloric acid. H., 5.5 to 6. Sp. gr., 2.4 to 2.5. The isolation of leucite from rock powder can be better accomplished by specific gravity than by chemical methods.

ANALCITE.

ISOTROPIC. ISOMETRIC.

COMPOSITION: $NaAlSi_2O_6 + H_2O$.

■Usual Appearance in Sections■: Secondary colorless grains, with no very characteristic microstructure or properties. Cleavage parallel to cube (100) usually seen. Index of refraction low (n = 1.488), hence rather rough surface. Between _crossed nicols_ may show optical anomalies, but not so marked as in garnet.

Distinguished from: LEUCITE, SODALITE and NEPHELITE. These minerals are most easily confused with analcite and recourse must be had to chemical tests, detection of optical anomalies, gelatinization test or turbidity by heating.

REMARKS: Occurs as a secondary product (commonly from nephelite or leucite) in alkali-rich eruptive rocks. Considered also as a primary mineral in igneous rocks.[81] Gelatinizes with hydrochloric acid, and becomes turbid by heating. H., 5.5. Sp. gr., 2.25.

SODALITE GROUP. Sodalite, Haüynite (Haüyne) and Noselite (Nosean).

ISOTROPIC. ISOMETRIC.

COMPOSITION:

Sodalite, $3NaAlSiO_4 + NaCl$. Haüynite, $2(Na_2Ca)Al_2(SiO_4)_2 + (Na_2Ca)SO_4$. Noselite, $2Na_2Al_2Si_2O_8 + Na_2SO_4$.

■Usual Appearance in Sections■: Dodecahedral rounded crystals or (S) irregular grains. Colorless, yellowish, brownish, greenish to deep blue. Refractive index low [$_n$ = 1.483(S) to 1.503(H)], hence the surface appears rather rough in sodalite and slightly rough in haüynite. Inclusions, abundant and characteristic, often rod-like and arranged regularly, making section translucent and especially dark at border, Fig. 37. Dodecahedral cleavage sometimes seen. Optical anomalies may occur.

■Alteration■: Takes place easily to aggregates of natrolite, other zeolites, mica, etc.

■Distinguished from■:

(_a_) ONE ANOTHER only by chemical tests. Gelatinization test with hydrochloric acid will show in addition to jelly, salt crystals for (S), abundant gypsum crystals ($CaSO_4 + 2H_2O$) for (H) and few if any gypsum crystals (absence of Ca) for (N). (H) and (N) turn blue when heated, but test will not work if minerals are decomposed. When treated with hydrochloric acid and nitrate of silver the black sulphide of silver will show on (H) and (N), but the white chloride on (S).

(_b_) NEPHELITE (Elæolite) by being isotropic.

(_c_) ANALCITE by no turbidity when heated.

REMARKS: These minerals are found in the basic, soda-rich rocks. (S) in elæolite-syenite also in trachyte and phonolite, (H) and (N) common in phonolite and leucite-porphyry. H., 5.5 to 6. Sp. gr., 2.3.

[Illustration:

FIG. 37.—Haüynite, showing dark centre and border, in nepelinite. (From Cohen.)]

PEROVSKITE, Perofskite.

ISOTROPIC. ISOMETRIC. COMPOSITION: $CaTiO_3$.

■Usual Appearance in Sections■: Microscopic, octahedral crystals or larger grains, pale brownish in color and not very transparent, darker colored in the larger grains. In reflected light grains appear yellowish with adamantine lustre. Refractive index very high (_n_ = 2.38), hence _relief_ very strong.

Between _crossed nicols_, the little crystals generally appear optically normal and remain dark; but the larger crystals may show a complicated penetration twinning.

■Distinguished from■: GARNET (melanite) and SPINEL (picotite) by much higher refractive index and reaction for titanium and by zonal coloration of melanite. When opaque it might be mistaken for the iron ores, but has no metallic lustre.

REMARKS: Found in the younger basic eruptive rocks, especially melilite-basalt. Commonly associated with the iron ores nephelite, augite and chrysolite. Insoluble in hydrochloric acid. H., 5.5. Sp. gr., 4.1.

RUTILE.

ANISOTROPIC. UNIAXIAL. TETRAGONAL. COMPOSITION: TiO_2. _■_ = c ELONGATION ■ _■_.

■Usual Appearance in Sections■: Sharp, elongated, prismatic crystals when microscopic, but granular when the individuals are large. Grains may be almost opaque, with adamantine lustre by reflected light. Knee- or heart-shaped twins, Figs. 38 and 39, common in the smaller crystals, the larger individuals may also show geniculated twinning. Small crystals sometimes form net-shaped groups (sagenite), by crossing one another at angles of 60°. Pleochroic halos may surround crystals. Color, yellowish to reddish-brown. Index of refraction very high (_n′_ = 2.712, $\alpha = 2.616$, $\gamma = 2.903$), hence _relief_ marked and surface very rough. Prismatic cleavage present in larger individuals, not observed in microscopic crystals. Pleochroism and strong absorption may be noticed, especially in the larger grains, but may fail entirely.

■Crossed Nicols■: Double refraction _very_ strong ($\gamma - \alpha = 0.287$). Interference colors[82] very high order, only seen in the microlitic crystals which do not appear dark due to total reflection; in other cases may not show at all. _Extinction_ parallel to prisms. In _convergent light_ optical character (+).

■Alteration■: May take place to a white or yellowish, fibrous or granular substance, strongly refracting, and similar to the alteration product of ilmenite. May be surrounded by grains of titanite.

■Distinguished from■: The OPAQUE ORES by adamantine lustre with reflected light; ZIRCON and CASSITERITE in concentrates by chemical tests. May not be possible to distinguish from cassiterite in sections.

REMARKS: Found in the metamorphic schists, amphibolites, slates, contact and fragmentary rocks, etc.; also as inclusions in quartz and mica. Especially common as a secondary product of titaniferous hornblende and biotite. The “sagenite” webs of the decomposed micas are probably secondary. Rutile is insoluble in hydrochloric acid. H., 6 to 6.5. Sp. gr., 4.2. It is easily separated from rock powder by its insolubility in acid and its high sp. gr.

[Illustration:

Rutile twins.

FIG. 38.—Twin plane (101). FIG. 39.—Twin plane (301).]

ZIRCON.

ANISOTROPIC. UNIAXIAL. TETRAGONAL. COMPOSITION: $ZrSiO_4$. _c_ = ■. ELONGATION ■ c′.

■Usual Appearance in Sections■: Small, short prismatic crystals, Fig. 33A, and grains. Shell-like (zonal) structure may be noticed. When enclosed in black-mica, hornblende, cordierite, etc., often surrounded by characteristic pleochroic halos.[83]

Color.—Colorless, rarely pale brownish.

Index of Refraction.—_n′_ = 1.95, ($\alpha = 1.931$, $\gamma = 1.993$) hence _relief_ very high and surface rough.

■Polarized Light■:

Pleochroism.—Not usually noticeable.

■_Crossed Nicols_■:

Double Refraction.—Very strong ($\gamma - \alpha = 0.062$).

Interference Colors.—Very high (4th) order, minute crystals show brilliant colors.

Extinction.—As zircon is uniaxial, basal sections remain dark during rotation of stage. In all other sections extinction is parallel to _■_.

■_Convergent Light_■: Basal sections, which are large enough to give interference figures, show several rings in addition to dark cross. Optical character (+).

■Alteration■: Very rarely takes place.

■Distinguished from■:

(_a_) APATITE.—By much higher relief and stronger double refraction.

(_b_) TITANITE.—By uniaxial character.

(_c_) RUTILE.—See under the latter.

Easily confused with xenotime, which, however, has higher interference colors and more distinct pleochroism; but chemical tests may be necessary.

REMARKS: Found widely distributed but not in quantity in eruptive and metamorphic rocks. Occurs in granite, syenite, diorite, gabbro, gneiss, etc. It is one of the oldest constituents of the rocks in which it occurs, and may often be found as inclusions in the ferro-magnesium minerals. Zircon is insoluble in hydrochloric acid. H., 7.5. Sp. gr., 4.5 to 4.7. It can easily be separated from rock powder on account of its high sp. gr., insolubility in acid and non-magnetic properties. The crystals can then be examined separately, or chemical tests made to prove the presence of Zr.

SCAPOLITE GROUP, Wernerite, etc.

ANISOTROPIC. UNIAXIAL. TETRAGONAL. COMPOSITION: Silicates of Ca, Al _■_ = a. ELONGATION ■ a′. and Na.

■Usual Appearance in Sections■: Colorless grains, lath-like individuals or prisms (dipyre, in contact metamorphic limestone). Index of refraction (_n′_ = 1.551 to 1.584;, $\alpha = 1.542$ to 1.558, $\gamma = 1.555$ to 1.597) about the same as quartz, hence usually no _relief_ and surface smooth. Cleavage distinct parallel to square prism. Inclusions (carbonaceous) may be abundant in contact rocks.

■Crossed Nicols■: Double refraction usually strong, but varies ($\gamma - \alpha = 0.013$ to 0.039), increases with the Ca percentage. Interference colors upper 1st or 2d order, more brilliant than those of most of the colorless minerals. Basal sections (showing cleavages intersecting at 90°) isotropic. _Extinction_ parallel in longitudinal sections. In _convergent light_ basal sections show distinct uniaxial interference figure; optical character (–).

■Alteration■: Takes place easily to a fibrous substance or to kaolin, muscovite, etc.

■Distinguished from■:

(_a_) FELDSPARS (not showing twinning) and IOLITE (Cordierite) by uniaxial character, cleavage and higher order interference colors.

(_b_) QUARTZ by cleavage, higher order interference colors and optical character; quartz is (+)

(_c_) APATITE (in grains) by lower index of refraction, cleavage and higher order interference colors.

REMARKS: Found especially in metamorphosed diabases and gabbros (Norwegian); also in gneisses, crystalline schists, metamorphosed limestones, etc. Dipyre occurs in contact zones of limestones and schists, where it might be confused with andalusite, but cross-sections show uniaxial character. The minerals of this group are more or less soluble in hydrochloric acid. When the scapolite contains Cl, the following test can be made on fresh material. Treat with a solution of silver nitrate in hydrofluoric acid and the jelly will be impregnated with chloride of silver which will turn brown. H., 5.5. Sp. gr., 2.68.

VESUVIANITE, Idocrase.

ANISOTROPIC. UNIAXIAL. TETRAGONAL. COMPOSITION: _■_ = a. ELONGATION ■ a′. $Ca_{6}Al_{3}(OH.F)(SiO_{4})_{6}$.

■Usual Appearance in Sections■: Grains or prismatic crystals. Almost colorless to reddish (when containing Mn). Index of refraction high (_n′_ = 1.715, α = 1.701 to 1.726, γ = 1.705 to 1.732), hence _relief_ marked and surface rough. Cleavage imperfect, parallel to prism. Pleochroism generally very faint.

■Crossed Nicols■: Double refraction very weak ($\gamma - \alpha$ = 0.001 to 0.006), may vary in different portions of the same crystal (optical anomalies due to the mineral being at times a mixture of isomorphous individuals). Interference colors very low 1st order, dark gray, etc., may often appear zonal. Basal sections isotropic when normal, but may show division into biaxial portions. _Extinction_ parallel in sections elongated ■ _■_ axis. In convergent light basal sections show a faint cross when normal; optical character generally (–).

■Alteration■: Not known in rock-making vesuvianite.

■Distinguished from■: EPIDOTE (Pistacite) by the very low order interference colors. CORUNDUM by weaker double refraction. GARNET (Grossularite), ZOISITE, and APATITE may be easily confused with this mineral and hard to distinguish from it.

REMARKS: Found in limestones, that have undergone alteration by contact with igneous rocks, and in metamorphic schists. Also may occur in dense (nephrite-like) aggregates in serpentine. It is insoluble in hydrochloric acid. H., 6.5. Sp. gr., 3.3 to 3.8.

MELILITE.

ANISOTROPIC. UNIAXIAL. TETRAGONAL. COMPOSITION: $Na_{2}(Ca,Mg)_{11}(Al,Fe)_{4}Si_{9}O_{36}$?. _■_ = a. ELONGATION ■ c′.

■Usual Appearance in Sections■: Almost colorless, tabular (■ base) crystals or irregular grains or shreds. Sections very commonly lath-shaped, and often characterized by the peculiar "peg-structure,"[84] the lines or markings being ■ _■_ (■ elongation of the section). Index of refraction (_n′_ = 1.630, α = 1.629, γ = 1.631) higher than that of the other associated colorless materials, hence _relief_ rather marked. Cleavage, parallel to base, very imperfect.

■Crossed Nicols■: Double refraction very weak ($\gamma - \alpha$ = 0.003), and diminishes with a decrease of Al. Interference colors the lower 1st order, grays, etc.; anomalous interference colors may show. _Extinction_ parallel to cleavage or the peculiar markings or lines. Optical character usually (–), but when poor in Al (+).

■Alteration■: Takes place frequently to a fibrous aggregate.

■Distinguished from■: NEPHELITE and FELDSPAR by higher relief, shape, "peg-structure" and usual dull appearance with reflected light.

REMARKS: Abundant in the leucite and nephelite rocks (associated with these minerals and with augite, perovskite and chrysolite), and takes the place of a feldspar in the melilite-basalt. It gelatinizes easily with hydrochloric acid. H., 5. Sp. gr., 2.9.

GRAPHITE.

HEXAGONAL.

COMPOSITION: C.

■Usual Appearance in Sections■: Minute particles, or flakes and grains of irregular shape, seldom crystallized.

Opaque, and by reflected light, black with metallic lustre.

■Distinguished from■: The similarly appearing ores by its insolubility in acids and the possibility of making it disappear by heating.

REMARKS: Graphite is widely distributed in the oldest rock formations, especially in the schists. It is often associated with rutile and the iron oxides. Graphite is not acted on by acids. H., 1 to 2. Sp. gr., 2.09 to 2.25. It is burnt with great difficulty in thin sections on platinum foil; but this test may vary, in many cases the graphite (when in bladed flakes) not being consumed even after long heating. When heated it may expand into worm-like forms.

Carbonaceous Matter.—Occurs in opaque, grayish-black particles having no lustre; and is found finely disseminated, sometimes in larger aggregations, in clay slates, limestones, etc.

HEMATITE.

HEXAGONAL.

COMPOSITION: Fe_2O_3.

■Usual Appearance in Sections■: Irregular scales, minute grains or earthy. Distinct crystalline forms not often observed in rocks.

Opaque, and by reflected light, black with metallic lustre, or red without lustre. May also be transparent in red tints. No marked pleochroism observed.

REMARKS: Found widely distributed in acid eruptive rocks, crystalline schists, etc. Also as inclusions in minerals, and as a red pigment in many rocks. It is insoluble in hydrochloric acid, and non-magnetic, unless attached to grains of magnetite. H., 5.5 to 6.5. Sp. gr., 4.9 to 5.3.

ILMENITE, Menaccanite.

HEXAGONAL.

COMPOSITION: $(FeTi)_2O_3$.

■Usual Appearance in Sections■: Irregular masses, without crystallographic outline, rhombohedral crystals, or skeleton-like growths. Also in brownish, translucent mica-like forms.

Opaque, and by reflected light, iron-black with metallic lustre.

When _translucent_: pleochroism brown to yellow; double refraction not very strong; optically (–).

■Alteration■: Often takes place to a whitish, strongly refracting, substance only slightly transparent, called _leucoxene_. This alteration product frequently develops along definite rhombohedral directions, Fig. 33 C. Also a change to titanite or rutile may occur, or the ilmenite may be surrounded by these minerals.

■Distinguished from■: MAGNETITE and HEMATITE.—By whitish, strongly refracting decomposition product. At times the distinction may be very difficult.

REMARKS: Ilmenite occurs principally in the soda-rich and basic eruptive rocks. The mica-like form is limited to the porphyritic eruptives. The brown pigment in the plagioclase of certain gabbros may be ilmenite. It is attacked slowly by hot hydrochloric acid, and the solution when heated with tin becomes violet. Pure ilmenite is indifferent towards the magnet, hence strong magnetic properties would indicate a mixture with magnetite. H., 5 to 6. Sp. gr., 4.5 to 5.

CORUNDUM.

ANISOTROPIC. UNIAXIAL. HEXAGONAL. COMPOSITION: Al_2O_3. _c_ = a.

■Usual Appearance in Sections■: Pyramidal or prismatic crystals, grains or basal plates. Zonal structure or twinning may be noticed. Colorless or with patches of blue. Index of refraction high (_n′_ = 1.766, α = 1.760, γ = 1.769), hence _relief_ well marked and surface very rough. Rhombohedral cleavage may show in larger individuals. Pleochroism only marked when color is deep.

■Crossed Nicols■: Double refraction weak ($\gamma - \alpha = 0.009$), like quartz. Interference colors middle 1st order, white to yellow. _Extinction_ parallel in elongated sections. Optical anomalies very rarely noticed in microscopic individuals. In _convergent light_ basal sections show a rather indistinct cross; optical character (–).

■Distinguished from■:

(_a_) APATITE and VESUVIANITE by brighter interference colors.

(_b_) TOURMALINE (light colored) by not having such strong absorption.

(_c_) CYANITE by uniaxial character.

Corundum may need to be isolated from the rock in order to be determined with certainty.

REMARKS: found in contact metamorphic rocks, eruptive rocks, granular limestones, etc. It is insoluble in hydrochloric acid. When rock sections are ground with emery, care must be taken not to confuse grains of emery with corundum in the rock. H., 9. Sp. gr., 3.9 to 4.

QUARTZ.

ANISOTROPIC. UNIAXIAL. HEXAGONAL. COMPOSITION: SiO_{2}. _■_ = c.

■Usual Appearance in Sections:■ Allotriomorphic in the granitoid rocks, when apparently the last mineral to form, Fig. 5. More or less chemically corroded pyramidal crystals (with cross-sections six-sided or rhombic with an angle of about 100°) in the porphyritic rocks. Rounded or angular grains in the "clastic" rocks; granular mosaic in crystalline schists and contact rocks, very rarely in distinct crystals in any rocks. May at times be mutually interpenetrated with an acid feldspar (the areas of quartz and feldspar extinguishing as entire crystals), producing "micro-pegmatitic" structure, Fig. 67. Finally may appear as pseudomorphs after other minerals, but may then consist of some of the other forms of silica.

Color.—Colorless, although by reflected light it may appear colored or cloudy if it contain many inclusions.

Index of Refraction.—_n′_ = 1.547 ($\alpha = 1.544$, $\gamma = 1.553$) hence no _relief_ and surface smooth.

Cleavage..—Rarely noticed, an important fact in determining quartz. Quartz breaks irregularly.

Inclusions.—Minute fluid, gas and mineral inclusions, often in irregular trains, are very characteristic of quartz in granite rocks and crystalline schists. The inclusions are not so abundant in porphyritic rocks, but a few glass inclusions may occur, filling up "negative" crystals in the quartz. Rutile, amphibole, etc., may occur as needle-like inclusions in quartz.

Polarized Light:

Pleochroism.—None.

■Crossed Nicols:■

Double Refraction.—Weak ($\gamma - \alpha = 0.009$).

Interference Colors.—The middle 1st order, white, yellow, etc.

Extinction.—As quartz is uniaxial, basal sections remain dark during a complete rotation of stage. In the other sections extinction is not characteristic, due to the absence of cleavage and crystallographic outlines. Thin sections do not show circular polarization.

■Convergent Light:■ Basal sections show a dark cross, without any rings. Optical character (+).

■Alteration:■ Does not take place, so quartz always appears fresh and unweathered in sections.

■Distinguished from:■

(_a_) SANIDINE (in fresh grains).—By use of convergent light. Feldspar is biaxial, or sections which appear uniaxial are (–).

(_b_) NEPHELITE.—By almost entire absence of hexagonal outline, stronger double refraction, fresh, unweathered appearance and (+) optical character.

(_c_) IOLITE (Cordierite), SCAPOLITE and TOPAZ.—See under the latter minerals.

Quartz may be distinguished from all silicates by being dissolved without residue in hydrofluoric acid.

REMARKS: Quartz occurs widely distributed, as in the great sandstone formations. It is also a characteristic mineral of all acidic rocks, being common in granite, aplite, rhyolite, quartz-porphyry, quartz-diorite, dacite, etc. Quartz is very brittle and hence is a good indicator of the dynamic forces which have affected the rocks. It may show traces of mechanical deformation by peripheral shattering of the larger grains or by "wavy extinction";[85] and also evidences of chemical corrosion by curved and looped contours. In some diabases the quartz may be surrounded by a rim of hornblende or augite needles ("quartz augen"). "Cataclastic" quartz may be biaxial. The "secondary enlargement" of quartz in clastic rocks may be noticed by the deposition of silica in crystallographic orientation around the clastic grains,[86] the new portion extinguishing at the same time as the core. Quartz is not attacked by ordinary acids. H., 7. Sp. gr., 2.6 to 2.7.

Chalcedony.—This variety of SiO_{2} has a radially fibrous structure and shelly parting. It may form sphærulites, central sections through which show a dark cross between crossed nicols, or line cavities in rocks.

The index of refraction is a little lower than for ordinary quartz. The optical character is (–), which must be determined by a mica or gypsum plate, _■_ = a. Elongation ■ a′.

Chalcedony occurs in the ground mass of very silicious porphyritic rocks, which have microfelsitic development; and is found as a secondary mineral in all kinds of silicate rocks.

TRIDYMITE.

■Usual Appearance in Sections■: This form of SiO_{2}, which is soluble in boiling caustic soda, appears in "tile-like" aggregates of minute colorless plates (pseudo-hexagonal) and is always secondary. The refractive index is extremely low (_n′_ = 1.477), hence the surface appears rough.

Between _crossed nicols_ the interference colors are very low in order (γ-α = 0.002), and the tablets may show a division into different areas (optical anomalies). In _convergent light_ an indistinct biaxial figure is generally seen.

REMARKS: Chiefly a volcanic mineral, found in rhyolite, trachyte and andesite. Commonly associated with opal and chalcedony.

CALCITE.

ANISOTROPIC. UNIAXIAL. HEXAGONAL.

COMPOSITION: CaCO_{3}. Ca may be replaced by small quantities of Mg, Fe, Mn, etc. _■_ = a.

■Usual Appearance in Sections:■ Grains and aggregates. May be fibrous or oölitic. Only in crystals in certain rocks.[87]

[Illustration:

FIG. 40.—Calcite, crossed twin lamellæ, in granular limestone. (From Cohen.)]

Twinning.—Polysynthetic, parallel to one or more faces of –½ R. (10■12). Very common in crystalline limestones, and may have been produced by pressure or by the grinding of the section. Shows itself between crossed nicols as a series of light and dark bands, parallel or intersecting, Fig. 40, about parallel to longer diagonal of cleavage rhombs. When the composition face of the twins is oblique to the face of the section, interference colors can be seen without the analyzer.

Color.—Colorless when pure, but may appear colored by transmitted light, due to organic pigments.

Index of Refraction.—_n′_ = 1.601 (α = 1.487, γ = 1.659) hence with ordinary light _relief_ not marked. Due to the great variation in refractive indices of the two rays, with polarized light, the surface will appear either quite smooth or rather rough, depending upon which vibration direction lies over the plane of the polarizer. This marked variation in appearance (sometimes called "twinkling") serves as a good test for calcite.

[Illustration:

FIG. 41.—Calcite, section parallel to face of rhombohedron, showing rhombohedral cleavage. (From Cohen.)]

Cleavage.—Parallel to unit rhombohedron (10■11), appearing in thin sections as many sharp cracks, whose angles of intersection depend on the position of the section, Fig. 41. Newton's colors may be seen along cleavage cracks.

■Polarized Light:■

Pleochroism.—None.

■Crossed Nicols:■

Double Refraction.—Very strong ($\gamma - \alpha = 0.172$).

Interference Colors.—Pale, iridescent colors of very high order.

Extinction.—As calcite is uniaxial, basal sections remain dark during rotation. Extinction angles with respect to the cleavage cracks vary with the position of the section.

■Convergent Light:■ Basal sections, even when very thin, show distinct interference figure, with cross and rings. Optical character (–).

■Distinguished from■:

(_a_) Other CARBONATES.—By ease with which it is attacked by cold dilute acids, test can be made on slide after removing cover.

(_b_) MAGNESIUM-BEARING CALCITE.—By micro-chemical tests.

(_c_) TITANITE (Sphene).—See under the latter.

REMARKS: Calcite is very widely distributed, in addition to the extensive sedimentary limestone deposits. Common limestone consists of dense aggregates of crystalline grains. Calcite is often a secondary product of the lime-bearing silicates in the more basic eruptive rocks. Pseudomorphs of calcite after olivine are noteworthy. Coarse aggregates of calcite occur in the crystalline schists and contact rocks. Calcite is exceedingly plastic to pressure and mechanical deformation may be recognized by curving of the cleavage cracks, crumpling of the twin lamellæ and "wavy" extinction. Calcite is easily attacked and completely dissolved with effervescence by cold dilute acids. H., 3. Sp. gr., 2.72.

DOLOMITE.

ANISOTROPIC. UNIAXIAL. HEXAGONAL.

COMPOSITION: $CaMg(CO_{3})_{2}$, when pure CaO = 30.4, MgO = 21.7, CO_{2} = 47.8. Proportions of Mg and Ca vary, and Fe and Mn also occur. _■_ = α.

■Usual Appearance in Sections:■ In rocks chiefly as crystals, even dense homogeneous aggregates showing tendency towards crystalline boundaries (saccharoidal structure). Crystals almost always unit rhombohedron (10■11) with tendency to curved surfaces.

Index of Refraction.—_n′_ = 1.622 (α = 1.503, γ = 1.682, $\gamma - \alpha$ = 0.179), a little higher than that of calcite. For variation in appearance of surface with polarized light, see under calcite.

The microscopic characters are similar to those of calcite, from which it may be _distinguished_ by not being so easily attacked by cold dilute acid (test can be made on slide with cover off), by tendency towards crystalline boundaries, by absence of twin lamellæ (or when present parallel to _–2R._ (20■21), hence about parallel to shorter diagonals of cleavage rhombs), and by micro-chemical tests. The distinction at times may be very difficult.

REMARKS: Occurs in sedimentary formations and as crystals in limestone and other rocks. In certain rocks the dolomite crystals may not have a very good "bond," and a "drusy" structure may also be characteristic of the cavities between dolomite crystals in rocks. Only slightly attacked by cold dilute acids, but if acid is heated it dissolves easily with effervescence.

APATITE.

ANISOTROPIC. UNIAXIAL. HEXAGONAL. COMPOSITION: _■_ = a. ELONGATION ■ a′. $Ca_{5}(Cl.F)(PO_{4})_{3}$.

■Usual Appearance in Sections■: Minute, slender hexagonal prisms, cross-sections having regular hexagonal boundaries, needles, and grains. Figs. 14 _a_ and 42.

[Illustration:

FIG. 42.—Apatite, showing cross fracture, in nepheline-basalt. (From Cohen.)]

Color.—Generally colorless, seldom bluish or brownish (only in eruptive rocks).

Index of Refraction.—_n′_ = 1.635 (α = 1.634, γ = 1.637), hence _relief_ more marked than that of the colorless associated minerals.

Cleavage.—Seldom observed microscopically.

Parting.—Long columnar crystals generally show a transverse jointing, so that the pieces may be more or less separated.

Inclusions.—Gas and fluid may be present.

■Polarized Light■:

Pleochroism.—None shown by the colorless crystals, the colored crystals show stronger absorption parallel to _■_.

■Crossed Nicols■:

Double Refraction.—Weak ($\gamma - \alpha$ = 0.003).

Interference Colors.—The lower first order, generally grayish-blue or white.

Extinction.—As apatite is uniaxial, basal sections remain dark during rotation of stage. In all other sections extinction is parallel to _■_ axis.

■_Convergent light_■: Basal sections show a cross, without rings. Optical character (–).

■Alteration■: Does not usually take place, apatite being found perfectly fresh in decomposed rocks, which is quite remarkable considering its easy solubility in acids.

■Distinguished from■:

(_a_) SILLIMANITE and TREMOLITE.—By weak double refraction and elongation ■ a′.

(_b_) NEPHELITE.—By being relatively much smaller and longer than the nephelite crystals, which are often decomposed. Also by higher relief and negative results with gelatinization test.

(_c_) ZIRCON.—By lower relief and much weaker double refraction.

(_d_) FELDSPARS (when granular and undecomposed).—By higher relief and uniaxial interference figure.

(_e_) VESUVIANITE and ZOISITE.—May be only possible by chemical tests.

(_f_) CORUNDUM.—See under the latter.

REMARKS: Found in most igneous rocks and crystalline schists. In the eruptive rocks it appears as one of the oldest secretions from the magma, and hence is often found as inclusions in other minerals, especially biotite, hornblende, etc. Apatite is easily soluble in hydrochloric and nitric acids. H., 4.5 to 5. Sp. gr., 3.19. On account of its high sp. gr., apatite, in rock powder, comes down in heavy solutions with the metallic minerals, and can be separated from them by the use of a magnet. This residue can also be tested for phosphorus in the wet way with ammonium molybdate.

NEPHELITE,[88] Nepheline, Elæolite.

ANISOTROPIC. UNIAXIAL. HEXAGONAL. COMPOSITION: 7NaAlSiO_{4} + _■_ = α. NaAl(SiO_{3})_{2}, with partial replacement of Na by K.

■Usual Appearance in Sections■: Nephelite in short hexagonal prisms and grains in the younger volcanic rocks, hence sections rectangular or hexagonal, Fig. 43; elæolite allotriomorphic in the older plutonic rocks.

Color.—Colorless.

Index of Refraction.—_n′_ = 1.539 (α = 1.538, γ = 1.542), hence no relief and surface smooth.

Cleavage.—Imperfect, parallel to prism (10■10) and base (0001). More marked in elæolite than in nephelite, especially when decomposition has commenced.

[Illustration:

FIG. 43.—Nephelite sections, showing zonal inclusions. (From Reinisch.)]

Inclusions.—Microscopic needles of augite, etc., also fluid and gas. Mostly in zones. Elæolite may be much clouded by inclusions and alteration products.

■Polarized Light■:

Pleochroism.—None.

■Crossed Nicols■:

Double Refraction.—Very weak (γ – α = 0.004), may only be detected by using a test-plate.

Interference Colors.—The lower first order, grayish-white, etc., a little lower than the feldspar colors.

Extinction.—As the mineral is uniaxial, basal sections remain dark during rotation of stage. In all other sections extinction takes place and is parallel to cleavage lines when these appear.

■Convergent Light■: Basal sections show a broad cross, without rings. Optical character (–).

■Alteration■: Takes place easily to fibrous zeolites (natrolite), or in certain rocks to mica.

■Distinguished from■: OTHER MINERALS by gelatinization test and staining with fuchsine. When present in small interstitial individuals (as is often the case in basalts) it is very difficult to distinguish without this test; but it must be remembered that other minerals, zeolites, etc., will also gelatinize. QUARTZ has stronger double refraction, rarely shows hexagonal outline, is always fresh and optically (+). FELDSPAR is biaxial and often shows twinning. ANALCITE.—See under the latter.

REMARKS: Nephelite bears the same relation to elæolite as sanidine does to orthoclase. It occurs only in the younger volcanic rocks; with sanidine in phonolite, with plagioclase in tephrite, without feldspar in nepheline-basalt, and with leucite in leucite-basalt. It is not found with primary quartz. Elæolite occurs with orthoclase in elæolite-syenite, etc. nephelite and elæolite frequently occur with the sodalite group. Nephelite gelatinizes with acids. H., 5.5 to 6. Sp. gr., 2.5 to 2.6.

TOURMALINE, Schorl.

ANISOTROPIC. UNIAXIAL. HEXAGONAL. COMPOSITION: Uncertain, _■_ = a. ELONGATION ■ a′. R_{18}B_{2}(SiO_{5})_{4}. R chiefly Al, K, Mn, Ca, Mg, Li.

■Usual Appearance in Sections■: Staff-like individuals, bunched or in radiating aggregates, Fig. 44 B, or prismatic crystals, Fig. 44 A. Basal sections may be nine-sided.

Color.—Varies greatly, grayish-blue, brown and green most common. Li-tourmaline (rare in rocks) is colorless. Zonal structure may be indicated by differences in color.

[Illustration:

FIG. 44.—_A_, Tourmaline, showing strong absorption at right angles to direction of elongation (_P_ = plane of vibration of polarizer). _Quartzite_, Black Hills, D. _B_, Tourmaline in radiate aggregate. _Granite_, Cornwall.]

Index of Refraction.—_n′_ = 1.633 (precious) to 1.674 (α = 1.620 to 1.651, γ = 1.640 to 1.685), hence _relief_ is marked and surface rough.

Cleavage.—Not seen in thin sections, but irregular, transverse and longitudinal cracks may appear.

■Polarized Light■:

Pleochroism.—Distinct, even in light colored varieties, increasing with the depth of color. The greatest absorption takes place at right angles to the direction of elongation of the crystal, Fig. 44 A. The other minerals having this very strong absorption are hornblende, dark colored mica (distinguished by cleavage and lamellar form) and allanite. Pleochroic halos may be noticed surrounding inclusions.

■_Crossed Nicols_■:

Double Refraction.—Quite strong ($\gamma - \alpha$ = 0.017 (precious) to 0.034).

Interference Colors.—Bright upper first or second order, but may not be noticeable, due to absorption of parts of the light.

Extinction.—As tourmaline is uniaxial, basal sections remain dark during rotation of stage. In all other sections extinction is parallel to _■_ axis.

■_Convergent Light_■: Cross-sections show a sharp cross. Optical character (–).

■Alteration■: Does not take place.

■Distinguished from■:

(_a_) HORNBLENDE.—By absence of cleavage, and by the fact that the greatest absorption takes place at right angles to the longitudinal axis, while in hornblende it takes place approximately parallel to the longitudinal axis, or to the cleavage lines which are parallel to this axis.

(_b_) APATITE (when colored).—By strong absorption at right angles to longitudinal axis.

(_c_) CORUNDUM.—See under the latter.

In some cases where recognition is difficult, chemical tests, to prove presence of boracic acid, must be made.

REMARKS: The black schorl is the only primary tourmaline and is found in granitoid rocks. Tourmaline in other rocks results from "fumarole" action; hence occurs in pegmatite, tin and copper veins, clay deposits, also (light colored) in contact rocks and crystalline schists. The hemimorphic terminations may sometimes be noticed. Tourmaline is not acted on by acids. H., 7 to 7.5. Sp. gr., 3 to 3.2. It can be separated from powdered rock by sp. gr. solutions combined with magnetic methods.

ANDALUSITE

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: Al_2SiO_5. _■_ = a. ELONGATION ■ a′.

■Usual Appearance in Sections■: In short, rounded, prismatic crystals, with almost square cross-section. Colorless or at times pale reddish and spotted. Index of refraction medium (_n′_ = 1.637, α = 1.632, γ = 1.643), hence _relief_ well marked and surface rough. Cleavage, parallel to almost square prism, may show. Pleochroism only marked in colored varieties, being reddish ■ _■_ (the direction of elongation or cleavage). Carbonaceous inclusions are characteristic, arranged as in macroscopic specimens (_Chiastolite_), Fig. 45. Pleochroic halos may surround inclusions.

■Crossed Nicols■: Double refraction weak ($\gamma - \alpha$ = 0.001). Interference colors middle 1st order, white to yellow. _Extinction_ in general parallel to _■_ axis in longitudinal sections, symmetrical in cross-sections. In _convergent light_ Ax. pl. ■ (010), Bx_{_a0_}. ■ _■_; axial angle very large (2_E_ > 180°); optical character (–).

■Alteration■: Often takes place to dense aggregate of mica, when the pseudomorph may be hard to recognize.

■Distinguished from■:

(_a_) SILLIMANITE by much weaker double refraction, less elongated crystals and by elongation ■ a′ (Sillimanite elong. ■ c′).

(_b_) DIOPSIDE by weaker double refraction, rhombic cross-section and parallel extinction in longitudinal sections.

REMARKS: Very characteristic of metamorphic schists and of contact zones of clay slates with granite, etc., but not found in rocks which have been formed at great pressure. The andalusite grains may often be arranged in divergent or finger-like manner. May also form parallel growths with sillimanite. It is insoluble in hydrochloric acid. H., 7 to 7.5. Sp. gr., 3.18.

[Illustration:

FIG. 45.—Chiastolite, showing characteristic carbonaceous inclusions. (From Cohen.)]

[Illustration:

FIG. 46.—Sillimanite aggregate, showing cross fracture, in mica schist. (From Cohen.)]

SILLIMANITE, Fibrolite.

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: Al_2SiO_5. _c_ = c′. ELONGATION ■ c′.

■Usual Appearance in Sections■: Long, slender, colorless prisms or needles; often in felt-like aggregates. Crystals often bent. Index of refraction rather high (_n′_ = 1.664, $\alpha = 1.656$, $\gamma = 1.677$), hence _relief_ marked. Transverse fractures common, Fig. 46.

■Crossed Nicols■: Double refraction rather strong ($\gamma - \alpha = 0.021$). Interference colors upper first or lower second order, red, purple, blue, etc. _Extinction_ parallel to prisms. Ax. pl. ■ (100), Bx_{_a_}. ■ _■_, 2_E_ = 35° to 55°. Optical character (+).

■Distinguished from■:

(_a_) APATITE by higher order interference colors and by elongation ■ c′ (apatite has elongation ■ a′).

(_b_) TREMOLITE by always parallel extinction and small size of axial angle.

(_c_) ANDALUSITE, see under the latter mineral.

REMARKS: Found especially in clay-rich contact rocks, gneisses and schists, often occurring with iolite (cordierite). Crystals may appear in bands. It is insoluble in hydrochloric acid. H., 6 to 7. Sp. gr., 3.24.

TOPAZ.

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: _■_ = c. $Al(Al(O,F_2))SiO_4$.

■Usual Appearance in Sections■: Colorless crystals of short prismatic habit, grains or rod-like radiating aggregates. Index of refraction about the same as that of calcite (_n′_ = 1.608 to 1.632, $\alpha = 1.607$ to 1.629, $\gamma = 1.618$ to 1.637), hence _relief_ medium. Cleavage perfect, parallel to base, but does not show as many cracks. Fluid inclusions abundant.

■Crossed Nicols■: Double refraction weak ($\gamma - \alpha = 0.008$ to 0.011), about the same as that of quartz. Interference colors middle first order, white, yellow, etc. _Extinction_ parallel to cleavage. In _convergent light_, Ax. pl. ■ (010), Bx_{_a_}. ■ _■_, axial angle large (2_E_ = 86° to 126°); interference figure obtained from basal sections (_i. e._, from sections showing no cleavage); optical character (+).

■Alteration■: May take place to kaolin or muscovite, by loss of F and taking up of H_2O and alkalies.

■Distinguished from■:

(_a_) QUARTZ by higher relief, cleavage and biaxial character.

(_b_) SILLIMANITE (when topaz is in radiating aggregates) by lower refraction and double refraction.

REMARKS: Common in greisen and all granite rocks containing tin ore. When formed by "fumarole" action (tin veins) the mineral shows rod-like radiating forms. It is insoluble in hydrochloric acid. H., 8. Sp. gr., 3.5.

STAUROLITE.

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: ELONGATION ■ ■. $Fe(AlO)_{4}(AlOH)(SiO_{4})_{2}$, but varying, may contain Mg or Mn. _■_ = c.

[Illustration:

FIG. 47.—Staurolite, showing twinning at 90° _b_ and 60° _c_, also granular quartz inclusions. (From Reinisch.)]

■Usual Appearance in Sections■: Short, flat prisms, which may be twinned at 90° or 60°, Fig. 47, or grains. Color yellowish to reddish-brown. Index of refraction rather high (_n′_ = 1.741, α = 1.736, γ = 1.746), hence _relief_ marked and surface rough. Cleavage, both prismatic and pinacoidal, variable. Inclusions of minute quartz grains and carbonaceous matter found in larger crystals, but not in microscopic crystals. Pleochroism distinct but not strong, showing red ■ _c_ (direction of elongation). Pleochroic halos may surround inclusions.

■Crossed Nicols■: Double refraction weak ($\gamma - \alpha = 0.010$). Interference colors middle first order, white to yellow, etc. (about like quartz). _Extinction_ in general parallel or symmetrical (in cross-sections) to cleavages or crystal outline. In _convergent light_, Ax. pl. ■ (100), Fig. 48. Bx_{_a_}. ■_■_, axial angle large (2_E_ > 180°); optical character (+).

[Illustration:

FIG. 48.—Staurolite, cross-section.]

■Alteration■: Rarely takes place.

■Distinguished from■: TITANITE, see under the latter mineral.

REMARKS: Found in metamorphic schists, associated with cyanite (disthene), iolite (cordierite), andalusite, etc. It is one of the minerals produced by thermal metamorphism, hence found in rocks of granite contact zones. It does not occur in the eruptive rocks or in schists rich in amphibole. Staurolite is not acted on by hydrochloric acid. H., 7 to 7.5. Sp. gr., 3.4 to 3.8.

THE ORTHORHOMBIC PYROXENES. Enstatite and Hypersthene.

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: $(Mg.Fe)SiO_{3}$. _■_ = c. ELONGATION ■ c′.

Enstatite contains little, if any, Fe. Hypersthene contains more Fe, its optical characters beginning to show with about 10 per cent.

[Illustration:

FIG. 49.—Enstatite, showing columnar or fibrous structure ■ _■_ axis. _Norite_, Harzburg.]

■Usual Appearance in Sections■: Irregularly bounded individuals (E) or rounded prismatic-pyramidal crystals (H). Columnar or fibrous structure ■ _■_ often shows in (E), Fig. 49. Prism angle about 92°. Outline of crystal sections very similar to that of monoclinic pyroxenes.

Twinning.—Not so common as in monoclinic pyroxenes. Parallel growths with monoclinic pyroxene (diallage) occur.[89]

Color.—Varies with Fe per cent., (E) colorless, (H) brownish.

Index of refraction.—_n′_ = 1.665 (E) to 1.723 (H) (α = 1.660 to 1.716, γ = 1.670 to 1.729) (about the same as in monoclinic pyroxene), hence _relief_ marked and surface rough.

Cleavage.—Variable, parallel to prism (angle 92°) common to all pyroxenes. Also cleavage or parting parallel to brachy pinacoid (010) (prominent) and macro pinacoid (100).[89]

Inclusions.—Parallel oriented, brownish plates and rods, producing "schiller" structure on the principal cleavage faces, Fig. 15. Glass inclusions abundant in (H).

■Polarized Light■:

Pleochroism.—Almost absent in (E), but distinct in (H), increasing with Fe per cent. The change in color may be very marked, from brownish-red to greenish ■ _■_.

■Crossed Nicols■:

Double Refraction.—Weak, much weaker than in the monoclinic pyroxenes, increasing with Fe per cent. ($\gamma - \alpha = 0.010$ (E) to 0.013 (H).)

Interference Colors.—Higher first order, about the same or a little higher than quartz.

Extinction.—Parallel to cleavages in longitudinal sections, which are parallel to _a_ or _b_, and bisecting angles of intersecting prismatic cleavages in basal sections.

■Convergent Light■: Axial plane parallel to brachy pinacoid (010),[89] _i. e._, parallel to best pinacoidal cleavage. Bx_{_a_}. ■ _■_ (E), ■ _a_(H). Axial angles large (2_E_ = 95° to > 180°). Optical character for (_E_)(+), for (_H_)(–). On account of weak double refraction the interference figures are not very marked.

■Alteration■: Takes place to bastite, serpentine, etc.

■Distinguished from■: The MONOCLINIC PYROXENES and AMPHIBOLES.—See under these species.

REMARKS: Found in the granular rocks of the gabbro-peridotite series, also in the olivine basalts (E); and in crystals in porphyritic andesite (H). These minerals are in general not attacked by acids. H., 5 to 6. Sp. gr., 3.1 to 3.5.

Bronzite is the name give to the variety containing about 5% Fe and having the characteristic bronzy lustre due to inclusions.

Bastite (an alteration product of the orthorhombic pyroxenes poor in Fe).—Composed of fibers, often traversed by irregular cracks. Color light yellowish or greenish and index of refraction about the same as Canada balsam. Pleochroism faint (only seen in thick sections), the greatest absorption taking place parallel to the fibers. Double refraction weak and extinction parallel to the fibers. Axial angle large and axial plane at right angles to principal cleavage face (010). The position of the axial plane is the surest distinction between bastite and the orthorhombic pyroxenes.

CHRYSOLITE, Olivine.

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: (Mg.Fe)_{2}SiO_{4}. ELONGATION ■ a′ or c′.

■Usual Appearance in Sections■: Prismatic crystals or in large angular fragments or grains. Longitudinal sections more or less lath-shaped, with pointed ends, Figs. 50 and 51, cross-sections six or eight-sided. Outlines of crystals often rounded or corroded. Skeleton forms may occur, and sometimes twinning may be observed.

[Illustration:

Chrysolite.

FIG. 50. FIG. 51. Basal section. Macro pinacoid section.]

Color.—Nearly colorless, may be reddish (with high Fe per cent.).

Index of Refraction.—_n′_ = 1.675 ($\alpha = 1.661$, $\gamma = 1.697$), hence _relief_ marked and surface rough.

Cleavage.—Parallel to brachy pinacoid (010), less distinct parallel to macro pinacoid (100), Fig. 50. Often only made visible by decomposition. An irregular fracturing occurs, which increases with alteration into serpentine.

Inclusions.—Chromite, opaque earths, apatite and the brown plates so common in hypersthene; also glass and slag (in basaltic rocks) and fluid (in peridotites and olivinfels).

■Polarized Light■:

Pleochroism.—In general none, but noticed in the reddish varieties, when the absorption is a little stronger parallel to _■_.

■_Crossed Nicols_■:

Double Refraction.—Very strong ($\gamma - \alpha = 0.036$).

Interference Colors.—Rather high in order (second or third), higher than the colors of augite.

Extinction.—In general parallel to cleavage lines.

■Convergent Light■: Axial plane parallel to base (001) and always at right angles to cleavage cracks, Fig. 51. Bx_{_a_}. ■ _a_. Axial angle very large (2_E_ > 180°). Optical character (+).

■Alteration■: Into serpentine very common,[90] producing "mesh-" or "lattice-" structure (see under serpentine, p. 114); also into amphibole, etc. In certain basaltic rocks the rims of grains may be changed into gœthite?, and in certain gabbros the crystals may be surrounded by a radial rim of amphibole.

■Distinguished from■:

Light colored MONOCLINIC PYROXENES.— By the absence of extinction angles, cleavage (the intersecting prismatic cleavages of augite being of equal distinctness), stronger double refraction and by axial plane being parallel to base, hence always at right angles to best cleavage (in augite axial plane lies in clino pinacoid, bisecting angles of intersecting prismatic cleavages). Also by gelatinization with acids.

REMARKS: Found only in basic rocks, as peridotite, diabase, gabbro, norite, basalts, etc. Chrysolite (olivine) is a very brittle mineral and shows under mountain making pressure "cataclastic" structure. Chromite is a characteristic associated mineral. When not too poor in Fe, chrysolite becomes permanently red and pleochroic when strongly heated. Chrysolite is decomposed by hydrochloric and sulphuric acids, with separation of gelatinous silica. H., 6.5 to 7. Sp. gr., 3.3 to 3.4.

Hyalosiderite (a more ferruginous chrysolite) and _Fayalite_ ($Fe_{2}SiO_{4}$) may be reddish in sections, and common in the basic porphyritic eruptive rocks.

IOLITE, Cordierite, Dichroite.

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: _■_ = a. ELONGATION ■ a′. $Mg_{3}(Al.Fe)_{6}Si_{8}O_{28}$.

■Usual Appearance in Sections■: Grains, more rarely crystals of short prismatic habit, which often form pseudo-hexagonal interpenetration twins. Crystals may have edges rounded or corroded. Colorless, but may be bluish. Index of refraction a little lower than quartz (_n′_ = 1.539, $\alpha = 1.535$, $\gamma = 1.544$), hence _relief_ low and surface smooth. Cleavage very variable, parallel to brachy pinacoid (010), especially noticeable when decomposition has taken place. Inclusions of sillimanite, zircon, rutile, etc., may be seen. Pleochroism usually not observed, but noticed in blue sections (yellowish white ■ _■_ to blue). Pleochroic halos (yellow) surrounding inclusions common, see p. 59.

■Crossed Nicols■: Double refraction weak ($\gamma - \alpha = 0.009$), like quartz. Interference colors middle first order, white to yellow. _Extinction_ in general parallel to cleavage cracks. In _convergent light_, Ax. pl. ■ (100), Bx_{_a_}. ■ _■_; axial angle large (hyperbolas only seen without ellipses) (2_E_ = 64° to 150°); optical character (–).

■Alteration■: Takes place readily, forming greenish mica-like decomposition products, the decomposition commencing along the crevices or about the inclusions.

■Distinguished from■: QUARTZ by observation in convergent light (quartz is uniaxial), decomposition and pleochroism or pleochroic halos. The section can also be treated with hydrofluosilicic acid, when the evaporated solution yields characteristic prismatic crystals of magnesium fluosilicate.

REMARKS: Found in gneiss, hornstone, granite, granulite, etc., and in some volcanic rocks. It is often associated with garnet, biotite, sillimanite, etc. In a thick section heating to redness makes the pleochroism more distinct. Iolite is only slightly acted on by acids. H., 7 to 7.5. Sp. gr., 2.6. It is hard to make a mechanical separation from quartz, on account of similarity in sp. gr.

NATROLITE.

ANISOTROPIC. BIAXIAL. ORTHORHOMBIC. COMPOSITION: _■_ = c. ELONGATION ■ c′. $Na_{2}Al_{2}Si_{2}O_{10} + 2H_{2}O$.

■Usual Appearance in Sections■: Aggregates of colorless, fibrous crystals, which may have sphærulitic structure, showing a dark cross between crossed nicols. Index of refraction lower than balsam (_n′_ = 1.483, $\alpha = 1.478$, $\gamma = 1.490$), hence (in large crystals) the surface would appear rather rough.

■Crossed Nicols■: Double refraction weak ($\gamma - \alpha = 0.012$). Interference colors the middle first order (yellow, etc.), a little higher than those of quartz. _Extinction_ parallel to fibres. Optical character (+).

REMARKS: Never a primary mineral in rocks, but found in igneous rocks filling amygdaloidal cavities, and also as a very common alteration product of sodalite, noselite, nephelite and acid plagioclases. It gelatinizes easily with hydrochloric acid. H., 5 to 5.5. Sp. gr., 2.2.

OTHER ZEOLITES.

COMPOSITION: Hydrous silicates; Al, Ca and Na being the chief bases.

■Usual Appearance in Sections■: The form depends on the individual mineral species, but the majority appear in elongated crystals or fibers. They are all colorless and most of them have a small index of refraction, hence no _relief_ (prehnite has distinct relief).

■Crossed Nicols■: The double refraction is generally very weak (between that of nephelite and quartz), giving very low order interference colors (prehnite and thomsonite have strong double refraction).

REMARKS: The zeolites are always secondary minerals in rocks. They gelatinize with hydrochloric acid.

GYPSUM.

ANISOTROPIC. BIAXIAL. MONOCLINIC. COMPOSITION: $CaSO_{4} + 2H_{2}O$.

■Usual Appearance in Sections■: Colorless grains or fibers. May be colored, however, by inclusions of carbonaceous matter, iron oxides, etc. Index of refraction about the same as orthoclase (_n′_ = 1.525, $\alpha = 1.521$, $\gamma = 1.531$), hence no _relief_ and surface smooth. Twinning lamellæ abundant. Cleavage parallel to (010) gives abundant cracks, other cleavages may also be noticed.

■Crossed Nicols■: Double refraction weak ($\gamma - \alpha = 0.010$), the same as quartz. Interference colors middle first order, white to yellow. _Extinction_ parallel to most perfect cleavage cracks in sections parallel to _b_ axis; large extinction angles noticed with reference to less perfect cleavages. In _convergent light_, Ax. pl. ■ (010), _i.e._, ■ to most distinct cleavages; Bx_{a}. (c) $\Lambda = 54°$ front; $2E = 104°$; optical character (+). As the characters of gypsum are not always very marked it may be necessary to employ micro-chemical tests.

REMARKS: Forms a rock by itself, often associated with rock salt. It also occurs as an alteration product of anhydrite. Gypsum is soluble in hydrochloric acid. H., 1.5 to 2. Sp. gr., 2.2 to 2.4.

MONOCLINIC PYROXENES, Augite, etc.

Including the monoclinic minerals of the Pyroxene Group, which show distinctly the characteristic cleavage parallel to an almost right-angled prism.

ANISOTROPIC. BIAXIAL. MONOCLINIC. ELONGATION ■ c′.[91]

COMPOSITION: $RSiO_{3}$, R = Ca, Mg, Mn, Fe, Al chiefly, with the Ca predominating over the Mg.

■Usual Appearance in Sections■: Both in crystals and more or less irregular grains, Figs. 4 and 12, the habit varying with the chemical composition as follows:

Diopside (Ca, Mg varieties), long columnar crystals and grains.

Augite (ditto, but containing also Al and Fe), short prismatic crystals and grains.

Diallage, granular or lamellar (|| (100)), may show fibrous structure ■ _■_.

Prism angle = 87° 06′ (important in cross-sections). Sections of crystals nearly at right angles to the vertical axis _■_ are octagonal or square with truncated corners, Figs. 4 and 53, while those parallel to the _■_ axis are lath-shaped. Pyroxene also occurs in skeleton crystals and acicular microlites in eruptive rocks.

[Illustration:

FIG. 52.—Augite, section parallel to _■_ axis showing prismatic cleavage, in leucite-basal. (From Cohen.)]

Zonal structure (especially in augites) may be marked by differences in color or extinction, and in some basalts the crystals have the "hour-glass" structure.

Twinning.—Common, usually the twinning plane being the ortho pinacoid (100). Twin lamellæ may be noticed. Intergrowths occur with orthorhombic pyroxene and amphibole.

Color.—From almost colorless through green (diopsides, Na pyroxenes, etc.) to brown (augites); the red to brownish-red color of certain augites has been considered due to manganese. Yellow color very rare.

Index of Refraction.—_n′_ = 1.68 to 1.72 (α = 1.671 to 1.706, γ = 1.700 to 1.728), hence _relief_ high and surface rough.

Cleavage.—More or less perfect parallel to prism of 87° 06′. Cleavage cracks distinct and numerous, but not generally running uninterruptedly through crystal, Figs. 12 and 52. Cleavage not so perfect as that of amphibole.

Parting.—Diallage and diopside have distinct parting parallel to ortho pinacoid (100), Fig. 53. Some crystals may show parting parallel to base (001).

Inclusions.—Tabular microscopic interpositions, similar to those in bronzite, may occur in diallage. The iron ores, apatite, etc., may occur in augite.

■Polarized Light■:

[Illustration:

FIG. 53.—Diallage, cross-section.]

Pleochroism.—Usually not noticed, and in general only appearing as different shades of the same color. In some cases (diallage, fassaite and Na rich augite) well marked, a and c green to yellowish green and b brownish to reddish-brown; hence pleochroism not intense in sections showing extinction angles. When Ti is present, violet parallel to _b_.

■_Crossed Nicols_■:

Double Refraction.—Strong ($\gamma - \alpha$ = 0.022 to 0.029), being stronger in the pale or colorless pyroxenes.

Interference Colors.—Second order, hence always bright tints.

Extinction.—Symmetrical in sections (through _b_ axis) showing intersecting cleavage lines, in such cases bisecting the angles of the cleavage. In sections showing parallel cleavage lines, only parallel in ortho pinacoid (100) sections, in all other sections an extinction angle being observed. The maximum extinction angle is large, lies in the obtuse angle, varies with the chemical composition from 36° 30′ to 54°, and is only obtained when the section of the crystal is parallel to the clino pinacoid (010), Fig. 54, varying from this angle to 0°, when the section is parallel to the ortho pinacoid (100). In Ti and Na pyroxenes the inclined dispersion is so great that extinctions are not sharp, but instead a change takes place in the interference color from bluish to brownish.

■_Convergent Light_■: Axial plane parallel to clino pinacoid (010). Fig. 54. A cleavage flake parallel to ortho pinacoid (100) shows the emergence of an optic axis (orthorhombic pyroxene parallel to best pinacoidal cleavage would not show figure). Bx_{_a_}.(c) Λ _■_ = 36° to 54° front. Axial angles large (2_E_ = 70° to 112°). Optical character (+). The interference figures are distinct on account of the strong double refraction.

■Alteration■: May take place to chlorite, serpentine or amphibole (uralitization[92]), depending on the chemical composition and the conditions producing the change.

[Illustration:

FIG. 54.—Diopside, clino pinacoid section.]

■Distinguished from■:

(_a_) ORTHORHOMBIC PYROXENES.—By extinction angle, the orthorhombic pyroxenes having always parallel or symmetrical extinction in sections parallel to _a_, _b_, or _c_, and by higher order interference colors. Also from hypersthene by absence of, or much fainter, pleochroism. Diallage and bronzite might be confused on account of pronounced pinacoidal parting, fibrous structure and inclusions; but may be distinguished by the presence or absence of extinction angles and also by the position of the optic axes relative to the best cleavage plates.

(_b_) AMPHIBOLE.—See under amphibole.

(_c_) EPIDOTE and CHRYSOLITE (Olivine). When light colored and granular, by examination in convergent light. The plane of the optic axes is parallel to the clino pinacoid (010), hence to the longitudinal axis and prismatic cleavage cracks, while in epidote it is at right angles to these directions and in chrysolite parallel to the base. Also yellow color is common in epidote but rare in pyroxene.

REMARKS: Next to the feldspars pryoxene is the most common constituent of the igneous rocks. Diopside and fassaite (green) are found in contact rocks; also, what appear to be the same pyroxenes, in many eruptive rocks, as andesites, monzonites, etc. Malacolite (light green) is found in amphibolites and eclogites, where it may be associated with a greenish amphibole (smaragdite). Diallage (bladed and twinned) occurs in gabbros and pyroxenites. Common augite (brown) is found in the remaining basic eruptive rocks. In the schists the pyroxene is colorless.

Finally augite occurs as a secondary product resulting from the “magmatic resorption” of hornblende and biotite.

Chemical corrosion and mechanical deformation may occur. The green and brown augites when heated to redness on platinum foil may become red in color. In general the pyroxenes are not attacked by acids. H., 5 to 6. Sp. gr., 3.3 to 3.5. The sp. gr. of the pyroxenes is considerably higher than that of the amphiboles of similar composition, hence mechanical separations are possible.

Acmite (_Ægirine_) (Na pyroxenes).—Occur in green or brown, elongated prismatic crystals, often not very transparent and with marked pleochroism (like amphibole). Zonal coloring is common. When zonally intergrown with pyroxene the outer zone is ægirine. The elongation is ■ a′ (distinction from amphibole whose elongation is ■ c′). The index of refraction is higher than in the other pyroxenes (_n′_ = 1.792, $\alpha = 1.763$, $\gamma = 1.813$) and the double refraction stronger ($\gamma - \alpha = 0.050$). The _extinction_ angle is small (5°) and the optical character (—).

The term _Ægirine-augite_ may be used to describe a soda, pleochroic augite with a large extinction angle.

These pyroxenes are only found in the eruptive rocks rich in alkalies, as elæolite-syenite, phonolite, certain trachytes, etc.; hence are associated with elæolite, sodalite, leucite, etc. The small, second generation, crystals, in the ground mass of a rock, are always the richest in Na of the pyroxenes in that rock.

AMPHIBOLE, Hornblende, etc.

ANISOTROPIC. BIAXIAL. MONOCLINIC. ELONGATION ■ c′.

COMPOSITION: $RSiO_3$. R = Mg, Ca, Fe chiefly also may contain Al, Na, Mn. The Mg predominates over the Ca.

[Illustration:

FIG. 55.—Hornblende, showing twinning between crossed nicols, in amphibole-biotite-granite. (From Cohen.)]

■Usual Appearance in Sections■: Both in crystals and more or less irregular grains, often fibrous, Figs. 55 and 56, the habit varying with the chemical composition as follows:

Tremolite (Mg_3Ca) and _Actinolite_ ($(MgFe)_3Ca$ varieties), in long columnar to needle-like individuals, with no terminal planes or with frayed out ends. May be in dense aggregates.

Pargasite in well developed crystals.

Common green Hornblende (aluminous varieties) in crystals, compact grains or shreds.

Basaltic Hornblende (iron rich, aluminous varieties) in prismatic crystals of varying length, which may often show "magmatic resorption" (to augite and magnetite) around outer zone or throughout whole crystal.

[Illustration:

FIG. 56.—Hornblende, section parallel to _■_ axis, showing prismatic cleavage, in hornblende-diorite. (From Cohen.)]

Crystals are simple in form of prismatic habit, with prism angle 124° 30′. Cross-sections are acutely rhombic, generally with acute angles truncated, hence six-sided (pyroxene being eight-sided). Longitudinal sections are lath-shaped and fibrous structure may be noticed. Skeleton crystals may also occur, being very fine in certain pitchstones.

Zonal structure and parallel growth may be noticed in the amphiboles.

Twinning.—Frequent, parallel to ortho pinacoid (100). Twins dual, less often multiple, Fig. 55. Intergrowths with pyroxene and biotite occur.

Color.—From colorless (tremolite), through green (actinolite, pargasite and hornblende) to brown (basaltic hornblende). Yellow in some varieties and bluish in the soda varieties.

Index of Refraction.—_n′_ = 1.621 to 1.641 (α = 1.607 to 1.629, γ = 1.634 to 1.653) (1.719, in the basaltic hornblende), hence _relief_ distinct and surface rough.

Cleavage.—Perfect, parallel to prism of 124° 30′. Generally appears in thin sections as sharp cracks crowded close together, Figs. 56 and 57. More perfect than in pyroxene.

Some of the long prisms (actinolite and tremolite) may show transverse parting.

Inclusions.—The iron ores, apatite, etc., may be found in hornblende.

[Illustration:

FIG. 57.—Hornblende, cross-section.]

■Polarized Light■:

Pleochroism.—All colored amphiboles show pleochroism, which in general is stronger the darker the color of the variety (actinolite and pargasite show but little). The absorption is very marked in the hornblendes, being greatest in the general direction of the cleavage lines in longitudinal sections. Marked differences in absorption are also characteristic of the mineral species biotite, tourmaline and allanite. Pleochroic halos (brownish) surrounding inclusions may be noticed.

■Crossed Nicols■:

Double Refraction.—Quite strong, but a little weaker than in pyroxene (γ-α = 0.019 to 0.027). Ferruginous basaltic hornblende has strong double refraction (γ-α = 0.072).

[Illustration:

FIG. 58.—Actinolite, clino pinacoid section.]

Interference Colors.—Second order, hence bright tints, but in darker colored varieties not so noticeable as in pyroxenes, due to the stronger absorption of parts of the light. The colors of basaltic hornblende are so high that they show no bright tints.

Extinction.—Always symmetrical in sections (through _b_ axis) showing intersecting cleavage lines, in such cases bisecting the angles of the cleavage. In sections showing parallel cleavage lines, only parallel in ortho pinacoid (100) sections, in all other sections an extinction angle being observed. The maximum extinction angle lies in the acute angle and is much smaller than in pyroxene, varying with the chemical composition from 0°–20°. In hornblende, actinolite and tremolite 12°–20°, Fig. 58; in the basaltic hornblende 0°–10°. The maximum extinction angle is only obtained when the section of the crystal is parallel to the clino pinacoid (010), varying from this angle to 0°, when the section is parallel to the ortho pinacoid (100).

■Convergent Light■: Axial plane parallel to clino pinacoid (110), Fig. 58. Bx_{_o·_}(c) Λ _■_ = 0°–20° behind. Axial angles large (2_E_ = 77° to >180°). Optical character (–). Pargasite is (+).

■Alteration■: May take place to chlorite, talc, serpentine, asbestus, etc., depending on the chemical composition. Amphibole frays out and becomes fibrous during alteration, and may also lose color.

■Distinguished from■:

(_a_) PYROXENE.—By usually much stronger pleochroism in the colored varieties, and by cleavage and extinction angle. In pyroxene the cleavage (parallel to prism of 87° 06′) is less perfect; and the extinction angle is much larger, varying from 36° to 54°.

(_b_) BIOTITE.—By the extinction in the mica being always about parallel to the cleavage. Both have strong absorption, but biotite shows very slight pleochroism in sections parallel to the cleavage, and has only the one cleavage parallel to the base. Also the biotite has lower index of refraction and generally shows uniaxial interference figure.

Colorless tremolite may be distinguished from muscovite and talc by extinction angles, relief and lower order interference colors.

(_c_) TOURMALINE.—By presence of cleavage, and by the fact that absorption is most marked about parallel to the elongation (also parallel to cleavage lines), while in tourmaline the absorption is strongest at right angles to the elongation.

(_d_) The ORTHORHOMBIC PYROXENES.—By extinction angles, the latter having parallel extinction in all sections parallel to _a_, _b_ and _c_, and by prismatic cleavage of 124° 30′. Pleochroism is strong in the colored varieties of both species, but in amphibole it appears more generally as a variation of the same color; while in hypersthene a change in color is often noticed, from brownish-red to greenish parallel to _■_ axis.

(_e_) SILLIMANITE and CYANITE.—See under the latter.

REMARKS: Amphibole comes next to pyroxene in importance and distribution of the dark colored ferruginous rock-forming minerals. As a rule it occurs in rocks with a large percentage of SiO_{2}, associated with quartz and orthoclase; while augite generally occurs in rocks of a basic nature, associated with plagioclase and little or no free SiO_{2}. Furthermore amphibole contains hydroxyl and is therefore naturally found in the deep eruptive rocks; its place being taken by augite in the effusives. By application of heat hornblende changes to augite, while hydrochemical processes bring about the opposite result “uralitization.”

Tremolite and actinolite are found in contact rocks and crystalline schists, also as a result of the alteration of olivine into serpentine. Pargasite occurs in contact rocks. Common green hornblende is found in the plutonic rocks (Na poor and SiO_{2} rich), also in contact rocks and crystalline schists (amphibolites). Brown hornblende replaces the green variety in the basic plutonic rocks. Basaltic hornblende is found in many effusive rocks.

The hornblende crystals in eruptive rocks, being among the first formed constituents, have often suffered subsequent corrosion by the magma, giving rise to the dark border already mentioned. The brown primary hornblende in some rocks may be changed by a process analogous to “uralitization” into a green, reed-like hornblende. Mechanical deformations are found in massive and schistose rocks. Light green amphiboles, with weak pleochroism, may often be colored intensely reddish-brown and made strongly pleochroic by heating to redness on platinum foil. In general the amphiboles are not affected by acids. H., 5 to 6. Sp. gr., 2.9 to 3.3.

Glaucophane, _Arfvedsonite_, etc. (Na rich amphiboles).—Occur blue to bluish-green in color, with pleochroism and weaker double refraction than the other amphiboles. Extinction angles vary from 4°–6° (glaucophane) to 14° (arfvedsonite). They are found in contact rocks, crystalline schists, eclogite, etc.

For the rarer and less known members of the amphibole group, resource should be had to more elaborate works.

Uralite.—Pyroxene altered to amphibole, having the outward crystal form of pyroxene and the physical characters and cleavage of amphibole. The change usually commences on the surface and the uralite does not form a single compact crystal, but consists of numerous slender columns parallel to one another. These little columns or fibers have their _c_ and [_=b_] axes parallel to the positions of these axes in the parent mineral. The color is green and the pleochroism weak to strong.

This change is called “_uralitization_” and results from hydrochemical processes. When the alteration is not complete, portions of the original pyroxene may be left, having all the characteristic optical properties of this latter mineral.

Anthophyllite, the orthorhombic amphibole, with always parallel extinction, is sometimes found in colorless to brownish, blade- to rod-like aggregates in crystalline schists and serpentine.

MICA GROUP.

ANISOTROPIC. BIAXIAL. MONOCLINIC. May appear hexagonal or orthorhombic. COMPOSITION: ELONGATION (■ cleavage) ■ c′.

Biotite (black or ferro-magnesium mica) = (H.K)_{2}(Mg.Fe)_{2}Al_{2}(SiO_{4})_{3}, approx.

Phlogopite = a magnesium mica, near biotite, but containing little Fe.

[Illustration:

FIG. 59.—Mica. _A_, biotite, showing hexagonal cross-section and zonal markings. _Minette_, Freiburg. _B_, Biotite, showing strong absorption parallel to cleavage and also zonal marking (_P_ = plane of vibration of polarizer). _Minette_, Cumberland. _C_, Muscovite in bent shreds in gneiss.]

Muscovite (white or potash mica) = H_{2}(K.Na)Al_{3}(SiO_{4})_{3}, with some replacement by Mg or Fe.

■Usual Appearance in Sections■: Scales, which may be notched or jagged, with lateral sections lath-shaped; or shreds, Fig. 59 C. When distinctly crystallized (magnesium micas) the thin hexagonal plates have plane angles of 120°, Fig. 59 A. Phlogopite crystals may be extended in direction of _■_ axis.

Zonal structure not uncommon in the magnesium micas, Fig. 59 A, which may also have dark iron ore border like hornblende.

Twinning.—Common, generally parallel to base; seen in sections showing cleavage by variations in extinction, in basal sections by distorted interference figures.

Micas of different kinds often associated together in parallel position, also intergrown with hornblende, pyroxene, chlorite and quartz.

Color.—Depends on chemical composition. Biotites, brown, green or red to almost opaque. Phlogopites, colorless or yellowish. Muscovites colorless.

Index of Refraction.—_n′_ = 1.564 to 1.619 (α = 1.541 to 1.580, γ = 1.575 to 1.638), hence somewhat marked _relief_ and surface varies in appearance from slightly rough to fairly rough. In polarized light the surface appears roughest when the cleavage cracks are parallel to the plane of the polarizer.

Biotite has more marked relief.

Cleavage.—Very perfect, parallel to base (001), Fig. 60. Basal sections show no cleavage, but all other sections show many sharp, parallel cleavage cracks.

[Illustration:

FIG. 60.—Biotite, showing basal cleavage, in biotite-granite. (From Cohen).]

For percussion and pressure figures, see reference given below.[93]

Inclusions.—May be arranged parallel to lines of pressure figure. Rutile needles, tourmaline, apatite, etc., common in magnesium mica. Zircon inclusions often surrounded by pleochroic halos.

■Polarized Light■:

Pleochroism.—Varies with the color, being very marked in the colored varieties (from pale yellow to chestnut-brown or black). The strong absorption, about parallel to the cleavage lines, is very characteristic of the colored mica, Fig. 59 B. Strong absorption is also noticed in hornblende, tourmaline and allanite. Absorption may even be noticed around inclusions (pleochroic halos) in colorless, non-pleochroic micas. Cleavage plates of biotite are not pleochroic unless the axial angle is large.

■Crossed Nicols■:

Double Refraction.—Very strong ($\gamma - \alpha = 0.034$ to 0.058).

Interference Colors.—High order (third). May be very bright in thin sections of the colorless micas, and at times be so high in order as not to show any marked color tints. May not be noticeable in sections of the colored varieties, due to absorption of parts of the light.

Extinction.—About parallel to cleavage lines. Very small extinction angles may be noticed in biotites. Basal sections of biotite (the approximately hexagonal mica) usually appear isotropic.

Mottled appearance (like "Birds-eye" maple) characteristic, caused by distortion of the flexible laminæ during grinding. Most noticeable in sections inclined to cleavage and near position of extinction.

■Convergent Light■: Axial plane[94] and Bx_{_a_}, practically at right angles to basal cleavage; therefore cleavage plates always show well defined interference figures, generally biaxial in character. The axial angles vary greatly, being usually small for biotite and phlogopite (may appear uniaxial) and large for muscovite (2_E_ = 55° to 90°). Optical character for all micas (–).

■Alteration■: Biotites decompose quite easily, lose color and may become completely bleached, which appears to be due to a leaching out of the iron. May also alter to green chlorite, with a fraying out of the mica and a change to chloritic structure.

Phlogopites may alter to fibrous, scaly masses, apparently chiefly talc. "Sagenite" webs of rutile may accompany the alteration.

Muscovites are characterized by their freshness, and do not seem to suffer from weathering.

■Distinguished from■:

(_a_) HORNBLENDE.—Magnesium mica has extinction about parallel to the cleavage, while hornblende may have extinction angles of from 0° to 20°. Both have strong absorption, but biotite shows very slight pleochroism in basal sections, which also give approximately uniaxial interference figures in convergent light.

(_b_) TOURMALINE.—Magnesium mica shreds show absorption parallel to elongation, while in tourmaline the absorption is at right angles to elongation. There is also an absence of cleavage in tourmaline.

(_c_) CHLORITE.—By strong double refraction, the very high order colors, however, being often not noticed. Chlorite also shows aggregate structure and is almost always greenish in color.

(_d_) TALC.—White mica by large axial angle of scales in convergent light and by micro-chemical tests. The distinction may be very difficult.

REMARKS: Muscovite is a rare primary mineral in eruptive rocks, except in two-mica granite, etc. As a secondary mineral it occurs in dense scaly aggregates or as pseudomorphs after feldspar, nephelite, etc. It is frequent in crystalline schists and is probably also the mica in amphibolite and eclogite. Phlogopite is found chiefly in contact metamorphic limestone; and may be distinguished from muscovite by nearly uniaxial character and less sharp cleavage. Biotite is much more widely distributed, occurring especially in eruptive rocks, crystalline schists and contact rocks.

Chemical corrosion occurs in original biotite of porphyritic rocks, producing a "resorption border" of augite and magnetite. Mechanical deformations, producing bending and slipping along "gliding" planes (oblique to cleavage), are common to all varieties of mica and may produce change to chlorite. The muscovites, together with the feldspars, are the most characteristic minerals of dynamo metamorphic origin. Biotites and phlogopites are attacked by sulphuric acid at high temperatures. Muscovite is but slightly attacked by acids. H., 2 to 3. Sp. gr., 2.7 to 3.2. The specific gravity separation between the micas is difficult on account of the scaly nature of the minerals.

Other micas occur, some being alteration products of those already described. Among these may be mentioned:

Lithia Mica.—Both light and dark colored, occurring in granitic rocks and often only distinguished chemically from muscovite and biotite.

Damourite (_Sericite_) (hydrous K mica).—A secondary product usually in colorless, fine scaly aggregates in phillites, sericite-schists, etc.

CHLORITE GROUP.

Embracing the members of the Chlorite Group, commonly occurring in rocks.

ANISOTROPIC. BIAXIAL. MONOCLINIC.

The minerals of this group usually appear uniaxial, and crystallize in part with hexagonal symmetry.

COMPOSITION: May be considered as isomorphous mixtures of $H_{4}(MgFe)_{3}Si_{2}O_{9}$ and $H_{4}(MgFe)_{2}(AlFe)_{2}SiO_{9}$ (Rosenbusch).

■Usual Appearance in Sections■: Minute, scaly aggregates, which may incline to radial grouping; or in minute grains as a pigment (veridite) in other minerals.

Twinning.—May be seen as in mica.

Color.—Generally green, varying from greenish white to dark green, rarely colorless or red.

Index of Refraction.—n' = 1.567 to 1.589 (α = 1.560 to 1.585, γ = 1.571 to 1.596), hence no marked relief and only slightly rough surface.

Cleavage.—Like mica, very perfect; parallel to flat face, which is considered to be the basal plane. This cleavage may not be noticed, especially in secondary chlorite in rocks.

■Polarized Light■:

Pleochroism.—In green and yellow tints (green ■ cleavage), being more marked in dark colored varieties. Basal sections are non-pleochroic, the mineral being practically uniaxial. Pleochroic halos may be seen.

■Crossed Nicols■:

Double Refraction.—Generally very weak ($\gamma - \alpha$ = 0.001 to 0.011).

Interference Colors.—Very low first order, gray or white, at times scarcely noticed. Anomalous colors, however, often seen (deep blue or brown.)

Extinction.—Plates parallel to cleavage generally appear isotropic or only show faint color. In other sections extinction is apparently parallel to the cleavage in the uniaxial type, but extinction angles may be noticed when type is biaxial. Complete extinction may not be noticed, due to aggregate structure.

■Convergent Light■: Plates parallel to cleavage show, at times, an indistinct interference cross, which may open into two hyperbolas, indicating biaxial nature of crystallization. Ax. pl. ■ (010); Bx_{_a_}. Λ _■_ = 0° to 15°; 2_E_ variable. Optical character (±).

■Distinguished from■: SERPENTINE.—By general green color (serpentine, with exception of Fe rich variety, is colorless), pleochroism and frequent anomalous interference colors; but the distinction between these two minerals may be very difficult. Chlorite may resemble decomposed or green mica (mica has, however, strong double refraction). The different species in the chlorite group cannot usually be distinguished in rocks.

REMARKS: The chlorites are essentially secondary minerals, derived from the aluminous silicates, biotite, augite, garnet, feldspar, etc. They are found abundantly in chlorite-schists, contact rocks, etc., and as pigment (veridite) in altered eruptive rocks. May occur as a primary constituent of eruptive rocks, often in parallel growth with biotite. Chlorides are acted on by hot hydrochloric acid, and decomposed easily by sulphuric acid. H., 2 to 3. Sp. gr., 2.6 to 2.96. A thin section heated to redness on platinum foil loses water and becomes opaque. Ferruginous varieties are turned reddish-brown to black by heating (serpentine, as it contains less iron, may give negative results with this test).

Delessite.—Found in sphærulites, filling cavities in amygdaloidal basic rocks, and in pseudomorphs. It appears to be much altered to other minerals.

TALC.

ANISOTROPIC. MONOCLINIC (Pseudo-Hexagonal). COMPOSITION: ELONGATION ■ c′. $H_{2}Mg_{3}(SiO_{3})_{4}$.

■Usual Appearance in Sections■: In fine scaly, colorless aggregates. Sections, cutting across the scales, would show rod-like forms. Index of refraction only a little higher than balsam (_n′_ = 1.572, α = 1.539, γ = 1.589), hence no marked _relief_ and only slightly rough surface. Cleavage perfect parallel to base, like mica.

■Crossed Nicols■: Double refraction very strong ($\gamma - \alpha$ = 0.050). Interference colors third order, like muscovite. _Extinction_ parallel to basal cleavage lines. In _convergent light_, Ax. pl. ■ (100), Bx_{_a_}. ■ _■_; axial angle small (2_E_ = small); optical character (–).

■Distinguished from■: MUSCOVITE (with which it is easily confused) by micro-chemical tests, proving absence of alkalies and Al; and often by the more aggregate structure of the talc. Also by smaller axial angle of scales in convergent light.

REMARKS: Found mainly in metamorphic schists, etc., always as a secondary product. It is insoluble in hydrochloric acid. H., 1 to 1.5. Sp. gr., 2.6 to 2.8.

EPIDOTE.

ANISOTROPIC. BIAXIAL. MONOCLINIC. ELONGATION ■ a′ or c′.

COMPOSITION: $Ca_{2}Al_{2}(AlOH)(SiO_{4})_{3}$, with some Fe replacing Al.

■Usual Appearance in Sections■: Columnar to thick tabular crystals, more or less elongated parallel to ortho axis [_=b_], Fig. 61, or in granular aggregates.

[Illustration:

Epidote.

FIG. 61. FIG. 62. Ortho pinacoid section. Clino pinacoid section.]

Twinning.—May occur but rarely noticed. Irregular interpenetrations common with other members of the group; also parallel growths.

Color.—Colorless to yellowish (Fe poor) or yellow to greenish to yellow-brown (Fe rich).

Index of Refraction.—_n′_ = 1.751 but may be lower (α = 1.731, γ = 1.768), hence _relief_ high and surface rough.

Cleavage.—Parallel to base (001), Figs. 61 and 62, imperfect parallel to ortho pinacoid (100). Basal cleavage cracks not very numerous and appear parallel to general direction of elongation.

■Polarized light■:

Pleochroism.—Varies with the color, being faint in the light colored varieties, but strong when the color is marked (Fe rich).

■Crossed Nicols■:

Double Refraction.—Variable, often very strong ($\gamma - \alpha$ = 0.037).

Interference Colors.—Variable, often high (third) orders. Intergrowths with other members of the group are clearly shown by the "flecked" interference colors.

Extinction.—Parallel to cleavage in sections parallel to [_=b_] axis. In other sections extinction angles vary, see Fig. 62.

■Convergent Light■: Axial plane ■ (010), _i. e._, at right angles to the elongation of crystal and cleavage cracks, Fig. 61. Bx_{_a_.}-(a) Λ _■_= 3° behind. Basal cleavage flakes show the almost ■ emergence of an optic axis. Axial angles very large (2_E_ > 180°). Optical character (–).

■Alteration■: Does not take place readily.

■Distinguished from■: Light colored MONOCLINIC PYROXENE.—By having plane of optic axes at right angles to cleavage cracks and direction of elongation; while in pyroxene plane of optic axes is parallel to parallel prismatic cleavage cracks or bisects the angle between intersecting cracks. Furthermore the yellow color is rare in pyroxene.

REMARKS: Epidote is essentially a secondary mineral, resulting from the alteration of the feldspars and the ferro-magnesium silicates. It is found in crystalline schists (especially those containing hornblende), gneiss, gabbro, diorite, diabase, lime-silicate hornstones, contact rocks, etc. Epidote is partially decomposed by hydrochloric acid. The Fe rich epidote can be changed to an intense color by "glowing" in the air. H., 6 to 7. Sp. gr., 3.32 to 3.45.

Piedmontite (containing Mn).—Red in color. Very pleochroic, red to yellow. Found in crystalline schists, the porphyrite of Scotland, the famous "Porfido rosso antico" of Egypt and in certain Japanese mica schists.

ZOISITE.

Essentially orthorhombic? members of Epidote group.[95]

COMPOSITION: Like epidote but without any Fe.

■Usual Appearance in Sections■: Similar to epidote or in columnar aggregates. Often intergrown with epidote.

Distinguished from epidote by general absence of color (colorless to yellowish) and pleochroism; by slightly lower refractive index (_n′_ = 1.699 to 1.720) and by much weaker double refraction ($\gamma - \alpha = 0.005$ and less). The interference colors are very low order, gray to white, but anomalous colors are often seen (yellow or prussian blue). Extinction is in general parallel to pinacoidal cleavage cracks (except in clinozoisite).

The plane of the optic axes may be parallel or at right angles to cleavage cracks, and the optical character is (+).

REMARKS: Generally a secondary mineral. Found in crystalline schists, amphibolites, contact rocks, eclogite, etc., and in "saussurite." May be hard to distinguish from vesuvianite and apatite.

ALLANITE, Orthite.

Monoclinic member of Epidote group.

COMPOSITION: Like epidote but containing cerium.

■Usual Appearance in Sections■: Similar to epidote in form; but distinguished by brown color (may be also almost colorless), strong pleochroism and absorption, and medium to weak double refraction ($\gamma - \alpha = 0.002$ to 0.030). Lamellar twinning clearly seen on account of oblique extinction. When included in hornblende and mica it is surrounded by pleochroic halos. _n′_ = 1.78 about. Optical character (±). Usually perfectly fresh.

REMARKS: Found as an accessory mineral in SiO_{2} rich eruptive rocks and connected crystalline schists, and (light colored) in amphibolite and eclogite.

TITANITE, Sphene.

ANISOTROPIC. BIAXIAL. MONOCLINIC. COMPOSITION: CaTiSiO_{5}. ELONGATION ■ a′.[96]

■Usual Appearance in Sections■: Wedge-shaped crystals (in Na rich rocks, more prismatically developed); grains, which may be elongated; and aggregates of small rounded particles, which appear nearly opaque. Sections of crystals commonly acute rhombs, Fig. 63.

Twinning.—Occurs, the twinning boundary bisecting the acute angles of the rhomb (only noticed between crossed nicols), Fig. 64.

Color.—Reddish-brown to yellowish to colorless.

[Illustration:

FIG. 63.—Titanite, showing acute rhombic cross-section.]

Index of Refraction.—_n′_ = 1.920 to 1.963 (α = 1.888 to 1.913, γ = 1.978 to 2.054), hence _relief_ very marked and surface very rough.

Cleavage.—Imperfect and not parallel to predominant form, hence only appears as a few rough cracks, which are not parallel to any crystallographic boundary, Fig. 63. Cleavage rarely observed in secondary grains.

■Polarized Light■:

Pleochroism.—Varies with the color, being more distinct in colored crystals, yellowish (the lighter color) ■ a′ and reddish-brown ■ c′. Scarcely noticed when the color is light.

■Crossed Nicols■:

Double Refraction.—Very strong ($\gamma - \alpha$ = 0.090 to 0.141).

[Illustration:

FIG. 64.—Titanite, showing twinning in nepheline-syenite. (From Cohen.)]

Interference Colors.—Very high order, like those of calcite. Due to the fact that the refractive indices of two of the rays are very nearly alike, some sections may show very low order colors.

Extinction.—Extinction angles not characteristic. There may be no complete extinction in white light, owing to dispersion.

■Convergent Light■: On account of the very strong characteristic dispersion of the optic axes ($\rho > \nu$), the axial angle varies a good deal with the color of the light used, (St. Gotthard) 2_E_{IA}_ = 57°, 2_E_{Tl}_ = 47°. By using colored glasses this variation in the axial angle can be seen. The axial plane lies in the clino pinacoid (010), hence bisects the obtuse angle in the rhombic cross-section, Fig. 63. Bx_{_a_}.(c) Λ _■_ = 51° front. The optical character is (+).

■Alteration■: May take place.

■Distinguished from■:

(_a_) STAUROLITE.—In convergent light the axial plane is shown to be in the shorter diagonal of the rhombic cross-section, while in staurolite it is in the longer diagonal.

(_b_) RUTILE.—By biaxial character.

(_c_) CALCITE.—The light colored titanite (sphene), in absence of twinning, by higher index of refraction.

Titanite may easily be confused with some of the rarer minerals.

REMARKS: Titanite is always an accessory mineral and is found distributed in all rocks, except SiO_2 rich eruptive and magnesia silicate rocks. As a secondary mineral it forms rims around other titanium minerals or pseudomorphs after them and also the principal part of _leucoxene_. It is partly soluble in hot hydrochloric acid and completely decomposed by sulphuric acid. H., 5 to 5.5. Sp. gr., 3.3 to 3.7. In a specific gravity separation it falls with the ferruginous minerals (on account of its density) and from these can generally be separated by electromagnetic methods.

FELDSPAR GROUP. Orthoclase, Microcline and the Plagioclases.

ORTHOCLASE.

ANISOTROPIC. BIAXIAL. MONOCLINIC. ELONGATION (■ cleavage) ■ a′.

COMPOSITION: $KAlSi_3O_8$, with some replacement by Na.

■Usual Appearance in Sections■: In crystals and grains. In porphyritic rocks habit of crystals more or less tabular parallel to clino pinacoid (010), or rectangular much extended parallel to clino axis _à_, with cross-sections six-sided, or rectangular to long lath shape, Figs. 65 and 66. Crystals may be changed into rounded or looped grains by chemical corrosion, Fig. 6. Adularia crystals

more prismatically developed, giving rhombic sections. Dimensions of crystals vary extremely; microlites occur, at times forming sphærulitic structure. The very fine grained ground-mass "microfelsite" (not resolved by the microscope) consists largely of feldspar.

[Illustration:

Orthoclase cleavage plates.

FIG. 65.—Basal. FIG. 66.—Clino pinacoid.]

Intergrowths with microcline and plagioclase common, forming "microperthite" when lamellæ are microscopic. May be in zonal formation with plagioclase (the orthoclase on the periphery). Also intergrown with quartz[97] forming "pegmatite" and "micro-pegmatite," Fig. 67.

[Illustration:

FIG. 67.—Micro-pegmatitic structure, in granophyric quartz-porphyry. (From Cohen.)]

Zonal structure often seen, Fig. 20, especially when decomposition has commenced; and in fresh crystals may be indicated by zonal arrangement of inclusions.

Twinning.—Very common, generally after _Carlsbad_ law, Figs. 18 and 69; the twinning boundary, dividing the section longitudinally, either being parallel to edges of crystal or bent or jagged. Twinning after _Baveno_ (twinning boundary diagonal, with the two parts extinguishing at the same time, but having a and c directions crossed in the two portions) and _Manebach_ laws less common.[98]

[Illustration:

FIG. 68.—Orthoclase, ortho pinacoid section showing cleavages intersecting at 90°, in augite-syenite.]

Color.—Colorless or tinged by oxide of iron. Cloudy if decomposed.

Index of Refraction.—_n′_ = 1.523 (α = 1.519, γ = 1.526), hence no _relief_ and surface smooth.

Cleavage.—Varies and sometimes only seen in very thin sections, but is an important character and should always be searched for. It occurs perfect, parallel to base (001), and almost as perfect parallel to clino pinacoid (010). The two cleavages intersect at 90° in section parallel to the [_=b_] axis, Fig. 68.

Inclusions.—May be present and arranged in regular or zonal order, but not important. Do not occur in individuals of a second generation.

■Polarized Light■:

Pleochroism.—None.

■Crossed Nicols■:

Double Refraction.—Very weak ($\gamma - \alpha$ = 0.007).

Interference Colors.—Lower first order, gray, white, etc., not quite so bright as colors of quartz and plagioclase.

Extinction.—Being monoclinic the extinction angle on base (001), with reference to clino pinacoid (010) cleavage cracks, is 0°. On clino pinacoid with reference to basal cleavage cracks, it is 5°. Some sections (notably in glassy sanidine grains) may appear dark during complete rotation. This is due to the fact that the axial angle is very small and the sections act approximately like those of a uniaxial mineral at right angles to the optic axis.

■Convergent Light■:[99] Plane of optic axes in general at right angles to clino pinacoid (010) (plane of symmetry), Fig. 65, hence parallel to trace of basal cleavage; but in some sanidines parallel to plane of symmetry. Bx_{_a_} (a) $\wedge$ _a_ = 5° above. Axial angles vary, 2_E_ = 125° (orthoclase), 0°–50° (sanidine).[100] May appear uniaxial when axial angle is very small. Optical character (–).

■Alteration■: Very common to clay,[101] muscovite, hydrargillite, etc. Generally commences along the cleavage cracks, and when it has progressed very far the whole feldspar appears opaque or cloudy, and no perceptible change may take place between crossed nicols. As decomposition is very prevalent in many rocks, the orthoclase is rarely clear or pellucid. Epidote is often formed when accessory solutions are present.

■Distinguished from■:

(_a_) The other FELDSPARS and MELILITE.—See under the latter minerals.

(_b_) QUARTZ.—Feldspar is biaxial but when occurring in clear glassy grains (notably sanidine), which appear uniaxial in convergent light, may resemble quartz. When tested the optical character is (–), while that of quartz is (+).

REMARKS: The members of the feldspar group are the widest distributed of the rock-forming minerals and their recognition is of the utmost importance on account of their bearing on the systematic classification of rocks. Orthoclase is found as an essential constituent in the more acid plutonic and older volcanic rocks, as granite, syenite, trachyte, porphyry, and also in gneiss, crystalline schists, more seldom in contact rocks and subordinate in clastic rocks.

Chemical corrosion (producing rounded or looped grains), Fig. 6, and mechanical deformation (producing angular, sharp-edged, broken grains, bending and undulatory extinction[102]), Fig. 7, occur in orthoclase. When a rock containing feldspar crystals is shattered, the orthoclase breaks parallel to basal cleavage and plagioclase parallel to twinning plane. Orthoclase is practically insoluble in acids. H., 6 to 6.5. Sp. gr., 2.56.

[Illustration:

FIG. 69. —Sanidine, showing Carlsbad twin and cross-parting, in nepheline-phonolite. (From Cohen.)]

Sanidine.—This clear, glassy variety of orthoclase occurs in the later eruptive rocks, rhyolite, trachyte, obsidian, etc. Sanidine often has a parting parallel to ortho pinacoid (100), which may be noticed in sections so thick that the cleavage is not seen, Fig. 69. In general it shows no sign of decomposition, and has a smaller axial angle than orthoclase. Inclusions of glass are more abundant than in orthoclase.

MICROCLINE.

ANISOTROPIC. BIAXIAL. TRICLINIC. COMPOSITION: $KAlSi_3O_8$.

■Usual Appearance in Sections■: As a rock constituent in irregular grains.

In general characters like orthoclase and _distinguished_ from it and the plagioclases by characteristic "_gridiron_" structure between crossed nicols, resulting from the polysynthetic twinning after both _Albite_ and _Pericline_ laws, Fig. 19. This crossed twinning will show in all sections except those parallel to the brachy pinacoid (010). The lamellæ are generally thinner than in the plagioclases and more "spindle-shaped."[103]

Furthermore the rather obscure triclinic crystallization is shown by an extinction angle of + 15° on basal cleavage plates with reference to brachy pinacoid (010) cleavage lines (distinction from orthoclase, which has O° extinction angle).

REMARKS: Found with orthoclase, often almost replacing it, in granite, syenite, gneiss, etc., and is one of the last minerals to form. It is notably resistant to decomposition. A structure like the microcline twin structure may be produced in orthoclase by dynamic action.[104]

THE PLAGIOCLASES. Albite, Oligoclase, Labradorite, Anorthite.

ANISOTROPIC. BIAXIAL. TRICLINIC.

ELONGATION (■ Albite twin lamellæ) ■ a′ (except in anorthite when it may be ■ a′ or c′).

COMPOSITION:[105]

Albite, $NaAlSi_3O_8$.

Oligoclase, _n_(NaAlSi_{3}O_{8}) + CaAl_{2}Si_{2}O_{8}, or _n_ Ab + An, _n_ = 2 to 6.

Labradorite, NaAlSi_{3}O_{8} + _n_(CaAl_{2}Si_{2}O_{8}), or Ab + _n_ An, _n_ = 1, 2 or 3.

Anorthite, CaAl_{2}Si_{2}O_{8}.

■Usual Appearance in Sections■: Much the same as orthoclase. Lath-shaped[106] forms and microlites very common, especially in the acid series.

[Illustration:

FIG. 70.—Plagioclase, showing narrow lamellæ, in diabase. (From Cohen.)]

[Illustration:

FIG. 71.—Plagioclase, showing broad lamellæ, in gabbro. (From Cohen.)]

Twinning.—Polysynthetic, after _Albite_ law, almost universal; the twinning appearing between crossed nicols as a series of dark and light bands, bounded by parallel edges, Figs. 70 and 71. The twin lamellæ are parallel to brachy pinacoid (010), hence not observed in sections parallel to this pinacoid. The lamellæ may appear irregular and interrupted, and seem to be broader in the basic than in the acid series. When this twinning fails, however, as in the basic plagioclases in certain metamorphic rocks, the determination becomes very difficult. In some cases polysynthetic twinning, after both _Albite_ and _Pericline_ laws, may take place at the same time, giving rise to a structure somewhat similar to that of microcline, Fig. 72. In addition the polysynthetic crystals may be twinned like orthoclase after _Carlsbad_ and _Baveno_ laws.

The general characters are the same as in orthoclase with the following differences:

Indices of Refraction: _n′_ = 1.535 (α = 1.532, γ = 1.540) Albite. _n′_ = 1.541 (α = 1.537, γ = 1.545) Oligoclase, Ab_{4}An_{1}. _n′_ = 1.559 (α = 1.555. γ = 1.563) Labradorite, Ab_{1}An_{1}. _n′_ = 1.582 (α = 1.575, γ = 1.588) Anorthite.

The surface of anorthite appears slightly rougher than that of orthoclase.

Cleavages, parallel to base (001) and brachy pinacoid (010), never intersect at right angles, as is the case in sections of orthoclase parallel to [_=b_] axis. This is due to the triclinic system of crystallization, but the divergence from a right angle is small (93° 36′ to 94° 10′).

[Illustration:

FIG. 72.—Plagioclase, showing crossed lamellæ, in olivine-gabbro. (From Cohen.)]

Inclusions at times may be quite important, as the vitreous inclusions of oligoclase in andesites, etc., and the iron ore inclusions and other microlites in labradorite. The arrangement of these inclusions may be zonal or in parallel orientation.

Double refraction is a little stronger than for orthoclase ($\gamma - \alpha$ = 0.008 to 0.013 (anorthite)), hence producing slightly brighter interference colors in sections of the same thickness.

Extinction takes place in all sections unsymmetrically with respect to crystallographic, twinning or cleavage lines (as these minerals are triclinic); hence extinction angles are always observed.

■Convergent Light■: All plagioclases show the emergence of a bisectrix,[107] more or less oblique, on brachy pinacoid (010) cleavage faces. These cleavage faces show no twin lamellæ, unless twinning after _Pericline_ law occurs, in which case the determination is much more complicated. The axial angle is large, 2_E_ = 155° (Albite). Optical character, depending on variety, (+) or (–).

■Alteration■: Partly the same as in orthoclase, forming clay, muscovite, etc. Calcite and epidote are more common as side-products, and zeolitization also occurs in some rocks. The plagioclases decompose more easily than orthoclase.

■Distinguished from■:

(_a_) ORTHOCLASE.—By repeated twinning after _Albite_ law, giving between crossed nicols a series of alternate dark and light bands.

When _Albite_ twinning is absent the distinction is very difficult.

(_b_) MICROCLINE.—By common absence of the microcline "_gridiron_" structure between crossed nicols.

Methods for Optical Determination of the Plagioclases.[108]

The correct determination of the particular plagioclase is of the greatest importance in the classification of rocks, and it is no longer sufficient to simply determine the feldspar as either orthoclase or plagioclase.

A quantitative analysis of isolated material would lead most surely to the desired result, but has many objections.

Modern optical methods now permit of a very accurate and convenient determination under ordinary circumstances. But of course these methods involve a knowledge of the approximate orientation of the section tested. When this section is not a definite cleavage fragment, its orientation can best be determined by convergent light tests.

Only an outline of these methods can be here given, and reference should be made to more complete works for an elaborate discussion of the subject.

It is very convenient to have at hand a set of glass models of the plagioclases, showing location of plane of optic axes, vibration directions and crystal axes.[109]

(1) _Schuster's_ method of recognizing the different feldspars by extinction angles measured on the cleavage plates[110] is very precise, but not always applicable for crystals in rock sections.

EXTINCTION ANGLES:

EXTINCTION ANGLES: ON BASE, MEASURED FROM TRACE OF ON BRACHY PINACOID, MEASURED FROM PINACOIDAL CLEAVAGE. TRACE OF BASAL CLEAVAGE. Albite + 4° Albite +19½° Oligoclase, Ab_{4}An_{1} + 2° Oligoclase, Ab_{4}An_{1} + 8° Labradorite, Ab_{1}An_{1} – 5½° Labradorite, Ab_{1}An_{1} –20° Anorthite –36½° Anorthite –41½°

Confusion may here arise between albite and labradorite if disregard be had to signs, but the more acid oligoclase is readily distinguished from the basic anorthite.

By convention the angles on base and pinacoids are (+) when the direction of extinction has apparently moved as the hands of a watch, with reference to the upper right hand edge (between base and pinacoid) of the crystal. When the reverse is true the angles are (–), see Fig. 73.

(2) The statistical method of _Michel Lévy_ and others is often applicable, especially in the following case:

Sections at right angles to the brachy pinacoid (010) and hence showing _Albite_ twinning.—These sections, as nearly perpendicular to the lamellæ as possible, are known by the sharp dividing lines, by the extinction angles on each side of the trace of the twinning plane being approximately equal and by the fact that the two adjacent lamellæ are of the same color when the trace of the twinning plane is parallel to the plane of vibration of either nicol. Also in the 45° position the lamellæ are exactly the same color and the dividing lines disappear. Measure the extinction angles in as many sections thus selected as possible and take the maximum value.[111] This should be very close to the maximum extinction angle, which is a constant for each kind of feldspar.

[Illustration:

FIG. 73.—Showing conventional signs of extinction angles.]

MAXIMUM EXTINCTION ANGLES IN SECTIONS PERPENDICULAR TO ALBITE TWINS. Albite 16° Oligoclase, Ab_{4}An_{1} 5° Labradorite, Ab_{1}An_{1} 27° Anorthite 53°

In the determination of rod-like microlites,[112] oligoclase extinguishes almost parallel to its length, while anorthite may show extinction angles of over 27°. When these microlites show _Albite_ twinning use the method just described.

(3) _Fouqué's_ method[113] can be used when the optical orientation of the section is known (as the result of a test with convergent light). The extinction angles of these known sections are of great diagnostic importance.

The best sections are those at right angles to the two bisectrices, and these may be obtained by rapidly testing those sections, in the rock, which show an interference color about half as high as the maximum color in the rock section, in this way avoiding the sections parallel to the optic axes.

Having found such a section, test it with a gypsum or ¼ undulation mica plate to prove whether the bisectrix is ■ a or c. If ■ a (these sections show sharp twinning striations) measure extinction angle between trace of axial plane and _albite_ twinning; if ■ c measure extinction angle between trace of axial plane and basal cleavage cracks.

EXTINCTION ANGLES IN SECTIONS:[114] ■ a, MEASURED FROM ALBITE STRIATIONS. ■ c, MEASURED FROM CLEAVAGE CRACKS. Albite 74° 19½° Oligoclase, Ab_{4}An_{1} 88° 5° Labradorite, Ab_{1}An_{1} 60° 22° Anorthite 55½° 48°

When both extinction angles can be obtained, the determination of the plagioclase is very certain, but the result cannot be regarded as definite when only one is found; and the method becomes more difficult as the crystals become smaller.

The position of the axial plane should be determined by convergent light test and not simply by the direction of extinction in parallel polarized light.

(4) _Michel Lévy's_ method[115] can be employed when twinning is present after both _Carlsbad_ and _Albite_ laws.

[Illustration:

FIG. 74.—Extinction Angles in the Zone normal to (010) in Carlsbad Twins of the Plagioclases.]

The section to be tested should be in the zone perpendicular to (010). Such sections show sharp boundary lines between the twin lamellæ and, between crossed nicols, the _Albite_ lamellæ show the same interference color when the trace of (010) is parallel to the cross-wires of the ocular, and also in the 45° position the lamellæ are the same color and no dividing lines show. The two parts of the _Carlsbad_ twin exhibit different interference colors in the 45° position, this difference being more marked as the composition approaches that of Anorthite. The extinction angles are measured from the trace of the _Albite_ twinning plane (010), paying regard to the + and – signs, and the _concurrent series_ of angles are to be obtained from the two parts of the _Carlsbad_ twin. The range of these angles (for four type compositions, Ab, Ab_{4}An_{1}, Ab_{1}An_{1} and An) is given in the accompanying diagram for all positions of the section in the zone normal to (010).

In the curves of this diagram (Fig. 74) the vertical distances are the extinction angles for every ten degrees measured from the trace of the _Albite_ twinning plane, and the horizontal distances represent varying positions of the section in the zone normal to (010) for every ten degrees of rotation from the position ■ to the edge (100)(010) (that is ■ _■_ axis), through a revolution of 180° to again ■ to the same position. The concurrent angles in one part of a _Carlsbad_ twin are represented by a heavy line and in the other part by a broken line. It will be observed that the difference between these concurrent angles is very small in Albite (3°) and increases markedly towards Anorthite (60°).

TABLE FOR BECKE METHOD.[116] Orthoclase ■ α ■< ω Quartz Microcline ■ β ■ „ Albite ■ γ ■ „

■■■

intermediate and basic composition.

Albite is found in granite (commonly intergrown with orthoclase), gneiss, etc., and frequently as a secondary constituent (secondary feldspar[119]) in the feldspar-quartz mosaic of mechanically metamorphosed rocks. It may also be present in acid eruptive rocks.

Oligoclase is very frequent in granite, syenite, gneiss, diorite, trachyte, andesite, diabase, etc.; and particularly accompanies orthoclase.

Labradorite is confined more to the gabbros,[120] basic eruptive rocks and crystalline schists, rich in amphibole and pyroxene.

Anorthite occurs in gabbros, the most basic porphyrites, basalts, etc.

Chemical corrosion and mechanical deformation[121] may take place as in orthoclase.

Anorthite and labradorite are more or less decomposed by hydrochloric acid, while albite and oligoclase are not acted on by the acid.

Especially interesting is the alteration of the plagioclase that takes place in gabbros, accompanied by "uralitization" of the pyroxene, forming "_saussurite_." This consists of a white to greenish confused aggregate, chiefly of zoisite, grossularite, vesuvianite, chlorite, secondary feldspar (albite), etc.

Anorthoclase (a Na K, triclinic, feldspar).—Shows between crossed nicols intersecting areas of exceedingly fine composite twin structure and others of homogeneous structure, producing a watery or "moiré" appearance. The twin structure may be only seen in very thin sections. All possible kinds of perthitic intergrowth occur. Further distinguished from orthoclase by small extinction angle (4°) on base and by smaller axial angle (2_E_ = 72° to 88°).

Replaces orthoclase in the Na rich eruptives. Found in augite-syenite and "Rhombenporphyr" of Norway (with rhombic cross-section), acid augite-andesite of Pantelleria and in the porphyries of the Hartz.

CYANITE, Disthene.

ANISOTROPIC. BIAXIAL. TRICLINIC. COMPOSITION: Al_{2}SiO_{5}. ELONGATION ■ c′.

[Illustration:

FIG. 75.—Cyanite, macro pinacoid cleavage section.]

■Usual Appearance in Sections■: Blade-like crystals without terminal planes, but with cross-section (six-sided) showing two long parallel edges and four shorter edges; also in columnar aggregates. Twinning common, with generally twinning plane parallel to macro pinacoid (100). Colorless or bluish and spotted. The index of refraction is high (_n′_ = 1.720, α = 1.712, γ = 1.728), hence _relief_ marked and surface rough. Cleavage perfect, parallel to macro pinacoid (100), appearing as sharp cracks, parallel to longest edges in cross-sections; less distinct, parallel to brachy pinacoid (010). Fibrous parting parallel to base (001), Fig. 75. Pleochroism (colorless to blue ■ c′) not noticed except in colored crystals.

■Crossed Nicols■: Double refraction quite strong ($\gamma - \alpha$ = 0.016). Interference colors upper first order, yellow, red, violet, etc. _Extinction_ angles observed in all sections (being triclinic), reaching a maximum of 30° on macro pinacoid (100), Fig. 75. Extinction on base, about parallel to most perfect cleavage. In _convergent light_ axial angle large; axial plane and Bx_{_a_}. about perpendicular to best cleavage (100); optical character (–).

■Alteration■: Seldom observed, but may take place to mica.

■Distinguished from■:

(_a_) AMPHIBOLE by cleavage (intersecting cleavages at 124° in amphibole and 90° in cyanite) and by (100) cleavage plates of cyanite showing emergence of acute bisectrix.

(_b_) CORUNDUM by being biaxial.

Distinction from similar appearing minerals may be difficult.

REMARKS: Found in gneiss, granulite, metamorphic schists, ecolgite, etc., commonly associated with garnet. It is not attacked by acids. H., 5 to 7. Sp. gr., 3.6.

SERPENTINE.

AGGREGATE. ELONGATION (of fibers) ■ c′.

COMPOSITION: $H_{4}Mg_{3}Si_{2}O_{9}$, with replacement by Fe.

■Usual Appearance in Sections■: Dense, fibrous (chrysotile) or scaly (antigorite) aggregates.

Color.—Colorless to light greenish, except the Fe rich variety which is green.

Index of Refraction.—_n′_ = 1.55 to 1.56 (α = 1.56, γ = 1.571 for antigorite), hence no _relief_ and surface smooth.

■Polarized Light■:

Pleochroism.—Not seen or very feeble, except in the Fe rich variety.

■Crossed Nicols■:

Double Refraction.—Rather weak ($\gamma - \alpha$ = 0.009 to 0.011).

Interference Colors.—Middle first order, gray, white, yellow, etc. Anomalous colors do not appear. The aggregate structure is distinctly seen between crossed nicols. Due to compensation aggregates may appear isotropic.

■Distinguished from■: CHLORITE.—By more usual absence of color, pleochroism and anomalous interference colors; but this distinction may be very difficult.

REMARKS: Serpentine (both antigorite and chrysotile) is essentially a secondary mineral, resulting in most cases from the alteration of chrysolite (olivine), Fig. 22, more rarely of pyroxene or amphibole.[122] The alteration of olivine to antigorite leads to the characteristic “lattice structure,” the alteration to chrysotile to “mesh structure.” In the case of the “mesh” formation the alteration starts from the surface and cracks, producing fibres of chrysotile, which stand at right angles to these edges and cracks. As serpentinization proceeds new cracks form, due to increase in volume, and the process may continue until complete pseudomorphism takes place. When this subsequent serpentinization of the meshes takes place the resulting serpentine may appear almost isotropic[123] and is certainly different from the chrysotile of the first formed veins (Weinschenk). Pieces of the parent mineral are often present.

Serpentine is found in ophiolites, the altered basic igneous rocks, pyroxenites, peridotites, etc., and as a primary mineral in the Central Alps peridotite, intergrown with fresh olivine (Weinschenk). It may also form a rock by itself. Serpentine is attacked quite strongly by hydrochloric acid, still more so by sulphuric acid. Common serpentine is not altered by heating (distinction from chlorite), but the Fe rich variety becomes brown and opaque. H., 2.5 to 4. Sp. gr., 2.5 to 2.7.

CLAY, Kaolin.

COMPOSITION: AGGREGATE. $H_{4}Al_{2}Si_{2}O_{9}$ (kaolinite).

■Usual Appearance in Sections■: Fine, scaly, colorless aggregates, which appear opaque (due to porous structure). The scales show basal cleavage. Index of refraction is about the same as balsam (_n′_ = 1.55), hence no _relief_. The double refraction is weak ($\gamma - \alpha$ = 0.008).

■Distinguished from■: Colorless MICA and HYDRARGILLITE [$(Al(OH)_{3})$, which as an alteration product of the feldspars is often confused with clay] by weak double refraction.

REMARKS: Clay results from the alteration of the feldspars (especially the plagioclases), elæolite, scapolite and other silicates. Kaolinite is insoluble in hydrochloric but decomposed by sulphuric acid. H., 2.5. Sp. gr., 2.6.

CHAPTER V. METHODS OF PREPARING SECTIONS.[124]

The methods described will be those used in making rock sections. The general principles involved are the same for both rock and crystal sections; although more difficulties are encountered in making the latter, due to the sections being required in some definite direction or of some precise thickness, or on account of the possibly fragile or brittle character of the crystals.

In the case of rock sections any section, taken “at will” through the rock, will generally do.

Cutting and Grinding Machines.[125]

Many different kinds are used, the power being furnished by steam, electric motor[126] or by the hand or foot.

The chip or fragment of rock to be sliced should be comparatively small in size, and may be cut by either a vertical diamond saw or by a horizontal emery-disc. The fragment is held in position by suitable guides. The moistened emery can be kept in the tray and fed to the disc by a spoon or some other device. Diamond saws are only needed in the case of hard rocks.

For cutting sections of crystals in definite directions a form of small hand apparatus[127] is shown in Fig. 76.

This cut shows how the plate, to which the crystal is cemented, can be given definite rotation in two directions. The simpler crystal holder, appearing loose on the stand, may be used when a section is required parallel to the face of the crystal cemented to the holder.

In these machines the cutting is done with rotating saws of sheet-tin, usually charged with either diamond dust or emery.

[Illustration:

FIG. 76.]

In the case of a very small crystal a section, parallel to any desired face, can be obtained by cementing this face to a suitable frame or holder and grinding down by hand on a glass plate with emery, the final polish being given with rouge. When the section required is not parallel to a crystallographic face or cleavage it must be verified geometrically with reference to other faces. If the crystals are soluble in water, some other liquid, as α bromnaphthalin or benzine, must be used in grinding; and very fragile crystals are rubbed down on a ground glass plate without emery or rouge, simply using bromnaphthalin or some other appropriate liquid.

When sections of a crystal are desired with strictly parallel faces, the form of grinding apparatus shown in Fig. 77 can be used.

This apparatus consists of a cylinder, held within a suitable frame supported on three set-screws, _a_{1}_, _a_{2}_ and _a_{3}_, of hard steel. The lower surface of the frame and consequently the bottom of the cylinder can be adjusted by the wedge _k_ and the set-screws so that it is exactly parallel to the grinding surface of the glass plate. The crystal to be ground down, _p_, is cemented to the bottom of the cylinder, and the whole apparatus rubbed over the grinding surface of the plate. The pressure of the hand on the upper part of the cylinder regulates the pressure of the crystal on the grinding surface. In this way a surface is obtained which is exactly parallel to the surface cemented to the cylinder.

[Illustration:

FIG. 77.]

Sections of definite thickness can also be obtained by using this apparatus; for the adjustments with the wedge _k_ may be so arranged that, when the stop _t_ in the cylinder has reached the bottom of the slot in the frame, the lower surface of the cylinder will be the required distance from the grinding surface of the glass plate. The wedge is graduated so that the value of one division on the sloping top is known in _mm._ of vertical distance.

Saws.

Saws,[128] of about six inches in diameter made from ½■■ inch sheet-tin, are convenient for general work, and may be charged with diamond dust by the operator as follows:[129] Crush one or two carats of rough crystals of diamond-bort in a small steel mortar to about the condition of fine sand, care being taken not to reduce the diamond to powder. Transfer the dust to a piece of flat iron and, after collecting it in a heap, moisten with a drop of oil. The cutting edge of the tin disk must now be prepared by making a series of incisions (½■■ inch deep) on the outer margin. This can be done by striking the disk with a sharp, thin knife edge. The larger the number of incisions and the closer they are together the better. Charging the saw is accomplished by gently hammering the edge against the iron plate, upon which is the paste of diamond dust and oil. The disk must be slowly rotated during this

charging process, which should be continued until all portions of the edge have been gone over two or three times.

Instead of charging with diamond dust the saws may be used with emery. The edges of the saws should first be "upset," as just described, and then while rotating charged with emery. The emery in the state of mud can be applied with the thumb and fingers, or the saw can be allowed to pass through a tray of emery mud. The finer grades of emery (Nos. 100 to 120) should be used.

The method of mounting saws, of course, depends on the way the saws and spindles are constructed. It is well, however, to have the hole in the center of the saw-disk sufficiently large to allow of adjustment for accurate centering.

Cutting.

During the process of cutting a lubricant must be used on the saw. Petroleum has been recommended by some, but water seems to be the most used. Holding a piece of soap against the cutting edge will also reduce friction. It is convenient to carry the water to the saw through a very small lead pipe, which permits of easy adjustment, so that the water can be delivered at just the right spot, the flow of water, of course, being regulated by a stop-cock.

Another method for cutting sections is used by the U. S. Geological Survey at Washington, D. C. The apparatus consists of an endless wire of soft iron, about ⅜■■ inch in diameter, revolving over two pulleys or wheels, one of which is driven by steam-power. The wire is charged by dipping the fingers in water, taking up a little fine (120 grade) emery and holding the fingers against the wire above the section. The wire revolves so as to cut downwards, thus carrying with it the emery taken from the fingers.

In cutting sections the thickness, of course, depends on the character of the rock; the more porous and fragile the rock the thicker the section should be made, an ordinary section being about as thick as a silver quarter of a dollar.

Very often by skill and practice a suitably shaped chip or fragment can be detached from the specimen with a hammer or with a hammer and cleavage chisels, thus avoiding the delay and trouble involved in the use of the section cutter.

Grinding Plates or Laps.

Copper laps, about 7–8 inches in diameter and ½ inch thick, seem to be best for general purposes; although laps made of lead or cast iron are also used. A lead lap, being soft, holds the emery well and thus hastens the grinding away of the section; but at the same time its own smooth surface is soon destroyed. A cast iron lap is much harder and retains its smooth surface better, but does not hold the emery so well and therefore retards the process of grinding. Copper, being intermediate in hardness between lead and iron, seems to combine the advantages of both.

It is always good practice to have at least two laps, one for the preliminary grinding with coarse emery and the other for the final grinding with the finest grades of emery. In this way one lap is always kept with a smooth surface, making it possible to give a uniform, plane finish to the section.

The surface of the laps should not be exactly plane, but turned or finished so as to be a little higher (1/■■ of an inch for diameter of 8 inches) at the axis than at the periphery; the idea being to compensate for the more rapid abrasive action towards the periphery.

Cementing.

For grinding down to a proper thinness for transparency it is necessary to _cement_ the fragment of rock to a holder, which consists of a small piece of plate-glass about ■ inch thick. If the piece of rock has been cut by a good diamond saw the surface will be comparatively smooth and uniform, and may only need polishing (described under _grinding_) before cementing. When, however, the piece of rock is in the shape of a chip or rough fragment it is first necessary to prepare a smooth ground surface on one side (described under _grinding_) before it can be cemented to the glass holder.

The pieces of plate-glass used should be free from flaws, bubbles or anything tending to destroy uniformity of surface, and should be a little larger than the chips and slices of rock for which they are to act as holders. Hardened Canada balsam, or better yet, a cement made of a mixture of shellac and Venice turpentine,[130] should be used.

The process of cementing is carried on as follows: Heat the glass support over an alcohol lamp or a Bunsen burner, place it on a good non-conductor of heat, as a piece of wood, and rub it with a stick of the cement until a sufficient quantity has been melted off. The piece of rock should then be treated in the same manner, applying the cement to the smooth finished portion. Care must be

taken that neither the glass nor rock preparation are heated too much, as this would cause the cement to smoke or bubble. After placing the rock preparation and plate together, use quite a little pressure in order to drive out all superfluous cement. Examine now, through the glass, the contact surface and see that it is entirely free from bubbles, etc.

Bubbles are usually caused by overheating of the parts before cementing. If only very few bubbles are seen, they may generally be removed by moving the rock preparation rapidly back and forth over the glass plate. If the bubbles are numerous or cannot be removed in the manner just described, the rock preparation must be separated from the glass plate and the cementing done over again.

Bubbles must _not_ be allowed to remain, as the portions of the rock over them, not having any cement backing, are ground away leaving holes in the section.

Grinding.

After the rock preparation has been cemented to its glass holder it is ready for the grinding process, for which are used horizontal laps, mounted on a vertical spindle in the tray _T_, Fig. 76. The copper lap for the first grinding is put in place, and, after it has commenced to rotate, is charged with emery and water. This can conveniently be done by dropping on the emery and water, either with the fingers or with a small bunch of rags at the end of a stick. A large camel's hair brush may be used for putting on the finest emery. The emery is distributed over the rotating lap by the motion of the rock preparation during grinding. The kind of emery used for this first grinding depends somewhat on the character of the rock section. If the section is composed of a hard, compact, fine grained rock, the first emery used may be quite coarse; the coarser the emery the more rapid being the grinding down. For rough, quick work, Nos. 80 to 100 emery can be used until the section becomes quite thin; then, still using the same lap, substitute the finest corn emery (next coarsest to flour emery) and continue grinding until the section becomes quite translucent. The lap must then be changed, and the grinding finished with the finest emery dust.

Too great care cannot be given to cleanliness while doing this sort of work. A single grain of coarse emery, getting on the lap or section during the final grinding, will often spoil the whole work by making a bad scratch. In grinding down the section, great care must be taken to see that the grinding surface is kept parallel to the surface cemented to the glass. The section is firmly pressed against the lap by means of two or three fingers, depending on its size, and uniform pressure should be maintained over all parts.

The section should be examined frequently, and if it is noticed that one part is thicker than another, place the section on the lap so that the thicker part is towards the periphery, and put a little more pressure upon this part. Gutting or grooving the copper laps is prevented by moving the section from center to periphery and back, at the same time giving to it a slight rotary motion. It is best to have the lap revolve from right to left (in the opposite way from the hands of a watch), as, holding the section on the right side of the lap, it is easier to keep it in place by a pulling motion rather than by pushing it against the motion of the lap. In the final stages of grinding and polishing great precaution must be exercised, as one or two turns too many of the lap will often tear away a large part of the very thin section. The section should be frequently examined, by transmitted light, with a small, low power microscope, a drop of water or oil being put on the section to render it more transparent. If the section is thick and fastened to the plate-glass with a good deal of cement, it will be found convenient, after the section has been ground quite thin, to remove most of this cement from around its edges. If this is not done, it may delay the final work of grinding down. A good rock section should be made so thin that all the transparent and translucent component minerals can be examined and studied. Well made rock sections average in thickness from 0.03 to 0.05 _mm._ The last part of the final grinding and polishing can be done by the hand on a ground glass plate, using the finest emery dust or rouge and water.

Flour emery may also be used entirely for grinding, and the finest emery dust for polishing. The finer emery makes better work, although it takes more time, and is much safer for porous or brittle sections, as the danger of tearing away pieces of the section is avoided. In the case of a porous or decomposed rock it is well before grinding to boil the section in Canada balsam or other equivalent material so as to fill all the pores and interstices, thus making the section more compact and less liable to chip away. Sometimes it may even be best before grinding to mount the section on its permanent glass slide, so that when it has been ground thin enough the cover can be put on without running any risk in transferring the section. The only objection is that the glass slide may be a little scratched by the emery.

Mounting.

When the section is sufficiently thin and has a smooth uniform surface it is ready to be transferred and mounted upon its permanent glass slide. The glass plate, which has held the section during the grinding, is gently heated, and, as soon as the cement begins to soften, the section is very gently pushed off into a shallow cup or evaporating dish containing turpentine or alcohol. Turpentine is convenient for general use, because common alcohol (on account of the water it contains) unites with the shellac to form a kind of white pasty substance, which is sometimes hard to remove from the section. The section should be carefully cleaned in the turpentine or alcohol bath by means of fine camel's hair brushes. A section-lifter, made from a piece of broad, flat watch-spring fastened to a small handle, is then gently placed under the section, which is lifted out of the bath in an inclined position so as to allow the liquid to drain off. If a drop still adheres it can be removed by touching it gently with the finger.

The section is now placed in a tray, upon a piece of white, unglazed paper, so that it may thoroughly dry; after which process it is transferred to a glass slide, and, if necessary, its rough edges chipped off with a knife.

If the section is very large, and it is desired to mount it in two pieces, it can easily be divided by holding one half tightly between two glass slides and gently bending the other half with the fingers. The fracture will take place along the edges of the glass slides.

A mixture of gum damar and benzole is recommended for mounting, the claim being made that gum damar does not turn yellow with age, whereas Canada balsam may do so. Two solutions of gum damar and benzole are used. One very thin, about the consistency of water, the other quite thick, about the consistency of mucilage. Both solutions are prepared by dissolving the gum damar in benzole and filtering through a linen or silk rag. If the solution is too thin it can be thickened by placing the bottle in a warm place and allowing the excess of benzole to evaporate, or if too thick, more benzole can be added. It is convenient to keep the solutions in short glass bottles, with wide necks and glass covers instead of corks. The solutions can be applied with glass rods.

When the section is all ready for its final mounting it is carefully centered with a coarse needle on the glass slide,[131] and a drop of the thin solution placed at the edge of the section. Capillary attraction will cause it to flow over the glass slide under the section, and while it is soft the section can be again adjusted in place. The slide is then placed in a cool, dust proof place and allowed to stand for about twelve hours, when the cement will be set and the section held firmly in place. The upper surface of the section is then washed with a drop of benzine, and as much as may be necessary of the thick mounting solution placed upon it with a glass rod. A cover of glass of the right size is gently heated and placed in position over the section. Care must be taken not to have the cover too hot, as it would cause bubbles to form in the cement. It is also best to rest one edge of the cover on the cement first, and then lower it gently so as to prevent air bubbles from being included. The cover is adjusted and then held firmly in position by means of a mounting clamp, which presses out all superfluous cement. If a few small bubbles remain near the edges they may be let alone, as they will generally work out by themselves in time. Sometimes a large bubble can be worked out by local pressure with the finger and gentle heating with a small iron rod. If the mounting is unsatisfactory the cover should be removed by heating, the old cement washed off with a camel's hair brush and benzole, and a fresh cover put on. After the cement has set, the clamp may be removed, but the slide should be left for 24 hours, or longer if necessary, until the cement is quite hard. This takes longer in hot than in cold weather.

The advantage of using two solutions for mounting is that the section is firmly held in place on the glass slide while the cover is being placed over it; there is thus no slipping or sliding of the section, and when the cover is adjusted in place the work is well finished and the section still in the centre of the slide.

Canada balsam, or balsam in xylol, are also often used for mounting. The advantage of the latter being its quick drying or "setting."

Cleaning and Finishing.

When the cement has set the superfluous part is singed by means of a small hot iron rod. Care must be taken not to use too large a rod or to have it too hot, as the cement under the cover might then soften and allow the cover to slip or air bubbles to form. The singeing drives off the more volatile part of the cement, leaving only a brittle residue, which can be easily scraped off with a knife. In some cases it may be necessary to singe and scrape twice. The final cleaning is done with a soft rag and benzole. The slides are now ready to be marked, either with a diamond pencil or with pasted labels.

Convenient Apparatus for Work in a Petrographical Laboratory:

Section lifters made of watch springs, three sizes.

Section holders or clamps for pressing out superfluous cement.

Needle points mounted in light handles.

Easy spring forceps.

Mounting frame for centering section on glass slide.

Small iron rod for singeing.

Small camel's hair brushes.

Cutting pliers and forceps.

Set of wooden section trays.

Glass stopper bottles for benzole, benzine, turpentine and alcohol.

Open neck bottles, with covers for two mounting liquids.

Rotating mounting stand.

Small microscope for testing transparency of section.

Glass rods.

Small squares and rectangles of plate-glass.

Round, oval and square cover-glasses.

Glass slides with ground edges.

CHAPTER VI. CHEMICAL AND MECHANICAL TESTS.

These tests may be necessary to confirm an optical determination or to assist in the differentiation of the closely related species of a group, as for example, the different plagioclases in the feldspar group. They may also be useful in the case of opaque substances.

The ordinary chemical methods employed in mineral analyses are often not applicable, on account of the minute size of the mineral under investigation and the lack of sharpness in the reactions. Those methods[132] are to be preferred which produce crystallizations independent of the relative proportions of the materials taking part in the reaction and also of the physical conditions invoked.

The tests can be made either on the crystal in a rock section or on the isolated crystal or fragment, the latter method being preferable when possible.

CHEMICAL TESTS MADE ON CRYSTAL IN SECTION.

The part of the section to be tested must be prepared by thorough washing with alcohol and benzole to remove all traces of balsam. If the section is covered, the cover-glass can be cut across with a diamond, and, after heating, the desired portion removed with a knife edge. Any portion of a section can be isolated by surrounding it with a rim of viscous balsam or by putting on a new cover-glass, in which a small hole has been made.[133] This hole can be accurately adjusted over the special portion of the section and the balsam removed by alcohol and benzole.

The treatment of rock sections with ordinary acids, such as hydrochloric, may show the presence of easily soluble minerals[134] and carbonates, or distinguish silicates that are soluble with jelly, or produce etched figures on the minerals.

Test for Carbonates. When only present in very minute grains the test can be made as follows: Cover the rock section with a drop of water and a cover-glass, then allow a drop of acid to slowly diffuse through the water film. The glass cover will prevent the escape of the gas bubbles[135] which will thus surely be detected.

If necessary the section can be warmed by heating the projecting part of a suitable stand, placed under the section on the stage of the microscope.

Test for Gelatinizing Silica. Cover the carefully cleansed section with a little dilute acid (commonly hydrochloric) and let stand. If too much acid is used the resultant gelatin will spread over the whole section and not appear simply on the gelatinizing silicate. Warm the section, if necessary, and finally rinse off the remaining acid thoroughly with water. Do not allow the action of the acid to continue too long, as it is desirable to obtain only a very thin film of gelatinous silica over the minerals attacked, so that the optical tests can still be made on these minerals. If after the first trial the action has not been pronounced enough, the test should be repeated.

The transparent film of gelatinous silica is made more visible by covering the section with a drop of water, containing a dilute solution of fuchsine. After standing for some time the section should be washed, when only those portions covered by the gelatinous film will show the color stain.

ETCHED FIGURES.[136]

The results of etching tests can not be regarded as very satisfactory in the case of sections of minerals in rock sections, on account of doubt as to the crystallographic orientation of these sections.

The symmetry of the etched figures depends essentially on the relation of the crystal faces on which they are obtained to the planes of symmetry.

The forms of the etched figures differ on the same face of a mineral, depending on the reagent used, but their degree of symmetry is independent of the reagent or its degree of concentration. The sharpest figures are produced on crystal and cleavage faces, the figures being less perfect on artificially prepared faces, even when polished. The etching tests may, however, be tried to prove the presence of twinning, or to distinguish between minerals of similar appearance but belonging to different systems.[137]

Various acids or alkalies are used to produce the etched figures, depending on the mineral to be tested. Different factors influence the formation of good etched figures, and that method must be used which seems to give most satisfactory results in the given case. The action of the reagent should be sufficiently pronounced to develop clearly the etched figures; at the same time the tests must be stopped before the solvent action has been too powerful.[138] After treatment for etching the section should be thoroughly washed and examined in some fluid of weak refraction (with _n_ lower than that of the crystal section), such as water or air.[139] The objective, of course, must be focused on the surface of the section.

HEATING SECTIONS TO REDNESS.[140]

The part of the section to be tested must be removed from the object glass, carefully cleansed of balsam, and held on platinum foil in the oxidizing blowpipe flame. After the test the fragment used may be remounted in Canada balsam for study.

As a result of heating:

Colorless, hydrous minerals (zeolites and chlorites) become cloudy in appearance.

Colorless silicates, containing protoxide of iron (as olivine, or faintly colored pyroxene or amphibole), become red or reddish-brown.

Colored minerals may change their color, chloritic substances becoming brown or black if heated enough.

Hornblende always becomes pleochroic, and olivine sometimes becomes so.

Members of the sodalite group may be turned blue, if not already of that color.

The dichroism (yellow to blue) of almost colorless iolite may be developed.

Carbonaceous particles may be distinguished from the iron oxides by being consumed.[141]

METHODS OF ISOLATING CRYSTALS OR MINERAL FRAGMENTS FOR TESTING.[142]

For the application of these methods the rock or aggregate of minerals should be reduced to homogeneous[143] grains of uniform size (preferably crystals or cleavages) and not to powder. This is best done by pounding in a metal mortar, avoiding all grinding motion.

The separations required may be made by specific gravity solutions or magnetic methods, alone or combined; and in some cases may be assisted by chemical action.

When other methods fail it may be necessary to separate single grains from a mixture by hand. A grooved piece of plate-glass, passed beneath the objective of the microscope, will be found useful. The desired grains in this groove can be picked out by means of a piece of fine waxed thread or a fine pointed stick moistened at the end.

The _hardness_ of the homogeneous grains may be obtained by pressing them firmly into the end of a lead stamp or holder and trying the effect of scratching upon the faces of minerals of known hardness.

Specific Gravity Separation.[144] Accomplished by use of fluids of different specific gravity. These fluids can be made specifically lighter by dilution, and hence the fragments will fall to the bottom in order of decreasing density. Dilution of the heavy solutions to any specific gravity may be affected empirically until the solution will just suspend a fragment of a mineral having the desired specific gravity; or the exact specific gravity of the solution may be determined by the Westphal balance.

The following _indicators_ may be employed to determine the limits of the specific gravity of the solution to be used for separation purposes (V. Goldschmidt):

NO. NAME. LOCALITY. SP. GR. 1. Sulphur, Girgenti, 2.070 2. Hyalite, Waltsch, 2.160 3. Opal, Scheiba, 2.212 4. Natrolite, Brevig, 2.246 5. Pitchstone, Meissen, 2.284 6. Obsidian, Lipari, 2.362 7. Pearlite, Hungary, 2.397 8. Leucite, Vesuvius, 2.465 9. Adularia, St. Gotthard, 2.570 10. Elæolite, Brevig, 2.617 11. Quartz, Middleville, 2.650 12. Labradorite, Labrador, 2.689 13. Calcite, Rabenstein, 2.715 14. Dolomite, Muhrwinkel, 2.733 15. Dolomite, Rauris, 2.868 16. Prehnite, Kilpatrick, 2.916 17. Aragonite, Bilin, 2.933 18. Actinolite, Zillerthal, 3.020 19. Andalusite, Bodenmais, 3.125 20. Apatite, Ehrenfriedersdorf, 3.180

Among the heavy solutions employed may be mentioned:

Thoulet's solution of potassium-mercuric iodide (KI: HgI_2 = 1: 1.24), maximum specific gravity 3.196. Klein's solution of cadmium borotungstate ($2H_2O$, 2CdO, B_2O_3, $9WoO_3$ + $16H_2O$), maximum specific gravity 3.6. These two solutions can be mixed with water in any proportion without being decomposed. Solution of barium mercuric iodide, maximum specific gravity, 3.588, cannot be diluted with water. Methylene iodide (CH_2I_2), specific gravity 3.3243 at 16° C. varying with the temperature, can be diluted with benzole but not with water.

Nitrates of silver and thallium[145] ($AgNO_3$: $TlNO_3$ = 1.1) fuse at about 75° C. to a clear mobile liquid with specific gravity over 4.5. Can be mixed while melted with water in all proportions; but cannot be used for separation of sulphides, as these nitrates are attacked by them.

Possible chemical action between the minerals and heavy solutions must not be overlooked in this method of separation.

The funnel-shaped apparatus for these separations must be so arranged, with stop-cocks, etc., that the heavier material collected at the bottom can be easily drawn off or removed at any stage of dilution.

These separations, for various reasons, are not always complete, but the best results are obtained when the processes are repeated several times.

Electro-magnetic Separation. All iron-bearing minerals may be separated from those free from iron by an electro-magnet.

The factors influencing the attraction of a mineral by an electro-magnet are not definitely known, and do not seem to depend only on the percentage of iron.

Minerals, such as amphibole, pyroxene, epidote, olivine and garnet (containing iron), may often be separated by an electro-magnet by regulating its magnetic intensity.[146]

Separation by Chemical Means. Very many different methods may be used, depending on the nature of the work to be accomplished; but they are generally only reliable in the hands of a good chemist. The material should be in the state of fine powder.

As an example may be mentioned the treatment with pure concentrated HFl, by which the minerals of a rock are attacked in a certain sequence, the feldspars and related minerals first, then the quartz and finally the ferro-magnesium silicates, such as amphibole, pyroxene, olivine, etc.

MICRO-CHEMICAL REACTIONS.

The first requisite is to bring the substance to be investigated into solution. This can be done in the case of non-silicates by the ordinary solvents, while silicates can be decomposed and investigated either by the methods of Borichy or Behrens. Both methods rest upon the recognition of the forms, etc., of artificially produced crystals.

The size of a fragment for testing may vary, according to circumstances, from that of a poppy seed to a pin head. Good results are recorded from fragments of not more than 0.2–0.7 sq. mm.

The substance to be tested is placed on glass, protected by a film of balsam, and covered with a spherical drop of the solvent,[147] which should be allowed to act until all the different elements composing the sample are in solution (in the case of a very small fragment until it has all dissolved). Transfer the solution to another protected object glass, and, after evaporation, the crystallizations characteristic of the different elements will be seen.

If the evaporation is too rapid and the crystallizations incomplete, the residue should be redissolved in water, or a very dilute solution of the solvent employed, transferred to a fresh glass and allowed to recrystallize.

Borichy's Method.[148] (Hydrofluosilicic Acid.)

This method has the advantage of simplicity of manipulation and relative distinctness in results; but on the other hand these results are only obtained after several hours, and the temperature has an influence on the crystalline forms obtained. It is well to make the tests in a temperature of about 15° C.

Put a spherical drop of pure hydrofluosilicic acid[149] on the fragment and leave it for some hours in damp air until the action has been sufficient, then transfer it to a dry air bell-glass and allow evaporation and crystallization to take place.

For the microscopic examination the objective (200–300 diams. best for these observations) can be protected with glycerine and a mica disc or thin cover-glass, or the drop can be all evaporated and the crystals covered with liquid balsam and a cover-glass.

Crystallizations Obtained by Borichy's Method.

Potassium. From hydrofluosilicic solutions,[150] isotropic, colorless crystals of $K_{2}SiFl_{6}$, in cubes, octahedra or combinations of these forms with the rhombic dodecahedron. Apparently orthorhombic crystals may form from acid solutions and at a low temperature, but if these crystals are dissolved in hot water and recrystallized they will assume the normal forms.

Platinic chloride will produce under proper conditions sharp, yellow octahedra of $K_{2}PtCl_{6}$.

[Illustration:

FIG. 78.—Fluosilicate of potassium.[151]]

[Illustration:

FIG. 79.—Fluosilicate of sodium.[151]]

Sodium. From hydrofluosilicic solutions, colorless, very weakly doubly refracting, hexagonal crystals of $Na_{2}SiFl_{6}$, which are generally longer the higher the percentage of sodium in the solution. This test is very certain even for small amounts.

[Illustration:

FIG. 80.—Fluosilicate of calcium.[151]]

[Illustration:

FIG. 81.—Fluosilicate of magnesium.[151]]

Calcium. From hydrofluosilicic solutions, monoclinic crystals of $CaSiFl_{6} + 2H_{2}O$ of various forms, generally spindle-shaped, with not very strong double refraction. The crystals have seldom straight-edged boundaries and are often grouped in rosettes. The addition of dilute $H_{2}SO_{4}$ decomposes the crystals, recrystallization yielding long prismatic crystals of gypsum (distinction from strontium).

Treatment with HFl and dilute H_2SO_4 (in excess), producing on evaporation characteristic crystals of gypsum, furnishes a very delicate test for small percentages of calcium.

Magnesium. From hydrofluosilicic solutions, rhombohedral crystals of $MgSiFl_6 + 6H_2O$ with plane faces and sharp edges. The crystals are colorless and strongly doubly refracting with positive optical character, Fig. 81.

The formation of struvite crystals ($NH_4MgPO_4 + 6H_2O$), of coffin-like forms, is very characteristic and takes place from very dilute solutions (rendered alkaline) on the addition of a grain of salt of phosphorus or a drop of sodium phosphate.

Iron. From hydrofluosilicic solutions, crystals of $FeSiFl_6 + 6H_2O$, which are isomorphous with those of magnesium salts, with the same optical characters. They may be differentiated by moistening with potassium ferrocyanide or ammonium sulphide, in the first case by turning blue, in the second case black.

Aluminium. From hydrofluosilicic solutions, not satisfactory on account of the gelatinous formation.

When the gelatinous formation is obtained by the action of hydrofluoric acid on an _aluminous silicate_, the staining test can be used to distinguish between fine grains of feldspar and quartz or iolite and quartz.

Behrens' Method.[152] (Hydrofluoric and Sulphuric Acids.)

This method depends on common reactions that can be made rapidly, but has the disadvantage of being rather complicated and requiring delicate manipulation.

The tests are best made upon about ½ mg. of powder with HFl (pure and fuming). As soon as the fluorides begin to dry treat with dilute H_2SO_4 and warm until white fumes of SO_3 appear. In this way the HFl and $SiFl_4$ are driven off and the sulphates are left. This part of the test can conveniently be made on a piece of platinum foil. Add excess of water and concentrate.

Transfer a drop to a clean object glass and, while still liquid, examine it with the microscope. Do not use a cover-glass over the drop.

Crystallizations Obtained by Behrens' Method.

Potassium. Add a little platinic chloride when octahedral crystals of K_2PtCl_6 (size .18 to .30 mm.) will appear, which are clear, bright yellow in color with strong refraction.

[Illustration:

FIG. 82.—Potassium platinic chloride.[153]]

[Illustration:

FIG. 83.—Sulphate of calcium (gypsum).[153]]

Sodium. Use sulphate of cerium and allow a small amount of this reagent to act through a capillary pipette upon a drop of the solution. Very small aggregates of brown crystals (size .02 mm.) of the double sulphate of cerium and sodium are formed, which are clearly visible with 600 diams. If potassium is present the double sulphate of that alkali will appear in larger, grayish grains (size .05 to .06 mm.). An excess of H_2SO_4 is to be avoided.

Calcium. After a few minutes little gypsum crystals ($CaSO_4 + 2H_2O$) will appear. In strongly acid solutions the thin acicular crystals will be grouped in bushes or stars; in neutral solutions the crystals will have the normal shape of selenite crystals or form swallow-tailed twins.

Magnesium. Use salt of phosphorus dissolved in water and allow it to mix with the solution (to which has been added ammonium chloride and ammonia) through a capillary pipette. From a solution containing more than 5 per cent. of magnesium are first deposited X-shaped skeletons and rudimentary crystals of $Mg.NH_4.PO_4 + 6H_2O$. If the solution is more dilute beautiful, sharp, hemimorphic crystals (.10 to .20 mm. in size) of the orthorhombic system will appear. These crystals often resemble the roof of a house. The formation of the crystals is assisted by heat. Iron and manganese phosphates yield crystals of the same type, but the iron is separated on the addition of ammonia.

Aluminium. Use chloride of cæsium. Take a drop of the solution, with excess of H_2SO_4 driven off, and touch it with a platinum wire that has been dipped in the melted chloride of cæsium. Large crystals (.40-.90 mm. in size) of cæsium alum will form, which are octahedral and cubo-octahedral in shape. Iron does not interfere, as its crystallization would take place much more slowly. The solution should not be too concentrated.

[Illustration:

FIG. 84.—Magnesiumammonium phosphate.[154]]

[Illustration:

FIG. 85.—Cæsium alum.[154]]

Special Tests.

Distinction between haüynite (contains $CaSO_4$) and noselite (contains Na_2SO_4). Treat with HCl and on evaporation the characteristic crystals of gypsum will be seen if the mineral is haüynite. Dilute acid should be used and as low a temperature maintained as possible, otherwise crystals of anhydrite would form instead of gypsum.

Recognition of apatite by test for phosphorus. Treat with a drop of ammonium molybdate dissolved in HNO_3. After complete action remove the solution to a clean object glass, when after slight warming a large number of very small yellow crystals (rhombic dodecahedral in shape) will form. The test may be used to distinguish this mineral from nephelite, melilite and natrolite. In the presence of soluble silica evaporate to render it insoluble and treat again with HNO_3 and the reagent.

Other micro-chemical tests are not mentioned for the reason that in elaborate chemical investigations of sections or isolated fragments recourse should be made to the most complete publications on the subject.

APPENDIX.

BRIEF SCHEME OF CLASSIFICATION INTO SYSTEMS BY OPTICAL DETERMINATIONS.

■HOMOGENEOUS.■ The whole substance shows the same optical character, except in the case of twin crystals when the different portions of the twin are affected differently.

■Isotropic■ All sections of the substance remain dark during a complete rotation between crossed nicols, and no interference figure is produced by convergent light.

Amorphous Absence of crystalline form or cleavage.

Isometric Presence of crystalline form or cleavage.

■Anisotropic.■ Sections generally show some interference color and extinguish four times, at 90° apart, during complete rotation.

Uniaxial. Determined by character of interference figures obtained by convergent light from sections which remain dark or nearly so during complete rotation.

All sections show parallel or symmetrical extinction.

Tetragonal Sections giving interference figures are four- or eight-sided, or show rectangular cleavage.

Hexagonal Sections giving interference figures are three-, six- or nine-sided, or show cleavage lines intersecting at 60°.

Biaxial Determined by character of interference figures obtained by convergent light.

Orthorhombic Extinction is parallel or symmetrical in all sections parallel to _■_, [_=b_] and _■_. Color distribution is symmetrical to two lines and to the central point, see p. 48.

Monoclinic Extinction is only parallel or symmetrical in sections parallel to the ortho axis [_=b_]; all other sections show extinction angles. Color distribution is only symmetrical to one line or to the central point, see p. 48.

Triclinic Extinction angles in all sections, although in some minerals these angles may be very small. No symmetry in color distribution, see p. 48.

■AGGREGATE.■ Not homogeneous, but made up of an aggregation of individuals, all extinguishing at different times.

Double Refraction (maximum).[155]

0.287 Rutile

0.179 Dolomite

0.172 Calcite

0.141 Titanite

0.090 Titanite

0.072 Hornblende (basaltic)

0.062 Zircon

0.058 Biotite

0.050 Talc

0.050 Ægirite

0.041 Muscovite

0.037 Epidote

0.036 Chrysolite (Olivine)

0.036 Scapolite (Meionite)

0.034 Tourmaline

0.034 Phlogopite

0.030 Allanite (Orthite)

0.029 Diopside

0.027 Actinolite

0.027 Tremolite

0.024 Hornblende (common)

0.024 Diallage

0.024 Anthophyllite

0.023 Augite

0.021 Sillimanite (Fibrolite)

0.018 Glaucophane

0.017 Tourmaline (precious)

0.016 Cyanite (Disthene)

0.013 Hypersthene

0.013 Scapolite (Marialite)

0.013 Anorthite

0.012 Natrolite

0.011 Chlorite (Clinochlore)

0.011 Andalusite

0.011 Topaz

0.010 Staurolite

0.010 Gypsum

0.010 Enstatite

0.010 Serpentine

0.009 Corundum

0.009 Iolite (Cordierite)

0.009 Quartz

0.008 Topaz

0.008 Kaolin

0.008 Labradorite, Ab_{1}An_{1}

0.008 Oligoclase, Ab_{4}An_{1}

0.008 Albite

0.007 Orthoclase

0.007 Microcline

0.006 Vesuvianite

0.005 Zoisite

0.004 Nephelite (Elæolite)

0.003 Apatite

0.003 Melilite

0.002 Tridymite

0.002 Leucite

0.002 Allanite (Orthite)

0.001 Chlorite (Penninite)

0.001 Vesuvianite

Indices of Refraction (mean).[155]

2.712 Rutile

2.38 Perofskite

2.00 Spinel (Chrome)

1.963 Titanite

1.95 Zircon

1.920 Titanite

1.856 Garnet (Melanite)

1.792 Ægirite

1.78 Allanite (Orthite)

1.78 Garnet (Almandite)

1.766 Corundum

1.751 Epidote

1.75 Garnet (Pyrope)

1.741 Staurolite

1.723 Hypersthene

1.72 Spinel

1.720 Zoisite

1.720 Cyanite (Disthene)

1.719 Hornblende (basaltic)

1.715 Vesuvianite

1.711 Augite

1.699 Zoisite

1.697 Diopside

1.688 Diallage

1.675 Chrysolite (Olivine)

1.665 Enstatite

1.664 Sillimanite (Fibrolite)

1.674 Tourmaline

1.644 Anthophyllite

1.64 Hornblende (common)

1.637 Andalusite

1.635 Apatite

1.632 Glaucophane

1.632 Topaz

1.630 Melilite

1.633 Tourmaline (precious)

1.622 Dolomite

1.621 Actinolite

1.621 Tremolite

1.618 Biotite

1.608 Topaz

1.588 Chlorite (Clinochlore)

1.587 Muscovite

1.582 Anorthite

1.576 Chlorite (Penninite)

1.572 Talc

1.584 Scapolite (Meionite)

1.564 Phlogopite

1.56 Serpentine

1.559 Labradorite, Ab_{1}An_{1}

1.55 Kaolin

1.547 Quartz

1.551 Scapolite (Marialite)

1.601 Calcite

1.541 Oligoclase, Ab_{4}An_{1}

■1.54■ + ■Canada balsam■

1.539 Nephelite (Elæolite)

1.539 Iolite (Cordierite)

1.535 Albite

1.525 Gypsum

1.525 Microcline

1.523 Orthoclase

1.509 Leucite

1.503 Haüynite

1.488 Analcite

1.483 Natrolite

1.483 Sodalite

1.477 Tridymite

1.46 Opal

[Illustration:

Diagram showing relation between strength of Double Refraction, Interference Colors and Thickness of Section.[156]]

ORDER OF CONSOLIDATION OF THE CONSTITUENT MINERALS IN PLUTONIC ROCKS.

"There is in plutonic rocks a normal order of consolidation for the several constituents, which holds good with a high degree of generality. It is in the main, as pointed out by Rosenbusch, a law of 'decreasing basicity.' The order is briefly as follows:

"1. Minor accessories (apatite, zircon, sphene, garnet, etc.) and iron ores.

"2. Ferro-magnesian minerals—olivine, rhombic pyroxenes, augite, ægirine, hornblende, biotite, muscovite.

"3. Felspathic minerals—plagioclase felspars (in order from anorthite to albite), orthoclase (and anorthoclase).

"4. Quartz, and finally microcline.

"In most rocks such minerals as are present follow the above order. The most important exceptions are the intergrowth of orthoclase and quartz and the crystallization of quartz in advance of orthoclase in some acid rocks, and the rather variable relations between groups 2 and 3 in some more basic rocks. The order laid down applies in general to parallel intergrowths of allied minerals; thus when augite is intergrown with ægirine or hornblende the former mineral forms the kernel of the complex crystal and the latter the outer shell; when a plagioclase crystal consists of successive layers of different compositions the layers become progressively more acid from the center to the margin.

"Certain constituents having variable relations are omitted from the foregoing list. Thus nepheline (elæolite) and sodalite belong to group 3, but may crystallize out either before or after the feldspar."[157]

OPTICAL SCHEME.

INTRODUCTION.

The scheme is designed to furnish the student with a practical method of recognizing the common minerals in rock sections.

The arrangement followed has been to group minerals having general optical characters in common, at the same time giving their specific characters so as to make it possible to distinguish one from another. In each rectangle the minerals are arranged in order of their indices of refraction.

A tabulation of the minerals, with a list of optical characters appended, is of aid to the skilled investigator, but of very little assistance to the beginner.

The more common minerals, or those which are important petrographically, are printed in heavy-faced type; the minerals of less importance in small capitals.

ABBREVIATIONS AND CONVENTIONS USED.

A. = Amorphous.

I. = Isometric system.

T. = Tetragonal system.

O. = Orthorhombic system.

M. = Monoclinic system.

Tri. = Triclinic system.

H. = Hexagonal system.

M(H). = Monoclinic, with hexagonal form or characters, as in the case of biotite.

■ = At right angles to.

El. = Elongation.

Ex. = Extinction.

■ Ex. = Parallel extinction, as when the crystals extinguish parallel to cleavage lines or crystal edges. Extinction which is symmetrical to intersecting cleavage lines is also included under this term.

The mean refractive indices are printed in heavy-faced type.

The term "grains" is used to describe not only minerals which occur in typically granular form, but also those which have coarser allotriomorphic form, as elæolite and sodalite in plutonic rocks, such as syenite, etc.

GENERAL RULES FOR USE OF SCHEME.

The division of the scheme into two vertical columns is based on the values of the mean refractive indices, as determined by the "relief" and appearance of the surface. When the refractive index is above 1.60, the relief is fairly well to distinctly marked and the surface rough to very rough, depending on the value of the index.

Most of the rock-forming minerals with indices below 1.60 show no relief and a smooth surface, except in the case of a few of the rarer minerals (mostly isometric), which have very low indices and hence rough surface.

Mistakes may easily be made in the case of minerals near the limit; but practice and the use of the Becke test should soon make possible the classification into the two groups suggested by the scheme, and the appended descriptions will help to check errors.

When an unknown mineral lies adjacent to one that is known, use the Becke test for obtaining the relative refractive index of the unknown mineral; focus sharply on the line of contact between the known and unknown minerals,[158] then raise the objective slightly and the "bright line" will appear on the side of the mineral having the higher index. The method of Schrœder van der Kolk may also be employed, see p. 22.

The horizontal divisions of the scheme depend on the relative strength of the double refraction based on the observed interference colors. These colors to be of use in classification must be correctly recognized. The lower and middle colors of the 1° order, from bluish-gray through white to yellow, are easily known. The bright red, blue, green, etc., colors of the 1°, 2° and 3° orders can also be differentiated without trouble from the very high order colors (4° and above), which are essentially white in tone with no decided color tint.

When confusion arises, the exact order of the color can be determined by a quartz wedge, as given on p. 35. Furthermore, a ¼ undulation mica plate serves to quickly distinguish between the 1° order white and the practically colorless, high order tint of calcite, titanite, etc.; as after the insertion of the test-plate the 1° order white suffers a marked change in color, while the very high order (practically white) tint shows no appreciable change.

In the determination of these interference colors care must be given to considerations of orientation and thickness. The section must give the maximum interference color of all the obtainable sections of the mineral in the rock section. Such sections will be parallel to the _■_ axis in the uniaxial minerals and to the axial plane in the biaxial minerals; and will, therefore, in convergent light never show the emergence of an optic axis or bisectrix. Crystal "form," cleavage, pleochroism, etc., may at times aid in the selection of these sections. The thickness of the section must also be considered, and it is well in all cases to pick out some known mineral in the section, as quartz, and note its maximum interference color. Knowing how this varies from the color given by the scheme for a section 0.03 mm.[159] in thickness, due allowance can be made for a like variation in the colors given by the other minerals. In the case of minerals with strong absorption the interference colors may not be noticeable on account of the absorption of parts of the light.

Under the subhead of pleochroism, the vibration direction of the ray of a definite color is given and not the direction of transmission of that ray.

The interference figures in convergent light increase in clearness and distinctness with the strength of the double refraction. In uniaxial crystals sections at right angles to the optic axis, _i. e._, sections which remain dark during a revolution between crossed nicols, show the best interference figures. In biaxial crystals the most characteristic interference figures are shown by sections at

right angles to the acute bisectrix.

Crystal sections which are too small do not give very satisfactory interference figures with convergent light.[160]

Any scheme, however designed, makes a more or less arbitrary classification of the minerals, and when in doubt it is always safer to look for the mineral on both sides of the scheme line.

The rarer minerals are not included in this scheme, so when the determination of a mineral is uncertain or not positive recourse should be had to more elaborate tables.

INDEX.

MINERAL NAMES IN HEAVY-FACED TYPE.

Abbreviations, ix

Abnormal interference colors, 30

Absorption, 26 directions, 26 tints, 17

■Acmite■, 83

■Actinolite■, 84

Acute bisectrix, 5

■Ægirine■, 83

■Ægirine-augite■, 84

Aggregate structure, 38

■Albite■, 103

■Allanite■, 96

Allotriomorphic, 15

Aluminium, test for, by Borichy's method, 137 test for, by Behren's method, 139

Amorphous bodies, 2

Amorphous substances, test for, 26

■Amphibole■, 84

■Analcite■, 56

Analyzer, 10

■Andalusite■, 72

Anhedron, 15

Anisotropic character, test for, 27

Anisotropic crystals, 2

Anomalies, optical, 27

■Anorthite■, 103

■Anorthoclase■, 113

■Anthophyllite■, 88

■Antigorite■, 114

■Apatite■, 68

Apatite, recognition of, by test for phosphorus, 139

Apparatus for petrographical laboratory, 127

Appendix, 141

■Arfvedsonite■, 88

■Augite■, 80

Automorphic, 13

Axes of elasticity, 4

Axial angle, 5 determination of, 47

Axial plane, 5

■Basaltic Hornblende■, 85

■Bastite■, 77

Becke's method for determining relative values of refractive indices, 19

Behren's method. (Hydrofluoric and sulphuric acids), 137

Bertrand lens, 11

Biaxial crystals, 4, 5 vibration directions in, 4

Biaxial interference figures, 43

■Biotite■, 89

Bisectrix, acute, 5 obtuse, 5

Borichy's method. (Hydrofluosilicic acid), 135

Broken or strained crystals, 15

■Bronzite■, 76

■Calcite■, 65

Calcium, test for, by Borichy's method, 136 test for, by Behren's method, 138

"Cap" nicol, 10

■Carbonaceous Matter■, 61

Carbonaceous particles, test for, 132

Carbonates, test for, 130

Cement, 122 for mounting, 126

Cementing, 121

Centering stage, 10

■Chalcedony■, 64

Characters observed by, convergent light, 40 crossed nicols, 26 reflected light, 13 polarized light, 25

Characters of opaque minerals, 13 transparent minerals, 13

Chemical and mechanical tests, 129

Chemical (micro) reactions, 134 separation, 134 tests on crystal in section, 129

■Chiastolite■, 72

■Chlorite group■, 92

■Chromite■, 52

■Chrysolite■, 77

■Chrysotile■, 114

Circular polarization, 3

Classification into systems by optical determinations, 141

■Clay■, 115

Cleaning and finishing sections, 126

Cleaning microscope, 11

Cleavage, 23

■Clinozoisite■, 96

Color, 17 diagram (interference), 143 fringes, 48

Condensing lens, 9

Consolidation of minerals in plutonic rocks, order of, 144

Conventions, ix

Convergent light, 40 characters observed by, 40

Convergent and parallel light, résumé of uses of, 49

■Cordierite■, 78

Corroded crystals, 15

■Corundum■, 62

Crossed nicols, characters observed by, 26

Crossed twinning, 37

Crystallites, 16

Crystallizations obtained by Behren's method, 137 Borichy's method, 135

Crystals bounded by planes, 13

Crystals without bounding planes, 15

Cutting, 120

Cutting and grinding machines, 117

■Cyanite■, 113

■Damourite■, 92

■Delessite■, 94

Diagram, showing relation between strength of double refraction, interference colors and thickness of section, 143

■Diallage■, 80

Diamond saws, 119

■Dichroite■, 78

■Diopside■, 80

■Dipyre■, 59

Directions of elasticity, ix

Dispersion, 5, 48

■Disthene■, 113

■Dolomite■, 67

Double image, 2

Double refraction, 2, 27 estimation of strength of, 30 strength of, measured by von Federow mica wedge, 35 table (maximum), 142

Effects produced by crystals on transmitted light, 2

■Elæolite■, 69

Elasticity, axes of, 4 directions of, ix

Electric motor for grinding machines, 117

Electro-magnetic separation, 134

Emery, grades of, for grinding, 124

■Enstatite■, 75

■Epidote■, 94

Etched figures, 130

Extinction, 31 angles, 5, 31 tests for, 32 wavy, 31

Extraordinary ray, 3

Eye-pieces, 11

Faster and slower rays, test for vibration directions of, 33

■Fayalite■, 78

■Feldspar Group■, 98

Feldspathoids, 69

■Fibrolite■, 73

Finishing and cleaning sections, 126

Focusing, 11

Form of crystals, 13

Fracture, 24

■Garnet■, 53

Gelatinizing silica, test for, 130

Glass slides, 125

■Glaucophane■, 88

■Graphite■, 61

Gravity (specific) separation, 133

Gridiron twinning, 37

Grinding, 123

Grinding and cutting machines, 117 apparatus for sections with parallel faces, 118 plates or laps, 121

■Gypsum■, 80

Gypsum test-plate, 33

Hardness of grains, 132

■Haüyne■, 56

■Haüynite■, 56

Haüynite and noselite, micro-chemical distinction between, 139

Heating sections to redness, 131

Heavy solutions, 133

■Hematite■, 61

Hexagonal crystals, 4

High relief, 17

■Hornblende■, 84

■Hyalosiderite■, 78

■Hydrargillite■, 115

Hydrofluosilicic acid test, 135

■Hypersthene■, 75

Idiomorphic, 13

■Idocrase■, 60

■Ilmenite■, 62

Inclusions, 24

Index of refraction, ix, 17 by Becke's method, 19 by Schrœder van der Kolk's method, 22 by Sorby's method, 19

Indicators for specific gravity separation, 133

Indices of refraction (mean), table of, 142

Interference color, determination of order of, 35

Interference colors, 28

Interference colors (abnormal), 30

Interference figures, 40 biaxial, 43 uniaxial, 40

Investigation of microscopic and optical characters of minerals, 13

■Iolite■, 78

Iron, test for, by Borichy's method, 137 test for, by Behren's method, 139

Isolating crystals or mineral fragments for testing, 132

Isometric crystals, 2

Isotropic character, 26, 40 crystals, 2

■Kaolin■, 115

■Labradorite■, 103

Laps for grinding, 121

■Leucite■, 54

Leucoxene, 62

Light, ordinary, 1 plane polarized, 1

■Limonite■, 51

■Lithia Mica■, 92

Machines for cutting and grinding, 117

Magnesium, test for, by Borichy's method, 137 test for, by Behren's method, 138

■Magnetic iron ore■, 52

■Magnetic pyrites■, 51

■Magnetite■, 52

Measuring strength of double refraction by von Federow mica wedge, 35

Mechanical and chemical tests, 129

■Melilite■, 61

■Menaccanite■, 62

Methods of preparing sections, 117

■Mica Group■, 89

Mica plate (quarter undulation), 33

Mica wedge, von Federow, 35

Micro-chemical reactions, 134

■Microcline■, 102

Microlites, 17

Microscope (petrographical), 7

Microscopic and optical characters of minerals, 51

Minerals and thickness of section, determined by table and diagram, 36

Monoclinic crystals, 4 principal vibration directions in, 5

■Monoclinic pyroxenes■, 80

Mounting sections, 124 solutions, 125

■Muscovite■, 89

■Natrolite■, 79

Negative optical character, biaxial, 46 uniaxial, 42

■Nepheline■, 69

■Nephelite■, 69

Nicol prism, 7

■Nosean■, 56

■Noselite■, 56

Noselite and haüynite, micro-chemical distinction between, 139

Nose-piece for microscope, 10

Objectives, 10

Oblique extinction, 31

Obtuse bisectrix, 5

■Oligoclase■, 103

■Olivine■, 77

■Opal■, 51

Opaque minerals, characters of, 13

Optical, anomalies, 27 character, biaxial, 46 character, uniaxial, 42 classification into systems, 141 distinctions between orthorhombic, monoclinic and triclinic sections (perpendicular to bisectrices), 48, 141 distinctions between tetragonal and hexagonal sections (perpendicular to optic axis), 141 and microscopic characters of minerals, 51 principal section, 3, 4 scheme, 145

Optic axes, 4

Optic axis, 3

Optics for optical mineralogy, 1

Order of consolidation of minerals in plutonic rocks, 144

Order of interference color, determination of, 35

Ordinary light, 1 ray, 3

■Orthite■, 96

■Orthoclase■, 98

Orthorhombic crystals, 4 principal vibration directions in, 4

■Orthorhombic pyroxenes■, 75

Parallel and convergent light, résumé of uses of, 49

Parallel extinction, 31

Parallel face sections, grinding apparatus for, 119

■Pargasite■, 85

■Perofskite■, 57

■Perovskite■, 57

Petrographical apparatus, 127

Petrographical microscope, 7

Phenocryst, 14

■Phlogopite■, 89

■Picotite■, 53

■Piedmontite■, 95

■Plagioclases■, 103

Plane polarized light, 1

Plates, grinding, 121

Pleochroic halos, 59

Pleochroism, 25 test for, 25

■Pleonaste■, 53

Polarization colors, 28

Polarized light, characters observed by, 25 plane, 1

Polarizer, 7 test for vibration plane of, 9

Polishing sections, 124

Polysynthetic twinning, 37

Positive optical character, biaxial, 46 uniaxial, 42

Potassium, test for, by Borichy's method, 136 test for, by Behren's method, 138

Preparation of sections, 117

Principal section, optical, 3, 4

Principal vibration directions, 3, 4

Prism, nicol, 7

Pseudomorphic structure, 39

■Pyrite■, 51

■Pyrites■, 51

■Pyroxenes, monoclinic■, 80

■Pyroxenes, orthorhombic■, 75

■Pyrrhotite■, 51

Quarter-undulation mica plate, 33

■Quartz■, 63 wedge, 34

Reflected light, characters observed by, 13

Reflector, 7

Refraction, double, 2, 27

Refraction, index of, ix, 17

Refractive indices (mean), table of, 142

Relief, 17 test for, 17, 18

Resorption border, 15

Résumé of uses of parallel and convergent light, 49

Rotating stage of microscope, 10

■Rutile■, 57

■Sagenite■, 58

■Sanidine■, 102

■Saussurite■, 96, 113

Saws, 119

■Scapolite Group■, 59

Scheme of classification into systems by optical determinations, 141

Scheme, optical, 145

Schiller structure, 25

Schrœder van der Kolk's method for determining refractive indices, 22

Sections, methods of preparing, 117 thickness of rock, 124

Selenite plate, 33

Separation, by chemical means, 134 by electro-magnet, 134 by specific gravity, 133

■Sericite■, 92

■Serpentine■, 114

Shagreened surface, 17

■Shorl■, 70

■Sillimanite■, 73

Simple twinning, 37

Single image, 2

Skeleton forms, 17

Slides, glass, 125

Slower and faster rays, test for vibration directions of, 33

■Sodalite■, 56

■Sodalite Group■, 56

Sodium, test for, by Borichy's method, 136 test for, by Behren's method, 138

Sorby's method for determining index of refraction, 19

Special micro-chemical tests, 139

Specific gravity separation, indicators for, 133

Sphærulitic structure, 39

■Sphene■, 96

■Spinel■, 53

Stage of microscope, rotating, 10

■Staurolite■, 74

Strained or broken crystals, 15

Strength of double refraction, measure of, 30, 35

Structure, 37

Symmetrical extinction, 31

Systems, classification into, by optical determinations, 141

Table, double refraction, 142

Table, indices of refraction, 142

■Talc■, 94

Test for vibration plane of polarizer, 9

Tetragonal crystals, 4

Thickness of rock sections, 124

Thickness of section and minerals, determined by table and diagram, 36

■Titanite■, 96

Transmitted light, characters observed by, 13 effect on crystals, 2

Transparent minerals, investigation of characters of, 13

■Tremolite■, 84

Triclinic crystals, 4 principal vibration directions in, 5

■Tridymite■, 65

■Topaz■, 74

■Tourmaline■, 70

Twinning, 37

Uniaxial crystals, vibration directions in, 3

Uniaxial interference figures, 40

■Uralite■, 88

Uralitization, 88

Uses of parallel and convergent light, 49

van der Kolk's, Schrœder, method for determining refractive indices, 22

■Vesuvianite■, 60

Vibration direction, 2 directions of faster and slower rays, test for, 33 directions, principal, 3, 4 plane of nicol, 9 plane of polarizer, test for, 9

von Federow mica wedge, 35

Wavy extinction, 16, 31

Wedge, mica, 35 quartz, 34

■Wernerite■, 59

Xenomorphic, 15

■Zeolites■, 79

■Zircon■, 58

■Zoisite■, 96 α and β, 96

Zonal structure, 38

ERRATA AND ADDENDA.

P. 33, line 23, _for_ beat _read_ be at.

P. 66, line 10, _after_ appearance _add_ (sometimes called "twinkling").

Corrections for mean index of refraction _n′_: p. 60, line 1, 1.551 to 1.584; p. 62, line 29, 1.766; p. 66, line 3, 1.601; p. 67, line 24, 1.622; p. 71, line 10, 1.633 to 1.674.

Corrections for Indices of Refraction (mean) in Table on p. 142: Corundum 1.766; Tourmaline 1.674; Tourmaline (precious) 1.633; Dolomite 1.622; Scapolite (Meionite) 1.584; Scapolite (Marialite) 1.551; Calcite 1.601.

Corrections for mean indices of refraction in Scheme (insert folder): Scapolite 1.551 to 1.584; Calcite 1.601 and transfer to Dolomite rectangle; Dolomite 1.622; Corundum 1.766; Tourmaline 1.633 to 1.674.

Footnote 1:

Often called a direction of maximum elasticity, c′ being a direction of minimum elasticity.

Footnote 2:

Rosenbusch's _Microskopische Physiographie_, p. 156.

Footnote 3:

For a more complete discussion of optics, in connection with Optical Mineralogy, the student is referred to A. J. Moses' _Characters of Crystals_, p. 85, et seq.; Moses' & Parsons' _Mineralogy, Crystallography and Blowpipe Analysis_, Chap. XVI., 4th Ed., 1909; Miers' _Mineralogy_, 1902; L. Fletcher's _Optical Indicatrix_, etc., 1892; Groth's _Physikalische Krystallographie_, 3d Ed.; Rosenbusch's _Mikroskopische Physiographie_, 4th Ed. and Iddings' _Rock Minerals_, 1911.

Footnote 4:

The electromagnetic theory of light is now very generally held, but, whatever may be the recurrent change of state to which light is really due, the principles of wave motion furnish a satisfactory geometric description of optical phenomena.

Footnote 5:

These sections are supposed to have plane parallel faces, such being the case in ordinary practice, and to be examined with parallel perpendicularly incident light.

Footnote 6:

It is interesting to remember in this connection that in the isometric system there is also the greatest possible symmetry of "form."

Footnote 7:

A. J. Moses, _Characters of Crystals_, pp. 85–97.

Footnote 8:

For this branch of optical physics, see A. J. Moses, _Characters of Crystals_, pp. 97–100.

Footnote 9:

This can be demonstrated by using a nicol and a plate of calcite which shows a double image. If the nicol is held between the calcite plate and the observer's eye it can be so adjusted that only one image is seen. If now the nicol is revolved 90° the first image will disappear and the other image alone will be seen.

Footnote 10:

In some cases a peculiar form of double refraction does take place parallel to this direction, as in the circular polarization of quartz and cinnabar; but in very thin sections these results are not noticed and can be disregarded.

Footnote 11:

A. J. Moses, _Characters of Crystals_, pp. 98, 99.

Footnote 12:

The terms axes of elasticity are commonly used for these principal vibration directions in text-books on petrography.

Footnote 13:

Instead of ω and ε, for convenience in tables, etc., α and γ are used, denoting the indices of refraction of the rays traversing the crystal with greatest and least velocity respectively, without regard as to which is the _O_ or _E_ ray. A good reason for this convention is that the symbol $(\gamma - \alpha)$ is used to express in decimals the relative strength of the double refraction of a crystal, whether uniaxial or biaxial. γ is always greater than α.

Footnote 14:

For most cases in observations with white light the "optics axes" may be regarded as approximately fixed in position.

Footnote 15:

Often spoken of as: a, the axis of maximum; b, the axis of intermediate, and c, the axis of minimum elasticity.

In the more recent American text-books on Optical Mineralogy by Iddings, Winchell and Phillips a is denoted by _X_, b by _Y_ and c by _Z_.

Footnote 16:

For a short historical sketch of the use of the microscope in connection with Petrology, see G. H. William's pamphlet, _Modern Petrography (Monographs of Education)_, Boston, 1886. For detail description and adjustments, see _Methods of Petrographic-Microscopic Research_, F. E. Wright, 1911, pp. 11, 61.

Footnote 17:

For description of the ordinary microscope, eye-pieces, objectives, magnification, etc., see _Manipulation of the Microscope_, by Ed. Bausch.

Footnote 18:

Text Book of Mineralogy, by E. S. Dana, 1898 Ed., p. 176.

Footnote 19:

It is convenient to assume that the vibrations of the polarized light are taking place in this plane, called the "plane of vibration," but all the phenomena caused by polarized light could be also explained on the assumption that the vibrations were taking place at right angles to this plane.

Footnote 20:

This condensing lens must be removed when very low power objectives are used.

Footnote 21:

Some microscopes are provided with adjusting screws bearing on the frame holding the objective, which can then be accurately centered to the axis of rotation of the stage.

Footnote 22:

In the Seibert microscope use objective No. 00 for the first general study of a rock section, No. II for general use and No. V for observations with convergent light. In the Fuess microscope use objective No. 4 for general use and No. 7 for convergent light tests. In the case of an English microscope a 1″ to ¾″ objective is used for general purposes and a ¼″ to ■″ for observations with convergent light.

Footnote 23:

See pp. 33 and 34.

Footnote 24:

In some microscopes the analyzer is in the form of a "cap" nicol, arranged to be fitted over the top of the eye-piece, and not introduced in the microscope tube as shown here. This form is not so convenient, as the "cap" nicol must be set by hand every time it is desired to make observations with crossed nicols. But at the same time it avoids any possible refocusing which may be

necessary when the other type of analyzer is introduced in the tube.

Footnote 25:

When accurate adjustments are possible of the vibration planes of the nicols and the cross-wires parallel to these vibration planes, reference should be made to _Methods of Petrographic-Microscopic Research_, p. 61, 1911, Fred. E. Wright.

Footnote 26:

In the Seibert microscope eye-piece No. 0 is used for most purposes. Other eye-pieces, Nos. 1 and 2, with cross-wires, are used for different degrees of magnification, and one eye-piece, No. 3, without cross-wires, is provided to be used in connection with an eye-piece micrometer.

Footnote 27:

With the Seibert microscope, Fig. 2, the No. 0 eye-piece and the No. II objective will prove most satisfactory for the following tests. With the Fuess microscope use No. 4 objective. With an English microscope use an ordinary eye-piece and a 1″ or ¾″ objective.

Footnote 28:

Twins may be recognized just as in macroscopic specimens, and zonal structure noticed if the zones differ in color. When a colorless mineral is surrounded by other colorless minerals, of about the same index of refraction, its outline is often best brought out by observation between crossed nicols.

Footnote 29:

The term “Anhedron,” meaning without planes, has been suggested by L. V. Pirsson to describe in rocks the crystal fragments which have no plane faces, as, for example, the augites of augitic rocks. _Science_, Jan. 10, 1896, p. 49.

Footnote 30:

Partial resorption and recrystallization may produce a border of secondary minerals, surrounding the original crystal.

Footnote 31:

The surfaces of all minerals in sections are more or less rough, but this roughness is only made visible when there is a marked difference between the indices of refraction of the minerals, and the index of refraction of the balsam in which the minerals are embedded. The index of refraction of balsam is about 1.54, so it is only when the mineral has a higher or lower index of refraction that its surface appears rough. When internal structure is to be studied, the crystal should be surrounded by a fluid of nearly the same index of refraction as that of the crystal, and when the exterior of the crystal is to be studied, then a fluid should be used with a very different index of refraction.

Footnote 32:

The Seibert microscope has a very convenient and quick lowering adjustment, by means of the lever _d_, for making this test. For convenience the lower nicol and condensing lens are generally left in place below the stage of the microscope, as polarized light serves as well for these investigations as ordinary light. An additional advantage in this arrangement is that the condensing lens is always ready for the “relief” test and the lower nicol for the pleochroism test; but it must be remembered that the polarizer or lower nicol cuts out one half of the light, which comes to it from the reflector, and this loss is important when high power objectives are to be used. When very low power objectives are used, the condensing lens must be removed.

Footnote 33:

Mem. de l’Acad., Paris, 1767–68.

Footnote 34:

Min. Mag., Vol. I., p. 193; Vol. II., p. 1.

Footnote 35:

Sitzungsberichte der k. k. Akad. der Wiss., Wien, 1893, I Abt., p. 358. Translation by L. Mcl. Luquer in _School of Mines Quarterly_, Vol. XXIII., Jan., 1902, No. 2, p. 127. Review by Viola in _Min. Pet. Mitt._, Vol. 14, p. 554. _Methods of Petrographic-Microscopic Research_, F. E. Wright, 1911, p. 95.

Footnote 36:

Most of the petrographical microscopes carry over the polarizer a convex lens the effect of which is to widen the illuminating cone and hence make less visible this phenomenon.

Footnote 37:

In Seibert student microscope, No. II _a_, use next to smallest light-stop. Some of the Fuess microscopes are supplied with an iris-blende for limiting the cone of light.

Footnote 38:

In Seibert microscope use No. V, not sufficiently marked results being obtained with No. II.

Footnote 39:

See Viola's diagram, _Minn. Pet. Mitt._, Vol. XIV., p. 556.

Footnote 40:

Seibert, No. II. Fuess, No. 4.

Footnote 41:

Kurze Anleitung zur mikrosk. _Krystallbestimmung_, Wiesbaden, 1898, and _Tabellen zur mikrosk._ _Bestimmung_, etc., Wiesbaden, 1900. _Methods of Petrographic-Microscopic Research,_ F. E. Wright, 1911, p. 93.

This method is particularly favorable for the accurate determination of the refractive indices of small isolated fragments or grains, by using liquids of known indices. In this case a bright line appears on the "near" edge and a dark line on the "far" edge if the grain has a higher index than the liquid. The reverse occurs when the index is lower than the liquid. When the index is the same (using white light) the "far" edge is blue and the "near" edge red and also the contours about disappear.

F. Krantz, of Bonn, furnishes a series of 21 liquids in small bottles, with indices from 1.447 to 1.83.

The indices of a few convenient liquids are: water, 1.34; alcohol, 1.36; glycerine, 1.41; olive oil, 1.47; nut oil, 1.50; clove oil, 1.54; aniseed oil, 1.58; almond oil, 1.60; cassia oil, 1.63; monobromnapthalene, 1.65; methylene iodide, 1.75.

Footnote 42:

Crystals that have two good cleavages often develop so that the direction of elongation is parallel to the intersection of the two cleavages, while in the case of crystals with one good cleavage the tendency seems to be towards a tabular habit parallel to the cleavage.

Footnote 43:

Harker's _Petrology for Students_, p. 306.

Footnote 44:

The lower nicol is generally so adjusted that its plane of vibration is parallel to the north and south cross-wire in the eye-piece. This adjustment can be tested by means of a section of biotite, showing cleavage cracks. When the plane of vibration of the polarizer is parallel to the N. and S. cross-wire in the eye-piece, the biotite section becomes almost dark when its cleavage cracks are parallel to the same cross-wire. The upper nicol, or analyzer, must, of course, be removed during this test. This method is more convenient than taking the nicol out of its frame, in order to ascertain its plane of vibration (the direction of its shorter diagonal).

Footnote 45:

Although the "absorption directions" may not necessarily coincide with the principal vibration directions in Monoclinic and Triclinic crystals; still for convenience the absorption colors are usually given for the light rays vibrating parallel to these principal vibration directions.

Footnote 46:

In the Fuess and Seibert microscopes the analyzer or upper nicol is so fitted that it slides in and out of the tube of the microscope with its plane of vibration always at right angles to the plane of vibration of the polarizer or lower nicol.

Footnote 47:

Moses' _Characters of Crystals_, p. 106. Moses and Parsons' _Min. Cryst._ and _B. P. Analysis_, p. 163.

Footnote 48:

Iddings' _Rock Minerals_, 1911, p. 172.

Footnote 49:

These sections always contain the principal vibration directions _a_ and _c_.

Footnote 50:

Methods of Petrographic-Microscopic Research, F. E. Wright, 1911, p. 101.

Footnote 51:

A chart of interference colors can be obtained from Baudry et Cie, Paris, and is also published in _Les Minéraux des Roches_, by Lévy and Lacroix, _Rock Minerals_ (1911), by Iddings and in Rosenbusch's _Mikroskopische Physiographie_.

Footnote 52:

Iddings' _Rock Minerals_, 1911, pp. 141, 183.

Footnote 53:

Methods of Petrographic-Microscopic Research, F. E. Wright, 1911, p. 132.

Footnote 54:

The ¼ undulation mica plate consists of a thin cleavage of mica on which is marked _c_, the vibration direction of the slower ray, which in mica is the line joining the "optic axes." The thickness is such that the slower ray is ¼ wave-length behind the faster and the interference color is a bluish-gray. The gypsum plate is a thin cleavage of gypsum, on which is usually marked a, the vibration direction of the faster ray. The chosen thickness is such as to produce the red interference color of the 1° order.

Footnote 55:

The test-plates are generally introduced in the slot _k_, in a microscope of the Seibert type, or if a cap-nicol is used in a slot below this. In case no provision is made by the instrument maker for these test-plates, the regular analyzer is left out of the tube, and a simple nicol prism is used as an analyzer and is held by the observer over the eye-piece. Care must be taken to have the plane of vibration of this nicol at right angles to that of the polarizer, and to leave sufficient room for the introduction, by hand, of the test-plate between the eye-piece and the nicol. With care the plates can be introduced with sufficient accuracy to make the test practical.

Footnote 56:

A scale or chart of interference colors, or the interference color diagram, should be before the observer in order to avoid any mistakes as to whether the new color is higher or lower in the scale.

Footnote 57:

The quartz wedge is cut so that one of its faces is exactly parallel to the _■_ axis (hence also parallel to the _c_ vibration direction) while the other face makes a very small angle with it. The direction _c_ is marked on the wedge.

Footnote 58:

Described under next test.

Footnote 59:

In applying this rule count the 1° order white as green and the 1° order gray as blue.

Footnote 60:

A. J. Moses, _Trans. N. Y. Acad. Sci._, Vol. XVI., p. 55, Jan., 1897.

Footnote 61:

E. von Federow, _Zeit. f. Kryst., etc._, Vol. XXXV., p. 340, 1895.

Footnote 62:

After the first rough determination of the phase difference by the mica wedge, the more exact phase difference can be obtained by the aid of a good color chart or diagram, see end of book.

Footnote 63:

It is not safe to use minerals near the edge of the section, as the thicknesses are apt to be unequal.

Footnote 64:

See at end of appendix.

Footnote 65:

In this way eliminate, so far as possible, the effect of the orientation of the mineral section.

Footnote 66:

The different mineral sections are all supposed to have the same thickness throughout the rock section.

Footnote 67:

Harker's _Petrology for Students_, 1895, p. 14.

Footnote 68:

Iddings' _Rock Minerals_, pp. 153, 173. Moses' _Characters of Crystals_, p. 115.

Footnote 69:

In the Seibert microscope use No. V objective, in Fuess microscope No. 7 objective, and in English microscopes a ¼″ or ■″ objective.

Footnote 70:

Each convergent ray will have its vibration direction either in or at 90° to the plane through the ray and the optic axis. Hence all rays vibrating parallel to the vibration planes of both nicols will be completely cut out. As the section is rotated new rays successively come into these positions, so the same effect is maintained.

Footnote 71:

In the Seibert microscope there is a little slot _k_ for this purpose just above the objective.

Footnote 72:

The optical character may also be determined in parallel light by proving _■_ = c(+), _■_ = a(–). The optical character of the principal zone or the sign of the elongation is often given in tables. This optical character or sign is (+) when the principal zone axis or the direction of elongation is parallel to c and (–) when parallel to a.

Footnote 73:

Iddings' _Rock Minerals_, 1911, p. 172.

Footnote 74:

This assumes the optic axes for different colors to emerge about at the same points. If there is marked "dispersion" the black bands and hyperbolas may be rainbow-hued, as with titanite.

Footnote 75:

The interference figure, perpendicular to the _obtuse bisectrix_, would be of the same type with a larger axial angle. Ordinarily this figure would not come within the limits of the field of view of the microscope. Confusion may arise, however, but in a section perpendicular to the acute bisectrix the cross dissolves more slowly into the hyperbolas than in the case of a section perpendicular to the obtuse bisectrix. At times it may be necessary to measure the axial angle to be sure. When, however, the mineral is known, the section perpendicular to the acute bisectrix can be recognized, because if the mineral is optically positive the trace of the axial plane is parallel to a and if negative parallel to c.

Footnote 76:

For construction of quartz wedge, see p. 34.

Footnote 77:

The wedge can be introduced in either of the several ways described for the introduction of the test-plates on p. 33.

Footnote 78:

For methods of measuring the axial angle, see _Methods of Petrographic-Microscopic Research_, F. E. Wright, 1911, p. 147.

For convenience in many cases only 2_E_ is recorded, as then an indication is given as to whether the axial angle is visible with an ordinary microscope (arranged for observation with convergent light for interference figures). If 2_E_ is very large the axial angle can only be observed by covering the section with some transparent, strongly refracting fluid. For the Seibert microscope with objective V the limit for good results is about 2_E_ = 90°–100°.

Footnote 79:

For dispersion, etc., see A. J. Moses' _Characters of Crystals_, p. 140.

Footnote 80:

The system of crystallization of leucite has been the subject of much discussion. Its habit is isometric. The consensus of opinion seems to be that leucite crystallizes in the isometric system, but that the isometric molecular arrangement, at least of the larger crystals, cannot exist for the temperature and pressure at the earth's surface. Hence molecular displacement takes place, giving rise to a more or less complicated apparent twinning, and optical anomalies are noticed. The isotropic character returns if the section is heated to 500° C. Iddings' _Rock Minerals_, p. 249, 1911.

Footnote 81:

C. W. Knight, _Canad. Rec. of Sci._, IX, No. 5. 265.

Footnote 82:

The interference colors of all minerals here recorded are those given by sections 0.03 _mm._ in thickness (very thin sections).

Footnote 83:

Shown by Mügge, Joly, etc., to be caused by radiations emanating from U, Th, R, etc. Iddings' _Rock Minerals_, 1911, p. 189.

Footnote 84:

Iddings' _Rock Minerals_, 1911, p. 392.

Footnote 85:

See page 31.

Footnote 86:

R. D. Irving, _Am. Jour. Sci._, June, 1883.

Footnote 87:

Granites of the central Alps, where the calcite crystals are intergrown with quartz.

Footnote 88:

The minerals Nephelite, leucite, sodalite (haüynite and noselite) and melilite are often grouped together under the name "_feldspathoides_"; on account of their relation in rocks being equivalent to that of the feldspars.

Footnote 89:

Oriented in conformity to the intergrowth with augite, etc., (010) and (100) are reversed.

Footnote 90:

For other alteration processes, see Iddings' _Rock Minerals_, p. 380.

Footnote 91:

May be difficult to determine in the case of prism zone sections, showing large extinction angles.

Footnote 92:

See p. 88.

Footnote 93:

Iddings' _Rock Minerals_, p. 456, 1911.

Footnote 94:

Depending on whether the axial plane is parallel or at right angles to the clino pinacoid (010) (the plane of symmetry), we have micas of the second (biotite) or first order (muscovite).

Footnote 95:

The distinction between zoisite α and β (essentially orthorhombic, but may be composite triclinic twins) and clinozoisite (monoclinic close to orthorhombic) depends on differences in position of plane of optic axes; axial figures shown by cleavage plates; dispersion; anomalous interference colors; etc. See Weinschenk's _Die Gesteinbildenden Mineralien_, p. 83. 1901.

Footnote 96:

Test not easily made on account of the very high order interference colors, resulting from the strong double refraction.

Footnote 97:

See under quartz, p. 63.

Footnote 98:

Iddings' _Rock Minerals_, p. 208, 1911.

Footnote 99:

On account of the weak double refraction the interference figures are not very sharp or well defined in thin sections. In most cases only the black hyperbolas are seen, without any colored curves.

Footnote 100:

By heating feldspar crystals the axial angle decreases to 0° and then increases in the plane of symmetry (at right angles to its former position). On cooling the axial angle returns to its former position if the temperature has not exceeded 500° C. If the temperature has been 600°–1000° C. for some time the axial angle will not return to its former position. This fact may give some clew as to the temperature at which the feldspar crystals formed.

Footnote 101:

This change to kaolin or clay in granite is called by Dolomieu "_La maladie du granit_."

Footnote 102:

See p. 31.

Footnote 103:

Hatch's _Introduction to the Study of Petrology_, p. 33.

Footnote 104:

J. W. Judd, _Geol. Mag._ [3], Vol. VI, p. 243, 1889.

Footnote 105:

The plagioclases have rather a complex composition; but may be regarded as forming a series from the composition $NaAlSi_{3}O_{8}$(Ab) to the composition $CaAl_{2}Si_{2}O_{8}$(An), consisting for the most part of isomorphous mixtures of these types, with some replacement by $KAlSi_{3}O_{8}$. The compositions of only a few of the common plagioclases are given above.

Footnote 106:

The lath-shaped feldspars, moulding the augite, give to diabases the so-called "ophitic" structure, Fig. 12. The peculiarity of this structure is that the feldspars crystallized before the augite, which is contrary to the usual order of formation.

Footnote 107:

For the positions of the optic axes, bisectrices, etc., relative to the cleavage plates of the different plagioclases, see Iddings' _Rock Minerals_, p. 222, 1911.

Footnote 108:

Die Gesteinsbildenden Mineralien (with tables), E. Weinschenk, Freiburg, 1901. _Étude sur la Détermination des Feldspaths dans les Plaques Minces_, Michel Lévy, Paris, 1894; and _The Determination of the Feldspars_, N. H. Winchell, _Am. Geol._, Vol. XXI, No. 1, 1898. Iddings' _Rock Minerals_, Wiley & Sons, 1911. _Étude sur la Détermination des Feldspaths_ (troisième fascicule), Michel Lévy, Paris, 1904.

Footnote 109:

Glass models of the feldspars (size 20 × 10 cm.) by F. Krantz, Bonn. Diagrams, showing optical orientation in the plagioclases, in _Die Gesteinsbildenden Mineralien_, E. Weinschenk, p. 133, 1901.

Footnote 110:

For this method of investigation little cleavage flakes or plates can often be obtained from the crushed mineral, but, on account of Albite twinning, plates are more apt to be obtained parallel to the twinning plane than to the best basal cleavage. If a fragment with only one cleavage surface is obtained, it must be cemented to a glass by this surface and ground down to a thin section with parallel sides.

Footnote 111:

This test is only possible when suitable sections of the given feldspar in the rock section can be found. The method, however, can be used with great accuracy with the aid of some form of apparatus for properly orienting the section. See "Klein's Apparatus for the Orientation of Thin Sections," _Sitzungsber. Berlin. Akad._, 1895, 1151; (also in _N. Y. Acad. Sci._, Vol. XVI, p. 51, 1897); and Von Federov's "Universal Table," _Zeit. für Kryst, etc._, Vol. XXV., p. 351.

Footnote 112:

In the determination of feldspar microlites it is well to remember the following facts: "Microcline is rarely, or never, seen in the condition of microlites, while the associations of labradorite and albite are so different that there is little danger of confounding them. Labradorite is the commonest product of the consolidation of the basic eruptives, and albite almost invariably results from metamorphism, frequently from the contact of igneous rocks on the calcareous clastics." N. H. Winchell, Determination of the Feldspars, _Am. Geol._, Vol. XXI, No. 1, p. 33, 1898.

Footnote 113:

These methods (both 2 and 3) are often not applicable on account of the tendency of the crystals in an effusive rock to parallel orientation, which may be so marked that the rock section does not show any favorable sections of the plagioclase.

Footnote 114:

These extinction angles, as well as those previously given, are those of only a few type feldspars of definite composition. As the composition varies through a long series, so the extinction angle changes, one being a function of the other.

For a complete list of compositions and related extinction angles, see Iddings' _Rock Minerals_ and Lévy & Lacroix's _Les Minéraux des Roches_.

Footnote 115:

Iddings' _Rock Minerals_, p. 228, Wiley & Sons, 1911. _Étude sur la Détermination des Feldspaths_ (troisième fascicule), Michel Lévy, Paris, 1904.

Footnote 116:

In quartz ω is the refractive index of the ray with vibration direction ■ a [that is the direction of vibration of the faster ray (the ordinary ray)]. Hence ω is direction ■ a and ε ■ c. In the feldspars; α ■ a, γ ■ c and β ■ b.

Footnote 117:

Am. Jour. Sci., May, 1906. This method is specially useful in detecting presence of orthoclase, when plagioclase is the dominant feldspar.

Footnote 118:

These tests are only possible on pure and fresh material. The specific gravity increases with the Ca % (albite 2.62, anorthite 2.75).

Footnote 119:

In clear unstriated granules, which may be distinguished from quartz by biaxial interference figure in convergent light.

Footnote 120:

The tendency of labradorite in gabbros to twinning, after both _Albite_ and _Pericline_ laws, is to be noted.

Footnote 121:

Werveke's (N. J. B., 1883, II, 97) theory is that a twin lamination may be caused by the forces producing mechanical deformations, as movement in the magma and mountain making pressure. Such lamellæ are characterized by the fact that their extent and course seem to depend on fracture lines in the crystal.

Footnote 122:

The derivation from pyroxene and amphibole appears to be doubtful, see Weinschenk's _Gesteinsbildenden Mineralien_, 1901, p. 121.

Footnote 123:

Harker's _Petrology for Students_, p. 63, 1895.

Footnote 124:

Sections can be obtained from Voight & Hochgesang, Göttingen; C. Marchand, rue Censier, 16ter, Paris; W. H. Tomlinson, Swarthmore, Pa., and G. D. Julien, 3 Webster Terrace, New Rochelle, N. Y.

Footnote 125:

Made by G. D. Julien, 3 Webster Terrace, New Rochelle, N. Y. Price: Power lathes (complete), $150.00 up; Foot-treadle lathes, $90.00 up.

Footnote 126:

A Crocker-Wheeler motor of ¼ to ½ H. P. will be large enough for an ordinary laboratory machine.

Footnote 127:

Made by Voigt and Hochgesang, Göttingen. Price, $15.00.

Footnote 128:

Saws charged with diamond dust can be obtained from Elisha T. Jenks, Middleboro, Mass. Price in 1910, $1.35 per diametrical inch. Foreign saws 6″ and 8″ diam. can be bought from G. D. Julien, New Rochelle, N. Y.

Footnote 129:

School of Mines Quarterly, Vol. XI, p. 32.

Footnote 130:

"Half a pound or less of ordinary shellac is melted in a flat-bottomed open vessel over a Bunsen burner. Then an equal quantity of Venice turpentine is carefully added under constant stirring. The mass should be allowed to boil for about ten minutes, during which the stirring is continued. Then small quantities are poured in separate heaps on an iron plate or other cold surface and rolled into sticks about seven inches long and half an inch thick."

Footnote 131:

Square or standard 26 × 46 mm. glass slides are recommended instead of the oblong slides (1 × 3 inches), which are very apt to project beyond the edges of the stage and be struck by the fingers while rotating the stage.

Footnote 132:

Reference can be made to the publications on this subject by: Borichy, Behrens (Behren's translation by Judd), Haushofer, Huysse, Klément, Streng, Rénard, etc.

Footnote 133:

In case an acid is to be used which would attack glass, the cover-glass can be replaced by a thin perforated disk of platinum.

Footnote 134:

The bases in solution can be determined by different methods of analysis, for which the student is referred to more elaborate works on this subject. In some cases it may be very advantageous to treat the section with acid, to remove certain soluble constituents, when other minerals not distinctly seen at first may be made more apparent.

Footnote 135:

The gas may be H_{2}S from a soluble sulphide, in which case the solution containing the bubbles will color filter paper moistened with lead water.

Footnote 136:

Geol. and Nat. History Survey of Minn., XIX., Ann. Rept., p. 42; also A. J. Moses, _Characters of Crystals_, p. 147.

Footnote 137:

The symmetry of the etched figures would, of course, be related to the system of crystallization.

Footnote 138:

A. J. Moses, _Characters of Crystals_, Chap. XVI.

Footnote 139:

When it is desired to preserve the section and at the same time to study the surface covered with a film of air, the edges alone of the cover-glass should be cemented.

Footnote 140:

Geol. and Nat. Hist. Survey of Minn., XIX, Ann. Rept., p. 50. Thin sections of 2–3 sq. mm. area are of a convenient size, and they should be subjected to a red heat for (1½)-3 minutes. Too long a continuance of heat may render the sections too dark or lessen their transparency or produce melting.

Footnote 141:

This test may vary, in many cases graphite not being consumed even after long heating.

Footnote 142:

The isolation of material for investigation is of more interest for the lithologist or chemist than for the student of optical mineralogy; therefore only a very brief outline of some of the methods employed will be given.

Footnote 143:

The grains passing through different meshes are investigated microscopically to ascertain which size grains are homogeneous; the rest of the sample should then be reduced to grains of this size.

Footnote 144:

Further reference can be made to _Iddings' Rock Minerals_, pp. 25 and 95, 1911. A convenient form of apparatus is also described in _School of Mines Quarterly_, Vol. X., p. 284, 1889.

Footnote 145:

S. L. Penfield, _Am. Jour. Sci._, Vol. L., p. 446, 1895. In this article a convenient form of separating apparatus is also described.

Footnote 146:

A convenient list of minerals, arranged in the order in which they would be attracted by increasing the force of the electro-magnet, is given in Weinschenk's _Tabellen_.

Footnote 147:

For micro-chemical work the reagents should be applied in very small drops, which spread out on glass to discs 2 mm. in diameter. For manipulating the reagents use platinum wires, 0.5 mm. in thickness.

Footnote 148:

Elemente einer neuen chemisch-mikroskopischen mineral- und Gesteins-analyse, Pragg, 1877.

Translation of above by Winchell in _Geol. and Nat. Hist. Survey of Minn._, Vol. XIX., Ann. Report, 1890.

Footnote 149:

The strength of the solution should be about 3½%; for if too weak many minerals do not give satisfactory results, and if too strong a very large number of fluosilicate crystals are formed together with the separation of much silica, thus making it impossible to carefully differentiate the crystals with a microscope.

Footnote 150:

As most of the rock-forming minerals that would be investigated are silicates, the hydrofluosilicic solutions can also be obtained by treatment with HFl.

Footnote 151:

After Lévy and Lacroix.

Footnote 152:

Naturkunde, Amsterdam, 2, Vol. XVII., 1881. _Chemical News_, Vol. LXIII., No. 1647, June 1891, et seq.

Micro-chemical Analysis, Behrens (Judd), Macmillan & Co., London, 1894.

Footnote 153:

After Lévy and Lacroix.

Footnote 154:

After Lévy and Lacroix.

Footnote 155:

Compiled from Weinschenk's Tables, as revised in _Petrographic Methods_ by Weinschenk-Clark, 1912.

Footnote 156:

Pirsson and Robinson, _Am. Jour. Sci._, iv, Vol. X, Oct., 1900.

Footnote 157:

Harker, _Petrology for Students_, p. 28, 1895.

Footnote 158:

Have the convergent lens or condenser lowered and the analyzer out during this test.

Footnote 159:

The minerals are grouped according to the maximum interference colors given by sections of the thickness of 0.03 mm.

Footnote 160:

In the case of very small crystals, the centering must be accurate and a cover with a small hole in the center, should be placed over the top of the tube. In this way the eye is brought directly over the axis of the microscope and figures can be observed from very minute crystals.

TRANSCRIBER'S NOTES

Page Changed from Changed to

80 occurs as an alternation product occurs as an alteration product of anhydrite. Gypsum is soluble of anhydrite. Gypsum is soluble in hydrochloric in hydrochloric

136 longer the higher the percentage longer the higher the percentage of calcium in the solution of sodium in the solution

● Typos fixed; non-standard spelling and dialect retained. ● The author used the old chemical symbol (Fl) for Fluorine. ● Corrected the Errata with the exception of the last paragraph "Corrections for mean indices of refraction in Scheme (insert folder)". ● Used numbers for footnotes, placing them all at the end of the last chapter. ● Enclosed italics font in _underscores_. ● Enclosed bold font in ■lower half block■. ● The caret (^) serves as a superscript indicator, applicable to individual characters (like 2^d) and even entire phrases (like 1^{st}). ● Subscripts are shown using an underscore (_) with curly braces { }, as in H_{2}O.

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Rethinking Indigenous Religious Traditions with Jace Weaver

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CIVILIZATION AND ETHICS

THE PHILOSOPHY OF CIVILIZATION

PART II

BY

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Second Edition

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To

MY WIFE

THE MOST LOYAL OF COMRADES

Printed in Great Britain.

PREFACE

MY subject is the tragedy of the Western world-view._(_1_)_

While still a student I was surprised to find the history of thought always written merely as a history of philosophical systems, never as the history of man's effort to arrive at a world-view. Later, when reflecting on the current of civilization in which I found myself living, I was struck by the strange and inexorable connexions which exist between civilization and our view of the world as a whole. Next I felt a still stronger compulsion to put to Western thought the question what it has been aiming at, and what result it has reached in the matter of world-view. What is there left of the achievements of our philosophy when it is stripped of its tinsel of learning? What has it to offer us when we demand from it those elemental ideas which we need if we are to take our position in life as men who are growing in character through the experience given by work?

So I came to an unsparing reckoning up with Western thought. I recognized and admitted that it has sought for that world-view from which alone a deep and comprehensive civilization can come. It wanted to reach a position [pg vi] of world- and life-affirmation and on that foundation lay down that it is our duty to be active, to strive for progress of all kinds, and to create values. It wanted to reach an ethical system and on that foundation lay down that for the sake of serviceable activity we have to place our life at the service of ideas and of the other life around us.

But it did not succeed in grounding its world- and life-affirming ethical world-view convincingly and permanently in thought. Our philosophy did nothing more than produce again and again unstable fragments of the serviceable world-view which hovered before its mind's eye. Consequently our civilization also remained fragmentary and insecure.

It was a fatal mistake that Western thought never admitted to itself the unsatisfying result of its search for a stable and serviceable world-view. Our philosophizing became less and less elemental, losing all connexion with the elementary questions which man must ask of life and of the world. More and more it found satisfaction in the handling of philosophic questions that were merely academic, and in an expert's mastery of philosophical technique. It became more and more the captive of secondary things. Instead of real music it produced again and again mere bandmaster's music, often magnificent stuff of its kind, but still only bandmaster's music.

Through this philosophy which did nothing but philosophize instead of struggling for a world-view grounded in thought and serviceable for life, we came to be without any world-view and therefore without any civilization.

Signs of an awakening of thought on this point are beginning to be visible. It is admitted here and there that philosophy must again try to offer a world-view. This is generally expressed by saying that people are encouraging it to venture once more on "metaphysics," that is to put forward definitive views about the spiritual nature of the world, whereas hitherto it has been occupied with the classification of scientific facts and in cautious hypotheses.

Not only in philosophy, but in thought generally this [pg vii] awakening of the need for a world-view expresses itself as a need for "metaphysics." Fantastic systems of "metaphysics" are sought for and offered. Individuals who believe that they have at their disposal peculiar psychic experiences, and assert that with their aid they can look behind the actual nature of phenomena, come forward as bringers of a world-view.

But neither the cautious academic, nor the much-claiming fantastic "metaphysics," can really give us a world-view. That the road to a world-view leads through "metaphysics" is a fatal error which has already enjoyed too long a span of life in our Western thought. It would be tragic if we renewed its vigour just now, when we are faced by the necessity of working our way out of that lack of world-view in which our misery, both spiritual and material, is grounded. No further wandering along the traditional roads that lead nowhere can save us, whether we advance as the successors of our fathers or on adventurous lines of our own. Only in a deep conception of and experience in the problems of world-view is there for us any possibility of advance.

That is why I am undertaking what has never been attempted in this way before, viz. so to pose the problem of the Western world-view as to make the Western search for a world-view come to a halt and take account of itself. There are two points on which it must be clear before it proceeds to further exertion. The first is the overwhelming importance in the search for a world-view of the quality of the world-view sought. What is it that we want? We want to find the world- and life-affirmation and the ethical system which we need for that serviceable activity which gives our life a meaning, based on such thought about the world and life as finds a meaning in them also. If our search for a world-view is once thoroughly permeated by the recognition that everything turns upon these two fundamental questions, it is thereby saved from betaking itself to by-paths, thinking that by some happy disposition of fortune it can reach its goal along them. It will then [pg viii] not search for a "metaphysic," thinking by means of it to reach a world-view, but it will search for a world-view and accept with it anything "metaphysical" that may turn up. From every point of view it will remain elemental.

The second task which the conscious search for a world-view must not shirk, is the consideration of what is the real and ultimate nature of the process by which it has hitherto attempted to secure that serviceable world-view which hovered before it. Reflexion on this is necessary that it may make up its mind whether further advance along the road it has hitherto followed gives any prospect of success. Our philosophy ought to have been philosophizing long ago about the road along which it was going in search of a world-view. It never did so, and therefore was always running uselessly round and round in a circle.

The process by which Western thought has hitherto sought for a world-view is doomed to be fruitless. It consisted simply in interpreting the world in the sense of world- and life-affirmation, that is, in attributing to the world a meaning which allowed it to conceive the aims of mankind and of individual men as having a meaning within it. This interpretation is acted upon by all Western philosophy. A few thinkers who venture to be un-Western and resolutely allow world- and life-negation and ethics to be made subjects of discussion, are side-currents which do not affect the main course of the river.

That this process followed by Western thought consists in adopting an optimistic-ethical interpretation of the world will not be clear without further explanation, for it is, indeed, not always openly followed. The optimistic-ethical interpretation is often to be found imbedded in the results of investigations into the nature of knowledge; it often appears beneath a veil of "metaphysics"; it is often so delicately shaded that it produces none of its usual effects. It is only when one has clearly grasped the fact that Western thought has nothing else in mind than to establish for itself a world-view based on world- and life-affirmation and ethical in character, that one can realize [pg ix] how in its theory of knowledge, in its metaphysics, and in all its movements generally in the game of life, it is guided, consciously or unconsciously, by the effort to interpret the world in some way or other and in some measure in the sense of world- and life-affirmation and of ethics. Whether in this attempt it goes to work openly or secretly, skilfully or unskilfully, honourably or craftily, does not matter. Western thought needs this interpretation that it may be able to give a meaning to human life. Its view of life is to be a result of its view of the world. No other course was ever taken into consideration by it.

But this awakening of Western thought will not be complete until that thought steps outside itself and comes to an understanding with the search for a world-view as this manifests itself in the thought of mankind as a whole. We have too long been occupied with the developing series of our own philosophical systems, and have taken no notice of the fact that there is a world-philosophy of which our Western philosophy is only a part. If, however, one grasps philosophy as being a struggle to reach a view of the world as a whole, and seeks out the elementary convictions which are to deepen it and give it a sure foundation, one cannot avoid setting our own thought face to face with that of the Hindus and Chinese in the Far East. The latter looks strange to us because much of it has remained even till now naïve and embodied in myth, while in other parts again it has spontaneously advanced to refinements of criticism and to artificialities. But this does not matter. The essential thing is that it is a struggle for a world-view: the form it takes is a secondary matter. Our Western philosophy, if judged by its own latest pronouncements, is much naïver than we admit to ourselves, and we fail to perceive it only because we have acquired the art of expressing what is simple in a learned way.

Among the Hindus we encounter the world-view which is based on world- and life-negation, and the way in which it grounds itself in thought is calculated to leave us not knowing what to make of our prejudice in favour of world- [pg x] and life-affirmation, which, as Westerners, we are inclined to assume as something more or less self-evident.

The attraction and tension which in Hindu thought govern the relations between world- and life-negation and ethics, afford us glimpses into the problem of ethics for which Western thought offers us no comparable opportunities.

Nowhere, again, has the problem of world- and life-affirmation, both in itself and in its relation to ethics, been felt in so elemental and comprehensive a fashion as in Chinese thought. Lao-tse, Chwang-tse, Kung-tse (Confucius), Meng-tse, Lie-tse, and the rest, are thinkers in whom the problems of world-view with which our Western thought is wrestling, encounter us in a form, strange indeed, but compelling our attention.

Discussing these problems with them means discussing them with ourselves also.

That is why I bade our search for a world-view seek to reach clear ideas about itself, and come to a halt in order to fix its attention on the thought of mankind as a whole.

My solution of the problem is that we must make up our minds to renounce completely the optimistic-ethical interpretation of the world. If we take the world as it is, it is impossible to attribute to it a meaning in which the aims and objects of mankind and of individual men have a meaning also. Neither world- and life-affirmation nor ethics can be grounded on what our knowledge of the world can tell us about the world. In the world we can discover nothing of any purposive evolution in which our activities can acquire a meaning. Nor is the ethical to be discovered in any form in the world-process. The only advance in knowledge that we can make is to describe more and more minutely the phenomena which make up the world and their course. To understand the meaning of the whole—and that is what a world-view demands—is for us an impossibility. The last fact which knowledge can discover is that the world is a manifestation in every way puzzling, of the universal will-to-live.

[pg xi]

I believe I am the first among Western thinkers who has ventured to recognize this crushing result of knowledge, and who is absolutely sceptical about our knowledge of the world without at the same time renouncing with it belief in world- and life-affirmation and ethics. Resignation as to knowledge of the world is for me not a hopeless fall into a scepticism which leaves us to drift about in life like a derelict vessel. I see in it that effort of honesty which we must venture to make in order to arrive at the serviceable world-view which hovers within sight. Every world-view which does not start from resignation in regard to knowledge, is artificial and a mere fabrication, for it rests upon an inadmissible interpretation of the world.

When once thought has become clear to itself about the relation in which world-view and life-view stand to each other, it is in a position to reconcile resignation as to knowledge with adherence to world- and life-affirmation and ethics. Our view of life is not dependent on our view of the world in the way that uncritical thought imagines it to be. It does not wither away if it cannot send its roots down into a corresponding world-view, for it does not originate in knowledge although it would like to base itself thereon. It can safely depend upon itself alone, for it is rooted in our will-to-live.

World- and life-affirmation and ethics are given in our will-to-live, and they come to be clearly discerned in it in proportion as it learns to think about itself and its relation to the world. The rational thought of other times aimed at getting to know the world, and at being able in that knowledge to conceive of the highest impulses of our will-to-live as purposive in view of the universe and its evolution. But that aim was unattainable. We are not meant to unite the world and ourselves in such harmony with one another. We were naïve enough to assume that our view of life must be contained in our view of the world, but the facts do not justify this assumption. The result is that our thought finds itself involved in a dualism with which it can [pg xii] never finally settle. It is the dualism of world-view and life-view, of knowing and willing.

To this dualism all the problems with which human thought has busied itself ultimately go back. Every fragment of the thought of mankind which has any bearing on man's view of the world—whether in the world-religions or in philosophy—is an attempt to resolve this dualism. It is sometimes softened down, but only to let a unitary, monistic world-view be adopted in its place; at other times it is left current, but is transformed into a drama with a monistic issue.

Innumerable are the expedients which thought used in trying to get rid of dualism. Everything it has undertaken commands respect, even the staggering _naïvetés_ and the meaningless acts of violence to which it committed itself, for it was always acting under the compulsion of an inner necessity: it wanted to rescue a serviceable world-view from the abyss of dualism.

But from this continuous mishandling of the problem no solution could issue capable of satisfying thought. We were to be taken over the abyss on tottering bridges of snow.

Instead of going on bridging this abyss with forced logic and imaginative ideas, we must make up our minds to get to the root of the problem and let it work upon us as it comes straight to meet us in the facts. The solution is, not to try to get rid of dualism from the world, but to realize it as something which can no longer do us any harm. That is possible if we leave behind us all the arts and the unveracities of thought and bow to the fact that, as we cannot harmonize our life-view and our world-view, we must make up our minds to put the former above the latter. The volition which is given in our will-to-live reaches beyond our knowledge of the world. What is decisive for our life-view is not our knowledge of the world but the character of the volition which is given in our will-to-live. The universal spirit meets us in nature as puzzling creative power. In our will-to-live we experience [pg xiii] it within us as volition which is both world- and life-affirming and ethical.

Our relation to the world as it is given in the character of our will-to-live, when this latter seeks to comprehend itself in thought: that is our view of the world. World-view is a product of life-view, not _vice versâ_.

The rational thought of to-day, therefore, does not hunt the phantom of getting to know the world. It leaves knowledge of the world on one side as something unattainable by us, and tries to come to clear ideas about the will-to-live which is within us.

The problem of world-view, then, brought back to facts and tackled by rational thought without assumptions being made, may be put thus: "What is the relation of my will-to-live, when it learns to think, to itself and to the world?" And the answer is: "From an inner compulsion to be true to itself and to remain consistent with itself, our will-to-live enters into relations with our own individual being and with all manifestations of the will-to-live which surround it, that are determined by the sentiment of reverence for life."

Reverence for life, _veneratio vitæ_, is the most direct and at the same time the profoundest achievement of my will-to-live.

In reverence for life my knowledge passes into experience. The unsophisticated world- and life-affirmation which is within me just because I am will-to-live has, therefore, no need to enter into controversy with itself, if my will-to-live learns to think and yet does not understand the meaning of the world. In spite of the negative results of knowledge I have to hold fast to world- and life-affirmation and deepen it. My life carries its own meaning in itself. This meaning lies in my living out the highest idea which shows itself in my will-to-live, viz. the idea of reverence for life. With that for a starting-point I give value to my own life and to all the will-to-live which surrounds me, I persevere in activity, and I produce values.

Ethics grow out of the same root as world- and [pg xiv] life-affirmation, for ethics, too, are nothing but reverence for life. That is what gives me the fundamental principle of morality, viz. that good consists in maintaining, promoting, and enhancing life and that destroying, injuring, and limiting life are evil. Affirmation of the world, which means affirmation of the will-to-live that manifests itself all round me, is only possible if I devote myself to other life. From an inner necessity I exert myself in producing values and practising ethics in the world and on the world even though not understanding the meaning of the world. For in world- and life-affirmation and in ethics I carry out the will of the universal will-to-live which reveals itself in me. I live my life in God, in the mysterious divine personality which I do not know as such in the world, but only experience as a mysterious Will within myself.

Rational thinking which is free from assumptions ends therefore in mysticism. To relate oneself in the spirit of reverence for life to the multiform manifestations of the will-to-live which together constitute the world is ethical mysticism. All profound world-view is mysticism, the essence of which is just this: that out of my unsophisticated and naïve existence in the world there comes, as a result of thought about self and the world, spiritual self-devotion to the mysterious infinite Will which is continuously manifested in the universe.

This world-affirming, ethical, active mysticism has always been hovering as a vision before Western thought, but the latter could never adopt it because in its search for a world-view it always turned into the wrong road of optimistic-ethical interpretation of the world, instead of reflecting directly on the relation which man assumes to the world under the inner compulsion of the deepest characterisation of his will-to-live.

From my youth onwards I have felt certain that all thought which thinks itself out to an issue ends in mysticism. In the stillness of the primæval forest in Africa I have been able to work out this thought and give it expression.

I come forward therefore with confidence as a restorer [pg xv] of that rational thought which refuses to make assumptions. I know indeed that our time will have absolutely no connexion with anything that is in any way rationalistic, and would like to know it renounced as an aberration of the eighteenth century. But the time will come when it will be seen that we must start again where that century came to a stop. What lies between that time and to-day is an intermezzo of thought, an intermezzo with extraordinarily interesting and valuable moments, but nevertheless an unhappy and fatal one. Its inevitable end was our sinking into a condition in which we had neither world-view nor civilization, and which contains in itself all that spiritual and material misery in which we languish.

The restoration of our world-view can come only as a result of inexorably truth-loving and recklessly courageous thought. Such thinking alone is mature enough to learn by experience how the rational, when it thinks itself out to a conclusion, passes necessarily over into the non-rational. World- and life-affirmation and ethics are non-rational. They are not justified by any corresponding knowledge of the nature of the world, but are the disposition in which, through the inner compulsion of our will-to-live, we determine our relation to the world.

What the activity of this disposition of ours means in the evolution of the world, we do not know. Nor can we regulate this activity from outside; we must leave entirely to each individual its shaping and its extension. From every point of view, then, world- and life-affirmation and ethics are non-rational, and we must have the courage to admit it.

If rational thought thinks itself out to a conclusion, it comes to something non-rational which, nevertheless, is a necessity of thought. This is the paradox which dominates our spiritual life. If we try to come through without this non-rational, the result is views of the world and of life which are without life and without value.

All valuable conviction is non-rational and has an emotional character, because it cannot be derived from [pg xvi] knowledge of the world but arises out of the thinking experience of our will-to-live, in which we stride out beyond all knowledge of the world. This fact it is which the rational thought that thinks itself out to a conclusion comprehends as the truth by which we must live. The way to true mysticism leads up through rational thought to deep experience of the world and of our will-to-live. We must all venture once more

to be "thinkers," so as to reach mysticism, which is the only direct and the only profound world-view. We must all wander in the field of knowledge to the point where knowledge passes over into experience of the world. We must all, through thought, become religious.

This rational thought must become the prevailing force among us, for all the valuable ideas that we need develop out of it. In no other fire than that of the mysticism of reverence for life can the broken sword of idealism be forged anew.

In the disposition to reverence for life lies enclosed an elementary conception of responsibility to which we must surrender ourselves; in it there are forces at work which drive us to revision and ennoblement of our individual social and political disposition.

It is the disposition to reverence for life, too, which alone is capable of creating a new consciousness of law. The misery prevailing under our political and social condition consists to a great extent in this, that neither jurists nor laity have in their minds a living and direct conception of law. During the age of rational thought there was a search made for such a conception, and effort was made to establish fundamental laws which were held to be given in the nature of man, and to get them generally recognized. Later on, however, this was given up, and laws passed at definite dates displaced natural law. Finally we got to the stage of being satisfied with purely technical law. This was the intermezzo which followed the period of rational thought in the sphere of law.

We have entered on a period in which the feeling for [pg xvii] law is hopelessly bereft of force, of soul, and of sense of moral obligation. It is a period of lawlessness. Parliaments produce with easy readiness statutes which contradict the idea of law. States deal arbitrarily with their subjects without regard to the maintenance of any feeling for law. Those, indeed, who fall into the power of a foreign nation are outlaws. No respect is shown for their natural right to a fatherland, or freedom, or dwelling-place, or property, or industry, or food, or anything else. Belief in law is to-day an utter ruin.

This state of things was in preparation from the moment when the search for the natural conception of law, grounded on rational thought, was given up.

The only thing to be done, then, is to make a new connexion in the sphere of law also, at the point where the thread of the rational thought of the eighteenth century got broken. We must search for a conception of law that is grounded in an idea which grows directly and independently out of a world-view. We have to re-establish human rights which cannot be infringed, human rights which guarantee to each person the greatest possible freedom for his personality in his own national body, human rights which protect his existence and his human dignity against any foreign violence to which he may be subjected.

Jurists have allowed law and the feeling for law to be ruined. They could not help it, however, for there was no idea provided by the thought of the time to which a living conception of law could have anchored itself. In the complete absence of any world-view law collapsed entirely, and it is only out of a new world-view that it can be built up again. It is from a fundamental idea about our relation to all that lives, as such, that it must flow in future, as from a spring which can never dry up and never become a swamp. That spring is reverence for life.

Law and ethics spring up together from the same idea. Law is so much of the principle of respect for life as can be embodied in an external code; ethics are what cannot be so embodied. The foundation of law is humanity. It is [pg xviii] folly to wish to put out of action the links between law and world-view.

In this way a world-view is the germ of all ideas and dispositions which are determinative for the conduct of individuals and of society.

Flying machines carry men to-day through the air over a world in which hunger and brigandage have a place. It is not in China only that one recognizes the grotesque character of such progress: it is almost typical for mankind generally, and such grotesque progress cannot be changed to the normal till a general disposition prevails which is capable of bringing order again into the chaos of human life through ethics. In the last resort the practical can be realized only through the ethical

What a remarkable circle! Rational thought which thinks itself out arrives at something non-rational and subjective which is a necessity of thought, viz. the ethical affirmation of world and life. On the other hand, what for the purpose of moulding the conditions of existence for individual men and mankind as a whole is rational, that is to say, what is objectively practical in this regard, can only be brought about by individuals perseveringly putting into action the above-mentioned non-rational and subjective. The non-rational principle underlying our activity, a principle which is provided for us by rational thought, is the sole rational and practical principle underlying all the happenings which are to be produced through human action. Thus the rational and the

non-rational, the objective and the subjective proceed each from the other, and return each into the other again. Only when the play of this mutual interchange is in full activity do normal conditions of existence arise for men and mankind. Let it be disturbed and the abnormal develops.

I have, then, in this book written the tragedy of the search for a world-view, and have myself trodden a new path to the same goal. Whereas Western thought has not arrived at any goal because it would not venture resolutely into the desert of scepticism about knowledge of the world, [pg xix] I make my way through this desert with calm confidence. It is, after all, only a narrow strip, and it lies in front of the ever-green oasis of an elemental world-view which grows out of thought about the will-to-live. In my attempt, however, to reach a world-view by this new method, I am conscious of having done no more than put together and think out to conclusions many gropings after this new method which were made by other seekers during the period covered.

But I also put into this book my conviction that mankind must renew itself in a new temper of mind, if it is not to be ruined. I entrust to it, further, my belief that this revolution will come about, if only we can make up our minds to become thinking men.

A new Renaissance must come, and a much greater one than that in which we stepped out of the Middle Ages; a great Renaissance in which mankind discovers that the ethical is the highest truth and the highest practicality, and experiences at the same time its liberation from that miserable obsession by what it calls reality, in which it has hitherto dragged itself along.

I would be a humble pioneer of this Renaissance, and throw the belief in a new humanity, like a torch, into our dark age. I make bold to do this because I believe I have given to the disposition to humanity, which hitherto has ranked only as a noble feeling, a firm foundation in a world-view which is a product of elementary thinking and can be made intelligible to everyone. Moreover, it has gained thereby a power of attracting and convincing which it has not had hitherto; and is capable now of coming to terms in energetic and consistent fashion with our so-called reality, and of proving its full value within it.

ALBERT SCHWEITZER.

July, 1923.

The two instalments of my Philosophy of Civilization which are now ready—_The Decay and Restoration of [pg xx] Civilization_ and _Civilization and Ethics_—will be followed by two others. In the next, which will be entitled _The World-view of Reverence for Life_, I elaborate this world-view, which so far I have only sketched for a conclusion to my discussion of the search for a world-view, as carried on down to the present day. The fourth and last will treat of the Civilized State.

* * * * *

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CONTENTS

I. THE CRISIS IN CIVILIZATION AND ITS SPIRITUAL CAUSE [I]

The material and spiritual elements in civilization [I] Civilization and world-view [6]

II. THE PROBLEM OF THE OPTIMISTIC WORLD-VIEW [11]

The Western and the Indian conceptions of civilization[11] The struggle for the optimistic world-view [12] Optimism and pessimism [14] Optimism, pessimism, and ethics [17]

III. THE ETHICAL PROBLEM [19]

The difficulties of ethical perception [19] The importance of thought about ethics [21] The search for a basic principle of morality [22] Religious and philosophical ethics [24]

IV. RELIGIOUS AND PHILOSOPHICAL WORLD-VIEWS [27]

The world-views of the world-religions [27] The world-views of the world religions and that of Western thought [29]

V. CIVILIZATION AND ETHICS IN THE GRÆCO-ROMAN PHILOSOPHY [32]

The beginnings: Socrates [32] Epicureanism and Stoicism. The ethic of resignation [35] Plato's abstract basic principle of the ethical. The ethic of world-negation [40] Aristotle. Instruction about virtue in place of ethics [42] The ideal of the civilised State in Plato and Aristotle [47] Seneca, Epictetus, and Marcus Aurelius [52] The optimistic-ethical world-view of the later Stoicism [57]

VI. OPTIMISTIC WORLD-VIEW AND ETHICS IN THE RENAISSANCE AND POST-RENAISSANCE PERIODS [61]

Belief in progress and ethics [61] Christian and Stoic elements in modern ethics [64]

VII. LAYING THE FOUNDATION OF ETHICS IN THE SEVENTEENTH AND EIGHTEENTH CENTURIES [71]

Hartley, Holbach. Devotion as enlightened egoism [71] Hobbes, Locke, Helvetius, Bentham [75] Altruism as a natural quality. Hume, Adam Smith [80] The English ethic of self-perfecting [84] Shaftesbury, An optimistic-ethical nature-philosophy [87]

VIII. LAYING THE FOUNDATIONS OF CIVILIZATION IN THE AGE OF RATIONALISM [90]

The mentality and the achievements of the ethical belief in progress [90] Obstacles to the reform movement. The French Revolution [99] The undermining of the rationalistic world-view [102]

IX. THE OPTIMISTIC-ETHICAL WORLD-VIEW IN KANT [106]

Kant's ethics, deepened, but lacking content [106] Kant's attempt to reach an ethical world-view [110]

X. NATURE-PHILOSOPHY AND WORLD-VIEW IN SPINOZA AND LEIBNIZ [116]

Spinoza's attempt to reach an optimistic-ethical nature-philosophy [116] Leibniz's optimistic-ethical world-view side by side with nature-philosophy [122]

XI. J. G. FICHTE'S OPTIMISTIC-ETHICAL WORLD-VIEW [125]

Speculative philosophy and Gnosticism [125] Fichte's speculative founding of an ethic and of optimism [126] Fichte's mysticism of activity incapable of being carried through [131]

XII. SCHILLER; GOETHE; SCHLEIERMACHER [136]

Schiller's ethical world-view: Goethe's world-view based on nature-philosophy [136] Schleiermacher's attempt at a nature-philosophy [138]

XIII. HEGEL'S SUPRA-ETHICAL OPTIMISTIC WORLD-VIEW [141]

Ethics in Hegel's nature-philosophy, and in his philosophy of history [141] Hegel's supra-ethical world-view. His belief in progress [145]

XIV. THE LATER UTILITARIANISM, BIOLOGICAL AND SOCIOLOGICAL ETHICS [150]

Beneke, Feuerbach, Laas, Auguste Comte, John Stuart Mill [150] Darwin and Spencer [153] The weak points in biological and sociological utilitarianism [156] Sociological ethics and socialism. Mechanical belief in progress [160]

XV. SCHOPENHAUER AND NIETZSCHE [165]

Schopenhauer. An ethic of world- and life-denial [165] Absorption of ethics in world- and life-denial [171] Nietzsche's criticism of current ethics [174] Nietzsche's ethic of higher life-affirmation [177]

XVI. THE ISSUE OF THE WESTERN STRUGGLE FOR A WORLD-VIEW [181]

Academic thinkers: Sidgwick, Stephen, Alexander, Wundt, Paulsen, Höffding [181] The ethic of self-perfecting, Kant's successors: Cohen, Herrmann [183] The ethic of self-perfecting: Martineau, Green, Bradley, Laurie, Seth, and Royce [185] Nature-philosophy and ethics. Fouillée, Guyau, Lange, Stern [186] Nature-philosophy and ethics in Eduard von Hartmann [194] Nature-philosophy and ethics in Bergson, Chamberlain, Keyserling, Haeckel [198] The death-agony of the optimistic-ethical world-view [202]

XVII. THE NEW WAY [205]

Why the optimistic-ethical world-view cannot be carried through to the logical conclusion [205] Life-view independent of world-view [208]

XVIII. THE FOUNDATIONS OF OPTIMISM SECURED FROM THE WILL-TO-LIVE [212]

The pessimistic result of knowledge [212] The world- and life-affirmation of the will-to-live [216]

XIX. THE PROBLEM OF ETHICS, STARTING FROM THE HISTORY OF ETHICS [221]

An ethic of self-devotion, or an ethic of self-perfecting? [221] Ethics and a theory of knowledge. Ethics and natural happenings. The enthusiastic element in ethics [224] The ethic of ethical personality, and the ethic of society [228] The problem of a complete ethic [230]

XX. THE ETHIC OF DEVOTION AND THE ETHIC OF SELF-PERFECTING [232]

The widening of the ethic of self-devotion into a cosmic ethic [232] The ethic of self-perfecting and mysticism [235] Abstract mysticism and the mysticism of reality. Supra-ethical and ethical mysticism [241]

XXI. THE ETHIC OF REVERENCE FOR LIFE [244]

The basic principle of the moral [244] The ethic of resignation. An ethic of veracity towards oneself, and an activist ethic [251] Ethics and thoughtlessness. Ethics and self-assertion [253] Man and other living creatures [256] The ethic of the relation of man to man [258] Personal and supra-personal responsibility. Ethics and humanity [262]

XXII. The CIVILIZING POWER OF THE ETHIC OF REVERENCE FOR LIFE [269]

Civilization as a product of reverence for life [269] The four ideals of civilization. The struggle for a civilized mankind in the machine age [271] Church and State as historical entities, and as ideals of civilization [278] The moralizing of the religious and political community [280]

FOOTNOTES INDEX [287]

CIVILIZATION AND ETHICS

CHAPTER I

THE CRISIS IN CIVILIZATION AND ITS SPIRITUAL CAUSE

The material and spiritual elements in civilization

OUR civilization is going through a severe crisis.

Most people think that the crisis was produced by the war, but that is wrong. The war, with everything connected with it, is only a phenomenon of the condition of un-civilization in which we find ourselves. Even in States which took no part in the war, and on which the war had no direct influence, civilization is shaken, only the fact is not so clearly evident in them as in those which were hard hit by the consequences of its peculiarly cruel spiritual and material happenings.

Yet is there any real, live thought going on among us about this collapse of civilization, and about possible ways of working ourselves up out of it? Scarcely! Clever men stumble about in seven-league boots in the history of civilization and try to make us understand that civilization is some kind of natural growth which blossoms out in definite peoples at definite times and then of necessity withers, so that new peoples with new civilizations must keep replacing the worn-out ones. When they are called upon, indeed, to complete their theory by telling us what peoples are destined to be our heirs, they are somewhat embarrassed. There are, in fact, no peoples to be seen whom one could imagine to be capable of even a portion of such a task. All the peoples of the earth have been in large measure under the influence both of our civilization [pg 002] and of our lack of it, so that they share more or less our fate. Among none of them are to be found thoughts which can lead to any considerable original movement of civilization.

Let us put on one side cleverness and interesting surveys of the history of civilization, and busy ourselves in a practical way with the problem of our endangered civilization. Of what character is this degeneration in our civilization, and why has it come about?

To begin with, there is one elementary fact which is quite obvious. The disastrous feature of our civilization is that it is far more developed materially than spiritually. Its balance is disturbed. Through the discoveries which now place the forces of Nature at our disposal in such an unprecedented way, the relations to each other of individuals, of social groups, and of States have undergone a revolutionary change. Our knowledge and our power have been enriched and increased to an extent that no one would have thought possible. We have thereby been enabled to make the conditions of human existence incomparably more favourable in numerous respects, but in our enthusiasm over our progress in knowledge and power, we have come to a defective conception of what civilization is. We value too highly its material achievements and no longer keep in mind as vividly as is desirable the importance of the spiritual. Now the results are upon us, and summon us to reflect. They tell us in terribly harsh language that a civilization which develops only on its material side but not in corresponding measure on its spiritual side, is like a ship which with defective steering gear gets at a constantly accelerating pace out of control, and thereby heads for a catastrophe.

The essential nature of civilization does not lie in its material achievements, but in the fact that individuals keep in mind the ideals of the perfecting of man, and the improvement of the social and political conditions of peoples, and of mankind as a whole, and that their habit [pg 003] of thought is determined in living and constant fashion by such ideals. Only when individuals work in this way as spiritual forces on themselves and on society is the possibility given of solving the problems which have been produced by the facts of life, and of attaining to a general progress which is valuable in every respect. Whether there is rather more or rather less of material achievement to record is not what is decisive for civilization. Its fate depends on whether or no thought keeps control over facts. The issue of a voyage does not depend on whether the vessel's pace is somewhat quicker or somewhat slower, but on whether it steers a correct course, and its steering gear keeps in good condition.

Revolutions in the relations of life between individuals, society, and peoples, as they follow in the train of our great material achievements, make, if they are to show real progress in the sense of valuable civilization, higher demands on the habit of thought of civilized people, just as the increased speed of a ship presupposes greater reliability in rudder and steering gear. Advances in knowledge and power work out their effects on us almost as if they were natural occurrences. It is not within our power so to direct them that they influence favourably in every respect the relations in which we live, but they produce for individuals, for society, and for nations, difficult and still more difficult problems, and bring with them dangers which it is quite impossible to estimate beforehand. Paradoxical as it may seem, our advances in knowledge and power make true civilization not easier but more difficult. One can even say that, judging by the events of our own and the two preceding generations, we are almost entitled to doubt whether in view of the way in which these material achievements have been showered upon us, true civilization is still possible.

The most widespread danger which material achievements bring with them for civilization consists in the fact that through the revolutions in the conditions of life men [pg 004] become in greater numbers unfree, instead of free. The type of man who once cultivated his own bit of land becomes a worker who tends a machine in a factory; manual workers and independent trades-people become employees. They lose the elementary freedom of the man who lives in his own house and finds himself in immediate connexion with Mother Earth. Further, they no longer have the extensive and unbroken consciousness of responsibility of those who live by their own independent labour. The conditions of their existence are therefore unnatural. They no longer carry on the struggle for existence in comparatively normal relations in which each one can by his own ability make good his position whether against Nature or against the competition of his fellows, but they see themselves compelled to combine together and create a force which can extort for itself better living conditions. They acquire thereby the mentality of unfree men, in which ideals of civilization can no longer be contemplated in the needful purity, but become distorted to correspond with the surrounding atmosphere of struggle.

To a certain extent we have all of us, under modern conditions, become unfree men. In every rank of life we have from decade to decade, if not from year to year, to carry on a harder struggle for existence. Overwork, physical or mental or both, is our lot. We can no longer find time to collect and order our thoughts. Our spiritual dependence increases at the same pace as our material dependence. In every direction we come to conditions of dependence which in former times were never known in such universality and such strength. Economic, social, and political organizations, which are steadily becoming more and more complete, are getting us more and more into their power. The State with its more and more rigid organization holds us under a control which is growing more and more decided and inclusive. In every respect, therefore, our individual being is depreciated. It is becoming more and more difficult to be a personality.

[pg 005]

Thus it is that the progress of our external civilization brings with it the result that individuals, in spite of all the advantages they get, are in many respects injured both materially and spiritually in their capacity for civilization through those very advantages.

It is our progress in material civilization, too, which intensifies in so disastrous a way our social and political problems. Through the social ones we are involved in a class struggle which shakes and throws into confusion economic and national relations. If we go down to rock-bottom, it was machinery and world commerce which brought about the world war, and the inventions which put into our hands such mighty power of destruction made the war of such a devastating character that conquered and conquerors alike are ruined for a period of which no one can see the end. It was also our technical achievements which put us in a position to kill at such a distance, and to wipe out the enemy in such masses, that we sank so low as to push aside any last impulse to humanity, and were mere blind wills which made use of perfected lethal weapons of such destructive capacity that we were unable to maintain the distinction between combatants and non-combatants.

Material achievements, then, are not civilisation, but become civilization only so far as the mental habit of civilized peoples is capable of allowing them to work towards the perfecting of the individual and the community. Fooled, however, by our advances in knowledge and power, we did not reflect on the danger to which we were exposing ourselves by the diminished value we put on the spiritual elements in civilization, and we surrendered completely to a naïve satisfaction at our magnificent material achievements, and went astray into an incredibly superficial conception of civilization. We believed in a progress which was a matter of course, because contained in the facts themselves. Instead of harbouring in our thought ideals approved by reason, and undertaking to mould reality into accordance with them, we were fooled [pg 006] by a vain feeling for reality, and wanted to come through with lowered ideals which were borrowed from it. By taking this course we lost all control over the facts.

Accordingly, just when the spiritual element in culture was necessary in extraordinary strength, we let it waste away.

Civilization and World-View

How could it come about that the spiritual element in civilization became so lost to us?

To understand that, we must go back to the time when it was at work among us in a direct and living way, and the path thereto leads us back into the eighteenth century. Among the Rationalists who approach everything through reason, and would regulate everything in life by rational considerations, we find expression given in elemental strength to the conviction that the essential element in civilization is a habit of thought. It is true that they are already impressed by modern achievements in discovery and invention, and do allow to the material side of civilization a corresponding importance. But they nevertheless regard it as self-evident that the essential and valuable element in civilization is the spiritual. That interest is focused first of all on the spiritual progress of men and humanity, and in that they believe with a mighty optimism.

The greatness of these men of the period of the “Aufklärung” lies in this, that they set up as ideals the perfecting of the individual, of society, and of mankind, and devote themselves to these ideals with enthusiasm. The force on which they count for the realizing of them is the general habit of thought; they demand of the human spirit that it shall transform men and the relations in which they live, and they trust to it to prove itself stronger than the facts of life.

But whence came the impulse to set up such high ideals of civilization, and their confidence of being able to realise [pg 007] them? It was from their view of the world (Weltanschauung).

The Rationalist world-view is optimistic and ethical, its optimism consisting in this, that it assumes as ruling in the world a general purposive adaptation which is directed to the perfecting of the world, and from this purposiveness the efforts of individual men and of mankind to secure material and spiritual progress derive meaning and importance and a guarantee of success.

This world-view is ethical because it regards the ethical as something in accordance with reason, and on that ground demands from man that, putting egoistic interests behind him, he shall devote himself to all ideals that are waiting for realization, taking the ethical as in everything the standard by which to judge. A habit of humane thought is for the Rationalists an ideal which they can be induced by no consideration to resign.

When at the close of the eighteenth century and the beginning of the nineteenth the reaction against rationalism set in and criticism began to play upon it, its optimism was reproached as being superficial and its ethics as being sentimental. But the good it did, in spite of its manifold imperfections, by inspiring men with ideals of civilization grounded in reason, the spiritual movements which criticise it and take its place cannot develop in the same way. The energy of thought about civilization decreases imperceptibly but

steadily. In proportion as the world-view of rationalism is left behind, the feeling for actuality makes its influence felt, until at last, from the middle of the nineteenth century onwards, ideals are borrowed no longer from reason but from actuality, and we therewith sink still further into a state of uncivilization and lack of humanity. This is the clearest and the most important of all the facts which can be established in the history of our civilization.

What has it to tell us? It tells us that there is a close connexion between civilization and world-view. Civilization is the product of an optimistic-ethical view of the world. [pg 008] Only in proportion as the prevalent world-view is one which is world- and life-affirming and at the same time ethical, do we find ideals of civilization put forward and kept influential in the habits of thought of individuals, and of society.

That this inner relation between civilization and the world-view of civilized peoples has never received the attention that it deserves, is the result of there having been among us so little real meditation on the essential nature of civilization.

What is civilization? It is the sum total of all progress made by men and mankind in every sphere of action and from every point of view, so far as this progress helps towards the spiritual perfecting of individuals as the progress of all progress.

The impulse to strive for progress in all spheres of action and from every point of view comes to men out of an optimistic world-view which affirms the world and life to be something valuable in themselves, and consequently bears within itself a compulsion to raise to its highest possible value all that is, so far as it can be influenced by us. Hence come will and hope, and effort directed to the improvement of the condition of individuals and of society, of peoples and of mankind. This leads to a lordship of the spirit over the powers of Nature, to the completion of the religious, social, economic, and practical grouping of men, and to the spiritual perfecting of individuals and of the community.

Just as the world- and life-affirming, that is, the optimistic world-view is alone capable of stirring men to effort aimed at promoting civilization, so in an ethical world-view alone is there latent the power to make men, when putting aside and giving up altogether their selfish interests, persevere in such effort for civilization, and keep them always turned in the direction of the spiritual and moral perfecting of the individual as the essential object of civilization. Bound the one to the other, then, world- and [pg 009] life-affirming world-view and ethics think out in harmony the ideals of true, complete civilization and set to work at realizing them.

If civilization remains incomplete or its level falls, this rests in the last resort on the fact that either the world- and life-affirmation of the world-view, or its ethics, or both of them have remained undeveloped or have gone backwards. And that is the case with us. It is evident that the ethics required for civilization have gone out of use.

For decades we have been accustoming ourselves increasingly to measure with relative ethical standards, and no longer to allow ethics to have their say in all questions alike. This renunciation of consistent ethical judgment we feel as an advance in practicality.

But our world- and life-affirmation also have become shaky. The modern man no longer feels under any compulsion to think about ideals of progress and to will them. To a large extent he has come to terms with actuality. He is much more resigned than he admits to himself, and in one respect he is even outspokenly pessimistic. He does not really believe any more in the spiritual and ethical progress of men and of mankind, which is nevertheless the essential element in civilization.

This stunting of our world- and life-affirmation and of our ethics has its cause in the constitution of our world-view. In regard to this we have since the middle of the nineteenth century been going through a crisis. It is no longer possible for us to arrive at a conception of the universe in which the meaning of the existence of men and of mankind can be recognized, and in which, therefore, there are also contained the ideals which flow from thoughtful world- and life-affirmation and from ethical volition. We are falling more and more into a condition of having no world-view at all, and from our lack of that comes our lack of civilization.

The great question for us is, therefore, whether we have to renounce permanently the world-view which carries within it in all their strength the ideals of the perfecting of men and of mankind, and of ethical effort. If we succeed [pg 010] in establishing again a world-view in which world- and life-affirmation is given in convincing fashion, we shall become masters of the decay of civilization which is in progress, and shall reach again a true and living civilization. Otherwise we are condemned to see the wreck of all attempts to arrest the degeneration. Only when the truth that renewal of civilization can only come by a renewal of our world-view becomes a universal conviction, and a new longing for a world-view sets in, shall we find ourselves on the right path. But this is not yet in prospect. The modern man is still without any correct feeling of the full significance of the fact that he is living with an unsatisfactory world-view, or without any at all. The unnatural and dangerous character of this condition must first be brought home to his consciousness, just as those persons who exhibit disturbances of the stability of their nervous system have to be clearly told

that their vitality is threatened, although they feel no pain. Similarly, we have to stir up the men of to-day to elementary meditation upon what man is in the world, and what he wants to make of his life. Only when they are impressed once more with the necessity of giving meaning and value to their existence, and thus come once more to hunger and thirst for a satisfying world-view, are the preliminaries given for a spiritual condition in which we become again capable of civilization.

But in order to learn the way to such a world-view we must see clearly why the struggle undertaken by the European spirit to secure it was for a time successful, but during the second half of the nineteenth century came to an unfortunate end.

Because our thinking is too little occupied with civilization it has been insufficiently noticed that the most important part of the history of philosophy is the history of man's struggle for a satisfactory world-view. Regarded in this light, the history unrolls itself like a tragic drama.

[pg 011]

CHAPTER II

THE PROBLEM OF THE OPTIMISTIC WORLD-VIEW

The Western and the Indian conceptions of civilization

FOR us Westerners civilization consists in this, that we work for the perfecting of ourselves and of the world at the same time.

But do the activities that are directed outwards and inwards necessarily belong together? Cannot the spiritual and moral perfecting of the individual, which is the ultimate aim of civilization, also be secured if he works for himself only and leaves the world and its circumstances to themselves? Who gives us any guarantee that the course of the world can be influenced so as to promote the special aim of civilization, viz., the perfecting of the individual? Who tells us that it has any meaning at all which can be further developed? Is not any action of mine which is directed on the world a diversion of what could be directed on myself, though everything depends finally upon the latter?

Moved by these doubts the pessimism of the Hindus and that of Schopenhauer refuse to allow any importance to the material and social achievements, which form the outward and visible part of civilization. About society, nation, mankind, the individual is not to trouble himself; he is only to strive to experience in himself the sovereignty of spirit over matter.

This, too, is civilization, in that it pursues the final object of the latter, viz., the spiritual and ethical perfecting of the individual. If we Westerners pronounce it incomplete, we must not do so too confidently. Do the outward progress of mankind and the inner completion of the individual really belong together as we imagine them to? Are we not, under an illusion, forcing together things which are [pg 012] different in kind? Has the spirit in one kind of action actually some gain for the other?

What we set up as our ideal we have not realized. We lost ourselves in outward progress, allowing the moralization and inward deepening of the individual to come to a stop. So we have not been able to produce practical proof of the correctness of our view of what civilization is. We cannot, therefore, simply put aside that other narrower conception, but must come to terms with it.

There will come a time—it is already being prepared for—when pessimistic and optimistic thought, which have hitherto talked past each other almost as strangers, will have to meet for practical discussion. World-philosophy is just dawning. It will shape itself in a struggle as to whether its world-view shall be optimistic or pessimistic.

The struggle for the optimistic world-view

The history of Western philosophy is the history of the struggle for an optimistic world-view. If in antiquity and in modern times the peoples of Europe have managed to produce a civilization, it is because in their thought the optimistic world-view was dominant, and held the pessimistic permanently in subjection, although it was not able to suppress it altogether.

The accessions of knowledge which have come in the course of our philosophy have been nothing in themselves: they always stand in the service of one world-view or the other, and attain only in it to their real significance.

But the characteristic thing about the way in which the settlement is made on each occasion, is that it never is made openly. The two world-views are never brought face to face and the case of each heard. That the optimistic alone is in the right is a conviction which is accepted as more or less self-evident. The only thing felt as a problem is how to marshal all possible knowledge in the

triumphal procession of proof to defeat the other, and to knock on the head anything that may still wish to rise in its defence.

[pg 013]

Since the pessimistic world-view has never made its presence properly felt, Western thought manifests a lofty unwillingness to understand it, though it has a splendid faculty for detecting it. Where it finds, as in Spinoza, too little interest for activity directed upon the world, it reacts immediately with rejection of it. Yet all objectively thinking investigation of the reality of nature is disliked by it because it may lead to the central position of the human spirit in the world being insufficiently emphasised. It is because materialism seems likely to be the last ally of pessimism that it carries on so embittered a struggle against it.

In the discussion of the problem of the theory of knowledge from Descartes to Kant and beyond him it is really the cause of the optimistic world-view which is being maintained. That is why the theoretical possibility of a depreciation or a denial of the world of sense is attacked with such obstinacy. By proving the ideality of space and time Kant hopes to make finally secure the optimistic world-view of rationalism with all its ideals and demands. Only so can it be explained that the most acute examinations of the theory of knowledge are carried through with the most naïve conclusions about world-view. The great post-Kantian systems of thought, however much they differ from one another in their subject-matter and the process of the speculation with which they deal with it, are all united in this, that they crown the optimistic world-view in their cloud-castles as the ruler of the universe.

To fit in the aims of mankind with those of the universe in a logically convincing fashion, that is the endeavour in which European philosophy serves the optimistic world-view. Anyone who does not help, or who is indifferent about it, is an enemy.

In its prejudice against scientific materialism philosophy was right. Materialism has done much more to shake the position of the optimistic world-view than Schopenhauer has, although it never proceeded against it with outspoken hostility. When, after the collapse of the great systems, [pg 014] it was allowed to seat itself at table with philosophy, which had now become more modest, it even exerted itself to find out in what sort of tone the latter would like the conversation to be carried on. In dealing with Darwin and others, philosophizing natural science made touchingly naïve attempts so to extend and stretch out the history of zoological development which led up to man, that mankind and with it the spiritual should appear again as the goal of the world-process, as in the speculative systems. But in spite of these well-meant efforts of the proletarian guest the conversation could no longer be carried on in the old spirit. Of what use was it for him to try to be better than his reputation? He brought with him more respect for nature and facts than was consistent with the convincing establishment of the optimistic world-view. He therefore shook it, even when he did not intend to.

To such a disregard of nature and science as was shown by the earlier philosophy we can never return. Nor can we expect the return of a system of thought which makes it possible to discover in any convincing way in the universe the aims and objects of mankind, as was allowed by the old methods. The optimistic world-view ceases, therefore, to be self-evident to us, or to be demonstrable by the arts of philosophy. It must give up the idea of finding for itself a solid foundation.

Optimism and Pessimism

Confusion is caused by the fact that the optimistic and pessimistic world-views seldom come forward in their purity in the history of human thought. Their relations are usually such that the one is predominant, while the other treats with it without being officially recognized. In India a tolerated world- and life-affirmation maintains for pessimism something of interest in the external civilization which it nominally denies. With us pessimism slips in and gnaws at the civilizing energies of the optimistic view, the result being that belief in the spiritual progress of [pg 015] mankind has left us. From it, too, comes the fact that we everywhere conduct the business of life with lowered ideals.

Pessimism is a lowered will-to-live, and is to be found wherever man and society are no longer under the pressure of all those ideals of progress which must be thought out by a will-to-live that is consistent with itself, but have sunk to the level of letting actuality be, over wide stretches of life, nothing but actuality.

It is where pessimism is at work in this anonymous fashion, that it is most dangerous to civilization. It attacks then the most valuable ideas belonging to life-affirmation, leaving the less valuable ones untouched. Like some concealed source of magnetic power it disturbs the world-view's compass, so that it takes, without suspecting it, a wrong course. Thus the unavowed mixture of optimism and pessimism in our thought has the result that we continue to approve the external blessings given us by civilization, things which to thinking pessimism are a matter of indifference, while we abandon that which alone it holds to be valuable, the pursuit of inner perfection. The desire for progress which is directed to objects of sense, goes on functioning because it is nourished by actuality,

while that which reaches after the spiritual becomes exhausted, because it is thrown back upon the inner stimulus which comes from the thinking will-to-live. As the tide ebbs, objects which reach deep down are left stranded, while what is just on the surface remains afloat.

Our degeneration, then, traced back to our world-view and what resulted from it, consists in true optimism having, without our noticing it, disappeared from among us. We are by no means a race weakened and decadent through excessive enjoyment of life, and needing to pull ourselves together to show vigour and idealism amid the thunderstorms of history. Although we have retained our vigour in most departments of the direct activities of life, we are spiritually stunted. Our conception of life with all that depends on it has been lowered both for individuals and for the community. The higher forces of volition and [pg 016] influence are impotent in us, because the optimism from which they ought to draw their strength has become imperceptibly permeated with pessimism.

A characteristic feature of the presence at the same time of optimism and pessimism as lodgers in "Thoughtless House" is that each goes about in the other's clothes, so that what is really pessimism gives itself out among us as being optimism, and _vice versâ_. What passes for optimism with the mass of people is the natural or acquired faculty of seeing things in the best possible light. This illumination of them is the result of a lowered conception of what ought to be now and in the future. A person ill with consumption is brought by the poison of the disease into the condition which is called Euphoria, so that he experiences an imaginary feeling of health and strength. Similarly there is an external optimism present in individuals and in society just in proportion as they are, without realizing it, infected with pessimism.

True optimism has nothing to do with any sort of lenient judgement. It consists in contemplating and willing the ideal in the light of a deep and self-consistent affirmation of life and the world. Because the spirit which is so directed proceeds with clear vision and impartial judgement in the valuing of all that is given, it wears to ordinary people the appearance of pessimism. That it wishes to pull down the old temples in order to build them again more magnificently is by the vulgar optimism put down to its discredit as sacrilege.

The reason, then, why the only legitimate optimism, that of volition inspired by imagination, has to carry on such a hard struggle with pessimism is that it always has first to track the latter down in vulgar optimism and unmask it. That is a task which optimism has never finished, for so long as it allows the enemy to emerge in any shape there is danger for civilization. When that happens, activity in promoting the special aims of civilization always diminishes, even if satisfaction with its material achievements remains as strong as before.

[pg 017]

Optimism and pessimism, therefore, do not consist in counting with more or less confidence on such or such a future for the existing state of things, but in what the will desires to have as the future. They are qualities not of the judgement, but of the will. The fact that up to now that inadmissible definition of these qualities was current side by side with the correct one, so that there were four items to deal with instead of two, made the game easier for the unthinking by deceiving us about what true optimism is. Pessimism of the will they passed off as optimism of the judgement, and optimism of the will they put aside as pessimism of the judgement. These false cards must be taken from them, so that they may not continue to deceive the world in such a fashion.

Optimism, Pessimism, and Ethics

In what relation do optimism and pessimism stand to ethics?

That close and peculiar relations do exist between them is clear from the fact that in the thought of mankind the two struggles, that for optimistic or pessimistic world-view and that about ethics, are usually involved in each other. It is the general belief that when one is being fought out the other is being fought as well.

This mutual connexion is very convenient for thought. When a foundation for ethics is being laid, optimistic or pessimistic arguments are unawares pressed into the service, and _vice versâ_ ethical arguments when optimism or pessimism have to be established. In this process Western thought lays most stress on justifying a life-affirming ethical system, that is an activist one, and thinks that merely by doing so it has proved the case for optimism in its world-view. With Indian thought the most important thing is finding a logical foundation for pessimism, and the justifying of a life-denying ethical system, _i.e._ a passivist one, is rather a derivative from that.

The confusion which resulted from the two struggles for [pg 018] optimism and pessimism and for ethics not being kept distinct, has contributed almost more than anything else to prevent the thought of mankind from attaining to clarity.

It was an easy mistake to make. The question whether it is to be affirmation or denial of life and the world, crops up in ethics in the same way as in the dispute between optimism and pessimism. Things which by their nature belong together feel themselves drawn together, so that optimism naturally thinks it can support itself on an affirmative ethical system, and pessimism thinks the same about a negative one. Nevertheless, the result has hitherto always been that neither of these two closely-related entities could stand firm, because neither of them chose to depend on itself alone.

[pg 019]

CHAPTER III

THE ETHICAL PROBLEM

The difficulties of ethical perception

HOW came mankind to think about morality and to make progress in that sphere of thought?

It is a picture of confusion that unrolls itself before the eyes of anyone who undertakes a journey through the history of man's search for the ethical. The progress made in that sphere of thought is inexplicably slow and uncertain. That the scientific view of the world could be delayed in its rise and development is to a certain extent intelligible, for its advance depended more or less on the chance of there existing gifted observers, whose discoveries in the realm of the exact sciences and the knowledge of nature was needed first, to provide new horizons and to point out new paths for thought.

But in ethics thought is thrown back entirely on itself: it has to do only with man himself and his self-development, which goes on by a process of causation from within. Why, then, does it not make better progress? Just because man himself is the material which has to be investigated and moulded.

Ethics and æsthetics are the step-children of philosophy. They both deal with a subject which is coy about submitting itself to reflexion, for they both treat of spheres in which man exercises his purely creative activities. In science man observes and describes the course of nature, and tries to penetrate its mysteries. In practical matters he uses and moulds it by applying what he has grasped of it outside his own person. But in his moral and artistic activities he uses knowledge and obeys impulses, [pg 020] perceptions, and laws which originate in himself. To establish these firmly and to create ideals from them is an undertaking which can be successful to a certain extent only. Thought lags behind the material on which it exercises itself.

This is evident from the fact that the examples with which ethics and æsthetics try to work upon reality are usually not quite consistent and are often foolish. And how far from simple is whatever is laid down in either this or that! How the assertions made contradict each other! The guidance that an artist can get for his activities from the best works on æsthetics is but small. Similarly, a business man who seeks in a work on ethics advice as to how, in any given case, he is to bring the demands of his business into harmony with those of ethics, can seldom find any satisfactory information.

The inadequacy in this respect of æsthetics is not of great importance for the spiritual life of mankind. Artistic activity is always the peculiar affair of individuals whose natural gifts develop more by the actual production of works of art than by consideration of the conclusions arrived at by æsthetic theorizing.

With ethics, however, it is a matter of the creative activity of the mass of men, an activity which is largely determined by the principles which are current in the general thought of the time. The absence of that progress which is still possible in ethics is something tragic.

Ethics and æsthetics are not sciences. Science, as the description of objective facts, the establishment of their connexion with one another, and the drawing of inferences from them, is only possible when there is a succession of similar facts to be dealt with, or a single fact in a succession of phenomena, when, that is, there is a subject matter which can be reduced to order under a recognized law. But there is no science of human willing and doing, and there never can be. Here there are only subjective and infinitely various facts to be studied, and their mutual connexion lies within the mysterious human ego.

It is only the history of ethics that is scientific, and that [pg 021] only so far as a history of man's spiritual life is scientifically possible.

The importance of thought about ethics

There is, therefore, no such thing as a scientific system of ethics; there can only be a thinking one. Philosophy must give up the illusion which it has cherished even down to the present day. As to what is good and what is bad, and about the considerations in which we find strength to do the one and avoid the other, no one can speak to his neighbour as an expert. All that one can do is to impart to him so much as one finds in oneself of that which ought to influence everybody, though better thought out perhaps, and stronger and clearer, so that noise has become a musical note.

Is there, however, any sense in ploughing for the thousand and second time a field which has already been ploughed a thousand and one times? Has not everything which can be said about ethics already been said by Lao-tse, Confucius, the Buddha, and Zarathustra; by Amos and Isaiah; by Socrates, Plato, and Aristotle; by Epicurus and the Stoics; by Jesus and Paul; by the thinkers of the Renaissance, of the "Aufklärung," and of Rationalism; by Locke, Shaftesbury, and Hume; by Spinoza and Kant; by Fichte and Hegel; by Schopenhauer, Nietzsche, and others? Is there a possibility of getting beyond all these so materially contradictory convictions of the past to something new which will have a stronger and more lasting influence? Can the ethical kernel of the thoughts of all these men be collected into an idea of the ethical, which will unite all the energies to which they appeal? We must hope so, if we are not to despair of the fate of the human race.

Does thought about ethics bring more ethics into the world? The confused picture offered us by the history of ethics is enough to make one sceptical about it. On the other hand, it is clear that ethical thinkers like Socrates, Kant, or Fichte had a moralizing influence on many of their [pg 022] contemporaries. From every revival of ethical reflexion there went forth ethical movements which made the contemporary generation fitter for its tasks. If any age lacks the minds which force it to reflect about the ethical, the level of its morality sinks and with it its capacity for answering the questions which present themselves to it.

In the history of ethical thought we wander in the innermost circles of world-history. Of all the forces which mould reality morality is the first and foremost. It is the determining knowledge which we must wring from thought. Everything else is more or less secondary.

For this reason everyone who believes that he can contribute something to help forward the ethical self-consciousness of society and of individuals has the right to speak now, although it is political and economic questions that the present day prescribes for study. For what is inopportune is really opportune. We can accomplish something lasting in the problems of political and economic life only if we approach them as men who are trying to think ethically. All those who help forward in any way our thought about ethics are working for the coming of peace and prosperity to the world. They are engaged in the higher politics, and the higher rational economics, and even if all they can do is nothing more than to bring ethical thinking to the fore, they have nevertheless done something valuable. All reflexion about ethics has as one result a raising and rousing of the general disposition to morality.

The search for a basic principle of morality

But however certain it is that every age lives by the energies which have sprung from its thought about ethics, it is equally certain that up to now the ethical thoughts which have become current have after a longer or a shorter period lost their power of convincing. Why has the establishment of an ethical system never met with more than a partial and temporary success, and never been a permanency? Why is the history of the ethical thinking of [pg 023] mankind the history of inexplicable stoppages and fallings-back? Why has there been in this sphere no organic progress which allows one period to build upon the achievements of preceding ones? Why in the sphere of ethics do we live in a town full of ruins, in which one generation builds for itself here, and another there, what is absolutely necessary?

"To preach morality is easy, to establish it is hard," says Schopenhauer, and that saying shows what the problem is.

In every effort of thought about ethics there is to be seen, distinctly or indistinctly, the search for a basic principle of morality, which needs no support outside itself, and unites in itself the sum total of all moral demands. But no one has ever succeeded in really formulating this principle. Elements only of it were brought to light and given out to be the whole, until the difficulties which emerged destroyed the illusion. The tree, however finely it sprouted, did not live to grow old, because it was unable to send its roots down into the permanently nourishing and moisture-giving earth.

The chaos of ethical views becomes to some extent intelligible as soon as one sees that we are concerned with differing and mutually contradictory views about fragments of the basic principle. The contradiction has its foundation in their incompleteness. There is ethical matter in what Kant objects to in the ethics of rationalism, as also in what he puts in its place; in that part of Kant's

writings where his conception of the moral is opposed by Schopenhauer, as also in what is to take its place in the ethical system of the latter. Schopenhauer is ethical in the points on which Nietzsche attacks him, and Nietzsche is ethical in his opposition to Schopenhauer. What is wanted is to find the fundamental chord in which the dissonances of these varied and contradictory ethical ideas unite in producing harmony.

The ethical problem, then, is the problem of a basic principle of morality, which is founded in thought. What is the common element of good in the manifold goods which we feel to be such? Is there such a universally valid [pg 024] conception of the good? If there is, in what does it consist, and how far is it real and necessary for me? What influence has it over my general disposition and my actions? Into what relations with the world does it bring me?

It is, then, on the basic principle of the moral that the attention of thought has to be fixed. The mere giving of a list of virtues and duties is like striking notes at random on the piano and thinking it is music. And when we come to discuss the works of earlier moralists, it is only the elements in them which can help the establishment of an ethical system that will interest us, not the way in which any system has been advocated.

Otherwise there is no success for any attempt to bring order into chaos. How utterly at sea Friedrich Jodl_(_2_)_ is in his history of ethics, the most important existing work in this department, when he tries to estimate the relative values of the various ethical standpoints! Failing to judge them directly by their distance from an initial basic principle of morality, he is unable to establish a standard of comparison. He gives us, therefore, only a survey of ethical views, and no history of the ethical problem.

Religious and philosophical ethics

When we come to look for the fundamental principle of morality, are we concerned only with the direct attempts of philosophy to find it? No, we are concerned with every kind, those of religion as well as others. We must trace out the whole experience of mankind in its search for the ethical.

The raising of a dividing wall between philosophical ethics and religious ethics is based on the mistaken idea that the former are scientific and the latter non-scientific. But neither of them is either: they are both alike merely thought; only one has freed itself from acceptance of the traditional religious world-view, while the other still maintains its connexion with it.

[pg 025]

The difference, however, is merely relative. Religious ethics appeal, indeed, to a supernatural authority, but that is rather the form which they assume. As a matter of fact, however high they rise, they still seek to find an independent basic principle of morality. In every religious genius there lives an ethical thinker, and every really deep philosophical moralist is in some way or other religious.

How indeterminate is the border-line is shown by Indian ethics. Are they religious, or are they philosophical? Originating in the thought of the priests, they claim to be a deeper exposition of the demands of religion, but in essential nature they are philosophical. With the Buddha and others, they venture to make the step from pantheism to atheism, but without giving up their claim to be religious. Spinoza and Kant, however, who are counted among philosophical moralists, do, if we judge by the general direction of their thought, belong at the same time to the religious ones.

It all depends on a relative difference in methods of thought. The one group works towards the basic principle of ethics by a more intuitive process, the other by a process which is more analytical. It is the depth, not the method of the thought, which decides the matter. The more intuitive thinker produces his ethical thought like an artist who with the production of an important work of art opens up new horizons. In deep-reaching moral sayings like the beatitudes of Jesus the basic principle of morality shines out. There comes progress in the recognition of what is moral, even if the provision of a foundation for it fails to advance in the same way.

On the other hand, the searching for the basic principle of the moral by the process of critical analysis may lead to an impoverished system of ethics, because there runs through it the effort to take into account only what is connected with the idea that seems to be what is being sought for. That is why philosophical ethics are as a rule so far behind practical ethics, and have so little direct influence. While religious moralists in one mighty word can get down to the [pg 026] waters flowing far below the surface, philosophical ethics often dig out nothing but a slight hollow in which a puddle forms.

Nevertheless, it is rational thinking alone which is able to pursue the search for the basic principle with perseverance and hope of success. It must find it at last, if it only goes deep enough, and is simple enough.

The weakness of all ethics hitherto, whether philosophical or religious, has lain in this, that they have not shown individuals how to deal directly and naturally with reality. To a large extent they merely talk "about it and about." They do not touch a man's daily experience, and therefore they exert no permanent pressure upon him. The result is lack of ethical thought, and mere platitudes about ethics.

The true basic principle of the ethical must be not only something universally valid, but something absolutely elementary and inward, which, once it has dawned upon a man, never lets him loose, which as a matter of course runs like a thread through all his meditation, which never lets itself be thrust aside, and which continually challenges him to come to an understanding with reality.

For centuries men who navigated the seas guided themselves by the stars. In time they rose above this imperfect method through the discovery of the magnetic needle, which by its natural principle of activity pointed them to the north. Now they can tell where they are in the darkest night on the most distant sea. That is the kind of progress that we have to seek in ethics. So long as we have nothing but an ethical system of ethical sayings, we direct our course by stars, which, however brilliant their shining, give us only more or less reliable guidance, and can be hidden from us by rising mist. During a stormy night they leave mankind, as we know by recent experiences, in the lurch. If, however, we have in our possession a system of ethics as a principle which is a necessity of thought and comes to clearness within ourselves, there begins a far-reaching ethical deepening of individuals, and steady ethical progress in mankind.

[pg 027]

CHAPTER IV

RELIGIOUS AND PHILOSOPHICAL WORLD-VIEWS

The world-views of the world-religions

IN the world-religions we can see powerful attempts to establish an ethical world-view.

The religious thinkers of China, Lao-tse (born 604 B.C.), Kung-tse (Confucius, 537-479 B.C.), Meng-tse (372-289 B.C.) and Chwang-tse (fourth century B.C.), all try to ground the ethical in a world- and life-affirming nature-philosophy. In so doing they arrive at a world-view which, because it is optimistic-ethical, contains incentives to inward and outward civilization.

The religious thinkers of India also, the Brahmanic philosophers, the Buddha (560-480 B.C.), and the Hindus, start, like the Chinese, from thought about the existing world, _i.e._ from nature-philosophy. They do not, however, take a world- and life-affirming view of it, but a world- and life-denying one. Their world-view is pessimistic-ethical, and contains, therefore, incentives to inward civilization only, not to outward as well.

Chinese religiousness, and Indian, recognize only a single world-principle. They are monistic and pantheistic. Their world-view has to solve the problem of how far we can recognize the original source of the world as ethical, and how far, correspondingly, we become ethical by the surrender to it of our will.

In contrast to these monistic-pantheistic world-views we find dualistic ones in the religion of Zarathustra (sixth century B.C.), in that of the Jewish prophets (from the eighth century B.C. onwards), and in those of Jesus and Mohammed, this last, however, showing itself to be in [pg 028] all points unoriginal and decadent. These religious thinkers do not start from an investigation of the existence which manifests itself in the universe, but from a view of the ethical which is quite independent of it. They put it in opposition to natural happenings. Accordingly they assume the existence of two world-principles, the natural and the ethical. The first is in the world, and has to be overcome; the other is incorporated in an ethical personality which is outside the world and has been given the final authority in this sphere.

If among the Chinese and the Hindus the basic principle of morality was life in harmony with the world-will, so among dualists it is an attempt to be something different from the world in harmony with an ethical divine personality which is outside and above the world.

The weakness of dualistic religions is that their world-view, because it rejects every kind of nature-philosophy, is always naïve. Their strength lies in the fact that they have the ethical within themselves, directly present and with undiminished force. They have no need to strain it and explain it, as monists have to, so as to be able to conceive it as an effluence from the world-will which

reveals itself in nature.

The world-views of the dualistic world-religions, taken as a whole, are optimistic. They live in the confident belief that ethical force will prove superior to natural, and so raise the world and mankind to true perfection. Zarathustra and the older Jewish prophets represent this process as a kind of world-reform. The optimistic element in their world-view asserts itself in a quite natural way. They have the will, and the hope of being able to transform human society and to make the races of the world fit for their higher destiny. Progress in any department of life means for them something gained, for they think of inward and outward civilization together.

With Jesus the value of the optimistic element in his world-view is impaired by the fact that he looks forward to the perfected world as a result of a catastrophic end to the natural one, and while with Zarathustra and the older [pg 029] Jewish prophets the Divine intervention is to a certain extent only the completion of the human activities which have been directed to the perfecting of the world, it is with Jesus the only thing which has to be taken into account. The kingdom of God is to appear in a supernatural way; it is in no way prepared for by any effort made by mankind to attain to civilization.

The world-view of Jesus, because it is fundamentally optimistic, accepts the ends aimed at by outward civilization. Being, however, entangled in the expectation of the end of the world, it is indifferent to all attempts made to improve the temporal, natural world by a civilization which organizes itself on lines of outward progress, and it busies itself only with the inward ethical perfecting of individuals.

Just in proportion, however, as the Christian world-view draws the consequences of the world's not coming to an end, and accepts the idea that the kingdom of God must be established by a process of development which transforms the natural world, it begins to understand and be interested in the completing of social organization, and in all such progress in outward civilization as contributes to it. Then the optimistic element in the world-view can again work unhindered side by side with the ethical. Thus we get an explanation of the fact that Christianity, which in the ancient world showed itself hostile to civilization, seeks in modern times with more or less success to conduct itself as the world-view which is for progress in every sphere of activity.

The world-views of the world-religions and that of Western thought

The questions which press for an answer from the world-religions in their struggle to reach an ethical and an optimistic-ethical world-view, are the same as those which present themselves to Western philosophy also. The great problem is to think out a connexion between the universe and ethics.

[pg 030]

The three types of world-view which show themselves in the world-religions, recur also in Western philosophy. The latter, too, attempts to find an ethical code either in a world- and life-affirming, or in a world- and life-denying, nature-philosophy, or it attempts, rejecting more or less completely all nature-philosophy, to reach a world-view which is in itself ethical. Only, it at the same time does its best to avoid acknowledging, and indeed to conceal, the naïve and dualistic element which is inevitably encountered when this last method of procedure is followed.

The world-views, then, of the world-religions, and that of Western philosophy, do not belong to different worlds, but stand in close inward relations to one another. Further, the distinctions between a religious world-view and a philosophical one is a quite superficial one. The religious world-view which seeks to comprehend itself in thought becomes philosophical, as is the case among the Chinese and the Hindus. On the other hand a philosophical world-view which goes really deep, assumes a religious character.

Although Western thought does, in principle, approach the problem of world-view without any presuppositions, it has not been able to keep itself entirely from being influenced by religious world-views. From Christianity it has received impulses of a decisive character, and the attempt to convert the naïve-ethical world-view of Jesus into a philosophical one has cost it more attention and effort than it admits to itself. With Schopenhauer and his successors the pessimistic monism of India finds expression, and it enriches their reflexion upon the nature of the ethical.

Thus the energies of all the great world-views stream into Western thought, and through the co-operation of these varied forms of thought and energy the latter is enabled to exalt into a universal conviction the optimistic-ethical world-view which hovers before its mind, and that too in a strength which it has never displayed in any previous age or in any other part of the world. And that is why Western thought has advanced farthest both in inward civilization and in outward.

[pg 031]

To give a real foundation to the optimistic-ethical world-view Western thought is indeed as little able as any of the world-religions were, and because the West experiences the problem of world-view in its most universal and most pressing form it is the scene of the greatest advances made by the civilized mind, but also of its greatest catastrophes. It experiences portentous changes in its world-view, and is familiar, too, with terrible periods when it has no world-view at all.

It is because our Western thought is so sensitive in both these directions, that it reveals most clearly the questions and difficulties amid which the search for an optimistic world-view moves.

How far does the history of our thought give to us Westerners the explanation of our fate? What road does it indicate to us as the best for our future search after a world-view in which the individual can find inwardness and strength, and mankind progress and peace?

[pg 032]

CHAPTER V

CIVILIZATION AND ETHICS IN THE GRÆCO-ROMAN PHILOSOPHY

The beginnings: Socrates.

IN the seventh century before Christ the Greek spirit begins to free itself from the world-view which underlay the traditional religion, and undertakes the task of establishing another on a foundation of knowledge and thought.

First there comes a nature-philosophy, the result of investigation of Being with reflexion upon what it really is. Then criticism begins its work. Belief in the gods is found unsatisfying, not only because the course of nature is not made intelligible by the rule of dwellers in Olympus, but also because these personalities no longer answer to the demands of feeling which is thoughtful and moral. These two elements, nature-philosophy and criticism, are found united in Xenophanes and Heraclitus in the sixth century B.C.

In the course of the fifth century B.C. Sophists appear, and begin to concern themselves critically with the accepted standards of value current for social life and individual activities._(_3_)_ The result is annihilating. The more moderate of these "Enlighteners" proclaim the overwhelming majority of these standards which pass for moral to be merely claims made by society on its members, leaving open thereby the possibility that a small remainder may be able to prove themselves to rational consideration as moral in [pg 033] themselves. But the younger radical sophists maintain the position that all morality, like all current law, has been invented by organized society in its own interest. Hence the thinking man who is freeing himself from this tutelage will make his own moral standards, and will follow in them nothing but his own pleasure and interests. Thus Western philosophical thought about the problem of ethics and civilisation starts with a shrill dissonance.

What was Socrates (470-399 B.C.) able to contribute, when he came forward to oppose this tendency?

In the place of the simply pleasurable he put the rationally pleasurable.

By rational consideration, he asserts, it is possible to establish a standard of action in which the happiness of the individual, rightly understood, is in harmony with the interests of society. Virtue consists in right knowledge.

That the rationally moral is that which procures for the agent true pleasure, or, what means the same thing, true profit, Socrates draws out into the most diverse applications in the simple everyday discussions which Xenophon has transmitted to us in his _Memorabilia_._(_4_)_ The dialogues of Plato show him going beyond this primitive utilitarianism, and seeking a conception of the good which has been made something inward and aims at the well-being of the soul; which stands, too, in relationship with the beautiful._(_5_)_ How much of these more advanced views are the Master's own, and how much of his own thoughts his pupil has in this way put into his mouth, cannot now be decided.

That Socrates spoke of an inner, mysterious voice, the "daimonion", as being the highest moral authority in man is indeed certain, for it is mentioned in his indictment. His [pg 034] utilitarian rationalism is therefore completed by a kind of mysticism. An empirical ethic, that is, one established out of past experience and with a view to future experience, and an intuitive ethic live in him side by

side and undistinguished from one another, to be separated later and developed in contrast to one another in his pupils, the Cynics and Cyrenaics on the one hand, and Plato on the other.

Was Socrates at all conscious that with the bringing back of the moral to that which is rationally pleasurable he builds the road only a short way further, and stops exactly at the point where the real difficulty makes its appearance, viz. that of defining the most general content of the moral as given by reason? Or was he so simple as to regard the general formula he had arrived at as the solution of the difficulty?

The confidence which he displays in all his public life leads us to suppose the latter. In his unaffected simplicity lies his strength. In that perilous hour when Western thought comes to the point of having to philosophize about the moral in order to arrest the dissolution of Greek society which has been begun by a body of unstable and disputatious teachers, the wise man of Athens shatters all scepticism by the mighty earnestness of his conviction that what is moral can be determined by thought. Beyond that general statement he does not go, but he is the source of that serious spirit in which antiquity after his day busied itself with the problem. What would that ancient world have become without him?

Characteristic for this prologue to Western philosophizing about the moral is the indifference with which Socrates stands outside the philosophic efforts to reach a complete world-view. He troubles himself neither about the results of natural science, nor about inquiries into the nature of knowledge, but is busied simply with man in his relation to himself and to society. Lao-tse, Confucius, the Indian philosophers, the Jewish prophets, and Jesus seek to comprehend ethics as somehow or other derived from, or [pg 035] forming part of, a world-view. Socrates gives them no foundation but themselves. On this stage, which has no scenery to form a background, there will appear in succession to him the utilitarians of every age.

And here a remarkable prospect opens to us. To all efforts to determine the content of the moral more help is afforded by the ethic which keeps clear of all connexion with a complete world-view than by any other. Such an ethic is the most practical. And yet this isolation is unnatural. The idea that ethics are rooted in a complete world-view, or must find their completion in one—that is, the idea that one's relations to one's fellow-men and to society are in the last resort rooted in some relation to the world—never loses its natural claim. Hence again and again—already in Plato, then in Epicurus and in the Stoic philosophy—ethics feel the need of again connecting themselves with world-view, and the same process continues in modern thought. But the practical search for the content of the ethical remains the prerogative of those who are busied with ethics in themselves.

In Socrates the ethical mysticism of devotion to the inner voice takes the place of the complete world-view, which was in future to be the foundation of the ethical determination of mankind.

Epicureanism and Stoicism. The Ethic of Resignation

Three tasks were left by Socrates to his successors: to determine more exactly the content of the rationally useful; to give the world the most universal general-notion of the good; and to think ethics into a complete world-view.

What conclusions are come to by those who concern themselves with the first question, and seek to determine the rationally useful from a corresponding experience of pleasure?

As soon as the notion of pleasure is brought into connexion with ethics it shows disturbances, as the magnetic [pg 036] needle does in the neighbourhood of the poles. Immediate pleasure shows itself as incapable in every respect of being reconciled with the demands of ethics, and it is therefore given up. Lasting pleasure is called on to take its place, but this retreat does not suffice. Lasting pleasure, interpreted seriously, can be nothing but pleasure of the mind. Even this position, however, is not tenable. Reflexion upon the ethic which is to produce happiness sees itself compelled at last to give up the positive notion of pleasure in any form. It has to reconcile itself to the negative notion which conceives pleasure as somehow or other a liberation from the need of pleasure. Thus the individualistic, utilitarian ethic, also called Eudæmonism, destroys itself as soon as it ventures to be consistent. This is the paradox which reveals itself in the ethics of antiquity.

Instead of coming to maturity in the following generations, the ethically-rational life-ideal put forward by Socrates succumbs to an incurable decline, because the notion of pleasure, which lives in it, denies itself as soon as it makes any attempt to think itself out.

Aristippus (_c._ 435-355 B.C.), the founder of the Cyrenaic school, Democritus of Abdera (_c._ 450-360 B.C.), the author of the atomic theory, and Epicurus (341-270 B.C.) seek to retain as much as possible of the positive notion of pleasure. The Cynic school of Antisthenes (born _c._ 440 B.C.), and the Stoicism which originated with Zeno, a native of Kittium in Cyprus (_c._ 336-264 B.C.),

keep from the very beginning to the negative notion._(_6_)_ But the final result is the same with both. Epicurus sees himself compelled at last to exalt the [pg 037] absence of desire for pleasure as being itself the purest pleasure, landing thereby on the shore of resignation where the Stoics take their exercise. The fundamental difference between the two great philosophical schools of antiquity does not lie in what they offer to men as ethical. About what the "wise man" does and leaves undone, they both frequently express themselves in the same way. What separates them is the world-view with which their ethic is combined. Epicureanism accepts the atomistic materialism of Democritus, is atheistic, asserts that the soul perishes, and is in every respect irreligious. Stoicism is pantheistic.

With Epicurus and Zeno ethics no longer trust themselves, as with Socrates, to maintain an independent existence. They see the necessity of attaching themselves to some sort of world-view. Travelling along this road, Epicurus is guided solely by the effort after veracity. He leaves the talking to the purely scientific knowledge of the world, not allowing ethics to join in the investigation of Being and introduce into it what might be of advantage to itself. How poor, or how rich, it will finally become is to him a matter of indifference. The one thing he is concerned about is that the world-view be a true one, and therein lies the greatness of Epicurus with its claim to our respect.

Stoicism seeks to satisfy the need for an inward, stable world-view; like the Chinese monists it tries to find a meaning in the world. It tries to widen out the ethical rationalism of Socrates into cosmic rationalism. The moral is to show itself to be conduct agreeable to the pronouncements of world-reason.

Stoicism has a vision of an optimistic-ethical affirmation of life, grounded in the nature of the cosmos, but it fails to reach it. It is not untutored enough to acquiesce in the ethical simplicity of a nature-philosophy such as can be seen in Lao-tse and in the older philosophical Taoism. It is ever struggling to discover in world-reason the notion of purposive activity, and is ever mercilessly thrust back upon that of activity pure and simple. Hence the ethic with which it is operating never has a sufficiently universalist [pg 038] character to let it form a natural connexion with world-reason. As might be expected from its origin, it is dominated by the problem of pleasure and not-pleasure, and therefore no longer possesses any efficacious instinct for effort. Its horizons, because still determined by the questions arising out of ancient citizenship and the ancient city-state, are narrow. It is, therefore, not advanced enough to engage in thought on nature-philosophic lines, concerned with both the world and man, although it does feel the inner necessity for doing so.

The vacillation which is characteristic of Stoicism comes, then, from the fact that the results it attains to do not match its aspirations, but are much poorer than the latter. The spirit of antiquity tries to find an optimistic-ethical life-affirmation in nature-philosophy, and to find in it also the justification of those instincts for reliable activity which it has possessed since the days when it was entirely untutored, but it cannot do so. Whenever it acknowledges what has happened it sees clearly that thinking about the universe leads only to resignation, and that a life in harmony with the world means quiet surrender to being carried along in the flood of world-happenings, and, when the hour comes, sinking into it without a murmur.

Stoicism talks, it is true, with deep earnestness of responsibility and duty, but since it cannot draw either from nature-philosophy or from ethics a well-established and living notion of activity, it shows us in these words nothing but beautiful corpses. It is impotent to command anything whatever that is bound up with voluntary activity which is conscious of its aim. Again and again evidence breaks through that its thinking has been pushed aside on to the track of passivity. Nature-philosophy only provides the cosmic background for the resignation to which ethics have come. The ideal which gives life to Chinese Monism, of the perfecting of a world through ethical and ethically organized mankind, is not really discerned, much less securely grasped.

One watches with dismay the shaping of the fate of [pg 039] ancient ethics in Epicureanism and Stoicism. In place of the vigorous life-affirming ethic which Socrates expects from rational thinking, resignation steps in. An inconceivable impoverishment takes place in the representation of the moral. The notion of action cannot be worked out to completion. Even so much of it as, thanks to tradition, still survives in the simple thought-methods of the Greek world in general, is lost.

The ancient Greek was more citizen than man. Active devotion to the cause of the community was to him a matter of course. Socrates presupposes it. In the conversations which Xenophon hands down to us in the _Memorabilia_ he is ever insisting on it that the individual must improve himself in order to become an active citizen. The natural course would have been that the thought which originated with him should deepen this mentality by setting before it the highest social aims. It was, however, never at all in a position to maintain the mentality as it received it. More and more it leads the individual to withdraw himself from the world and from all that goes on in it.

By a never-ceasing process of change the ethics of Greek thought become in Epicureanism and Stoicism ethics of decadence. Not being capable of producing ideals of progressive development for collective bodies, they are also impotent to become really ethics of civilization. In place of the ideal of the man who works for civilization they set the ideal of the "wise man." It is only the inward individual civilization of refined and reflective self-liberation from the world that now floats before its eyes, but this in all its depth.

It is true that there is power in the preaching of resignation which ancient thought, now become knowing about life, allows to go forth to mankind. Resignation is the lofty porch through which one enters upon ethics. But Epicurus and the Stoics stop in this porch. Resignation becomes for them an ethical world-view. Hence they are incapable of leading ancient society from its untutored life- and world-affirmation to one based on thought.

[pg 040]

The conception of the rationally pleasurable, which was the legacy of Socrates, is not productive enough to keep a world alive. It is impossible to develop out of it the ideas of a utilitarianism directed to the welfare of the community, although he believed he found them in it. Ethical thought remains confined within the circle of the self-regarding. Every attempt to ennoble the rationally pleasurable ends in life-affirmation changing into life-denial. On this logical fact was wrecked the ancient West, which, after the critical awakening of the Greek spirit, could have been saved only by means of a reflective optimistic-ethical world-view. It was able to develop seriously what Socrates gave it, but not to make it capable of producing life and civilization.

Plato's abstract basic principle of the ethical. The ethic of world-negation

Plato, too (427-347 B.C.), and Aristotle (384-322 B.C.), the two great independent thinkers of antiquity, are incapable of producing an ethic of action, and so giving civilization a firm foundation.

Plato seeks the general notion of the Good, but he abandons the path which was pointed out, even if not followed to the end, by Socrates, viz. the determination of it by a process of induction. He gives up trying to arrive at the nature of the Good by considerations of the kind, the object, and the results of action, that is to say, by its content. He wants to establish it by a purely formal process, by abstract logical thinking.

In order to arrive at an ethic he uses a detour through the theory of ideas. All similar phenomena, he says, are to be conceived of as varying copies of an original—to express which he uses the word "idea." In trees there is to be seen the idea of tree, in horses, that of horse. The idea does not come to us, as we are inclined to think, by our abstracting from trees the idea of tree, and from horses that of horse. We have it within us already. It originates, not in our [pg 041] experience of the empirical world but in the recollection which our soul brought with it from the supra-sensuous, pure world of ideas, when it began its existence in a body. In the same way we have brought with us the idea of the Good.

Thus in a tortured doctrine which is disfigured everywhere with fancies and obscurities, Plato tries to found ethics on a theory about the character of our knowledge of the world of sense, and he is encouraged to this undertaking by the consideration that it is not from reflexion that we obtain our conception of the Beautiful, which is closely allied with that of the Good: we bring that conception also with us, ready made.

Plato is the first of all thinkers who feels that the presence of the ethical idea in man is what it is: something profoundly puzzling. That is his greatest distinction. Hence he cannot profess to be satisfied with the attempt of the historic Socrates to explain the Good as that which is rationally pleasure-giving. It is clear to him that it is something unconditional, with a compelling force of its own, and to preserve for it this character seems to him, as later to Kant, to be the great task of thought.

But what is the result of his undertaking? A fundamental principle for ethics which is devoid of content. In order to secure its lofty character it is allowed to be born of abstract considerations in the country of the supra-sensuous. It can, therefore, never find itself at home in reality and become familiar with it, nor can any rules for concrete ethical conduct be developed from it. Thus Plato, when he treats practically of ethics, is compelled to abide by the chief virtues, as popularly conceived. In the _Republic_ he names four of them: wisdom, courage, temperance, and justice, and he founds them not on his general idea of the Good, but on his psychology.

But the characteristic ethic of Plato has nothing whatever to do with such virtues. If the conception of the Good is supra-sensible and the immaterial world is the only real one, then it is only thought and conduct which deal with the [pg 042] immaterial that can have any ethical character. In the world of appearance there is nothing of value to be made actual. Man is simply compelled to be an impotent spectator of its shadow-play. All willing must be directed to enabling oneself to turn away from this, and get sight of that

true activity which goes on in the light.

The true ethic, then, is world-negation. To this view Plato was committed the moment he allowed the ethical to find its home in the world of pure Being. Thoughts of ascetic inactivity find expression in him side by side with the Greek feeling for reality, and it is confusing that he does not recognize the conflict between them, but speaks now in one sense, now in the other. His ethic is a chaos, and he himself an expert in inconsistency.

Plato's ethic of world-denial is not an original creation; he takes it over in the Indian setting in which it is offered to him by Orphism and Pythagoreanism. By what route there found its way into Greek thought this pessimism which has been thought out to a system and provided with the doctrine of re-incarnation, we do not know, and shall probably never learn. The presence side by side in Greek thought of an artless optimism and a mature pessimism will always remain for us the great puzzle of Greek civilization. But if the pessimism had not been there, Plato must have introduced it. The abstract basic principle of morality which he adopts in order to preserve the absolute character of morality which he was the first to pronounce to be a necessity, precludes any other content than that of the denial of the sensible world and of natural life.

Aristotle. Instruction about virtue in place of ethics

Plato's fate alarms Aristotle. He refuses to soar to the heights where Plato lost himself. How then does he fare?

His object is the establishment of a serviceable ethic which is in harmony both as to extent and content with reality. What he accomplished lies before us in the [pg 043] so-called _Nicomachean Ethics_, the comprehensive work which he composed for the benefit of his son, Nicomachus. The general thought of Socrates, that ethics are a striving after happiness, he acknowledges. But at the same time he makes quite clear his opinion that the part played by activity in ethics must be a much more important one than is given to it in Plato or in the other post-Socratics. Aristotle feels that the crux of the question is the conception of activity, and this he wants to save. He therefore avoids Plato's paths of abstract thinking, and rejects the ethic of pleasure and not-pleasure over which the Cyrenaics and Cynics work so hard. In his ethical thinking the vitality of the ancient world tries to find expression.

In magnificent fashion he lays down the pre-suppositions which are necessary for the carrying through of his undertaking. He finds the motive to activity in the conception of pleasure, a thing he can do because his whole philosophy has indeed for its aim and object the conceiving of Being as formative activity. Hence the essential element in human nature also is activity. Happiness is to be defined as activity in accordance with the law of excellence. Rational pleasure is experience of the perfecting of one's activity.

Starting from the conception of pleasure which experiences itself as activity, Aristotle is on the way to comprehend ethics as deepened life-affirmation, and to attack the problem of leading the ancient world up from a naïve and unreflecting world-affirmation to a thinking one. But on the way he diverges from the high-road.

When he has to ask the decisive question as to what make activity moral, he shrinks from discussing the problem of the basic principle of the moral. Ethics are not some sort of knowledge which gives a content to activity, he says in opposition to Socrates. The content of the will is already given. No reflexion and no knowledge can put anything new into it, or alter it.

Ethics consist, then, not in a guiding of the will by aims and objects which knowledge puts before it, but in the will's [pg 044] own regulation of itself. The right thing to do is to establish the correct balance between the different elements in the given contents of the will. Left to itself, the latter rushes to extremes. Rational reflexion keeps it in the correct middle path. Thus brought to a state of harmony, human activity can be conceived as motived and ethical. Virtue, therefore, is readiness to observe the correct mean which is to be acquired by practice.

Instead of creating an ethic, Aristotle contents himself with a doctrine of virtue. This depreciation of the ethical is the price he pays in order to reach an ethic which ends neither in the abstract nor in resignation. While he shirks the problem of the basic principle of the moral, he still remains able to establish an ethic of activity, though the latter contains indeed no live forces, only dead ones.

Aristotle's ethic is therefore an æsthetic of the impulses of the will. It consists in a catalogue of virtues and in the demonstration that they are to be conceived as a mean. Thus courage lies between rashness and cowardice, temperance between sensuality and insensibility, truthfulness between boastfulness and irony,_(_7_)_ liberality between prodigality and avarice, high-mindedness between conceit and small-mindedness, gentleness between quarrelsomeness and characterless good-nature.

On this excursion through the field of the ethical, there open up many interesting views. In an acute and living discussion Aristotle lets his readers survey the questions of the relations of man to his fellow-men and to society. How much that is deep and true there

is in the chapter on moral excellence and in that on friendship! How he wrestles with the problem of justice!

No one can fail to feel the charm of the _Nicomachean Ethics_. There is revealed in them a noble personality with abundant experience of life, depicted with a magnificent simplicity. But just in proportion as the method followed [pg 045] is advantageous technically, it is valueless in itself. The ethical is reconciled with reality without having first tried to come to clear understanding of itself. It is in this reconciliation that the understanding is to be found, so Aristotle thinks, but he is mistaken. His mind is seduced through his having observed that some virtues—but even these more or less under compulsion—allow themselves to be conceived as real means between two extremes, and he is misled into developing on these lines the whole of his ethical system.

But a more or less natural quality, which in ordinary speech is called a virtue, is one thing, virtue in the really ethical sense is another. The middle quality between prodigality and avarice is not the ethical virtue of liberality, out the quality of rational economy. The middle quality between rashness and cowardice is not the ethical virtue of courage, but the quality of rational prudence. The combination of two qualities only produces a single one. But virtue, in the ethical sense, means a quality guiding itself by an ideal of self-perfection, and being serviceable for some object which looks towards the universal. Liberality as an ethical virtue means a process of spending which serves some object recognized by the person practising it as valuable in principle, and in such a way that any natural tendency to prodigality, should there be such in the giver, plays no part, while the tendency to avarice is paralysed.

Devotion of one's property or one's life to an object which is valuable in principle is under all circumstances ethical, while prodigality and avarice, rashness and cowardice as simple qualities not inspired by any higher aim have never any ethical character; they are merely something natural. Whether the devotion of one's property or of one's life for an object valuable in principle is made more completely than need be or exactly to the extent required by the circumstances, does not alter in any way the ethical character of the decision and the action. Such excess or defect only shows how much or how little the ethical will has allowed [pg 046] itself to be at the same time influenced by considerations of prudence.

Aristotle's representation, then, rests on the fact that he allows virtue in ordinary speech and virtue in the ethical sense to get mixed up. He smuggles in the really ethical, and then offers it as the resultant of two natural qualities, each of which is an extreme.

In the chapter on temperance—_Ethics_, Bk. III., 10—he has to allow that the theory which makes the ethical a mean between two extremes cannot be carried through completely. The love of beauty, he says plainly, however strong it becomes, remains what it is; there can never be any question of excess. He throws out this admission without seeing that he thereby undermines his feeble definition of the ethical as the appropriate relative mean, and, like Socrates and Plato, acknowledges that there can be something which its content allows to be reckoned as good in itself.

Aristotle is so firmly resolved not to let himself be entangled in the problem of the basic principle of ethics, that he will allow nothing to lead him to the discussion of it. He means to voyage along the coast, keep to facts, and deal with ethics as if they were a branch of natural science. Only he forgets that in science we can confine ourselves to venturing from definite given happenings through hypotheses to the nature of the Being which lies behind them, while in ethics, on the contrary, we have to establish a basic principle through the application of which we secure our happenings.

It is because he misunderstands their nature that Aristotle cannot help ethics forward. Plato rides off over the head of Socrates and loses himself in abstractions. Aristotle, in order to maintain the connexion with reality goes down below Socrates. He brings together material for a monumental building, and runs up a wooden shack. Among teachers of virtue he is one of the greatest. Nevertheless, the least of those who venture on the search for the basic principle of the ethical, is greater than he.

[pg 047]

Ethical theory is no more ethics than cartilage is bone. But how strange is this inability to establish the basic principle of ethical action which Socrates regarded as the certain, and from the very first sure and certain, product of thoughtful reflexion on the ethical! Why do all the ancient thinkers who in succession to Socrates search for it, always miss it? Why does Aristotle cease to concern himself with it, and so condemn himself to a doctrine of virtue in which, as a matter of fact, there is hardly any more living ethical force than there is in the abstract ethical system of Plato or in the ethics of resignation of the rest?

The Ideal of the Civilized State in Plato and Aristotle

How little Plato and Aristotle are capable of establishing an ethic of action can be seen from the way in which they sketch their ideal of the civilized State. Plato develops his in the _Republic_, Aristotle his in the _Politics_. At this very time, Mencius (Meng-tse) is

putting before the princes of China a doctrine of the civilized State.

That the State must be something more than a union which regulates in the most practical way the common life of a number of persons whom natural conditions compel to depend upon one another, is quite clear to both of them. They also agree in demanding that the State shall promote the true prosperity of its citizens. This is, however, unthinkable and impossible without virtue, and the State must therefore develop into an ethical institution. "Honourable and virtuous conduct is the object which the political community aims at," is the way Aristotle puts it.

The State, which is given by history, is therefore to come under the influence of a representation of its nature as a political body which is both ethical and rational. In the _Republic_ Plato puts in the mouth of Socrates the following sentiment: "Unless it happen that either philosophers acquire the kingly power in States, or those who are to-day called kings and potentates cultivate philosophy truly and sufficiently, and thus political power and philosophy [pg 048] become as one . . . there can be no deliverance from evil for States, nor ever, so I think, for the human race" (Bk. V, 473, C and D).

When, however, it comes to a more detailed carrying out of the ideal of the civilized State, Plato and Aristotle betray remarkable embarrassment. First of all, their vision of the State of the future is not that of a community which embraces a whole nation, but is always just a copy of the Greek city-republic with appropriate improvements. That they think out their ideal within such narrow limits is historically intelligible, but for the development of the philosophical idea of the civilized State it is deplorable.

One result of these narrow limits is that both are anxiously concerned to provide that the well-being of the city-republic shall not be endangered by the increase of the population. The number of the inhabitants is to be kept as far as possible always near the same figure. Aristotle is not frightened by the proposal that weakly children shall be allowed to die of hunger, and that unborn children shall be got rid of by intentional abortion. That the Spartan State, on the contrary, regards the increase of the population as desirable, and exempts a citizen from all imposts as soon as he has four children, does not seem to him to be reasonable.

Again, just as these two thinkers cannot work themselves up to a general idea of a national State, so they are unable to reach the idea of mankind. They make a strict line of division between the unfree on the one side, and the free on the other. The former they regard merely as creatures made for work, who are to maintain the material well-being of the State. What becomes of them as human beings is to them a matter of very little interest. Such beings as they are not meant to have any share in the growth towards perfection which is to be brought about by means of the civilized State.

Slavery was, indeed, attacked now and again by the Sophists from their point of view, not, however, on the [pg 049] ground of humanity but from a desire to raise doubts about the accepted justification of existing institutions. Aristotle defends it as a natural arrangement, but recommends kindly treatment.

Artisans, and in general all who earn their living by the labour of their hands, are not to be allowed to be citizens. "One cannot practise virtue, if one leads the life of an artisan, or of one who labours for pay," says Aristotle. An ethical valuation of labour as such is still something unknown to him, even though he conceives of happiness as "activity in accordance with the law of excellence." Plato and he are still entirely under the influence of the ancient view that only the "free" man can have full value as a man.

In details of the ideal of the State, however, the two part company, and Aristotle argues against Plato, though, unfortunately, just those parts of the _Politics_ in which he sketches his ideal State have not come down to us complete. The main difference is that Aristotle keeps closer than Plato to the historically given. He builds his State upon the family; Plato makes the State into a family. In his _Republic_ the free men live with property, wives, and children owned in common. They are to possess nothing as their own, so that they may not by private interests be held back from working for the general welfare. Moreover, the general welfare allows the State to breed its citizens systematically. He prescribes the connections which men and women are to form, and permits only such as allow the expectation of a new generation which is sound both in body and mind. The offspring of unions not approved by the authorities are either to be killed before birth, or got rid of by starvation.

Aristotle contents himself with guaranteeing the quality of the offspring by legal regulation of the age for marriage. Women may get married at eighteen, men not till they are thirty-seven. Moreover, marriages are to take place preferably in winter, and as far as possible, when the wind is in the north.

[pg 050]

In what, then, does the good consist which is to be realized by this civilized State? To this decisive question Aristotle and Plato have in reality only the answer that it is meant to make it possible for a number of its members, viz. the "free" men, to devote themselves entirely to their own bodily and mental culture free from care about material things, and to take the lead in public affairs. It is not established with a view to the production of anything ethical in any deeper sense, nor for the sake of an ideal of progress on lines which could be described as in any sense great and noble. Nowhere do the characteristic limitations of ancient ethics reveal themselves so clearly as in the poverty of their ideal of the State.

The ethical valuation of man as man has not yet been reached. Hence the State has for its object, not the growth to perfection of all, but only that of a particular class.

The nation, too, is not yet recognized as a great entity both natural and ethical, and therefore no consideration is given to the question of uniting the various city communities for the joint pursuit of higher objects. Each remains isolated. Plato thinks he has satisfied the claims produced by membership of the same nation by requiring that in wars waged by Greek States against one another the houses shall not be destroyed nor the fields laid waste, as if the war were against barbarians.

The idea of humanity as a whole has not yet come in sight. It is, therefore, not possible for Plato and Aristotle to make their State work in co-operation with others to promote the general progress of mankind.

They therefore establish their civilized State on a type which is hemmed in in every direction by narrow horizons. Moreover, the political community which they adopt as the type is at the very time when they are writing already a dying entity. While Aristotle is writing his _Politics_, his pupil, Alexander the Great, is founding an empire, and Rome is beginning to subject Italy to her rule.

More important still than all external faults in their ideal [pg 051] of the civilized State is the fact that these two thinkers are unable to introduce into the community the energies which are needed for its maintenance. The idea of the civilized State is present with the vitality needed, only when the individual is by the impulse contained in his world-view moved so far as to devote himself to organized society with enthusiastic activity. Without civic idealism no civilized State! But to assume anything of that kind in the members of their State is impossible for Plato and Aristotle, since both have already reached the ideal of the wise man who withdraws himself prudently and gracefully from the world.

Plato admits this. His wise citizens who are destined to be rulers devote themselves to the service of the State only when their turn comes, and are glad when they are set free and can again in retirement busy themselves, as wise among wise, with the world of pure Being.

Aristotle, when he raises in the _Politics_ the question whether the contemplative life is not to be preferred to that of political activity, decides in theory in favour of the latter. "It is a mistake," he says, "to value inactivity higher than activity, since happiness consists in activity." But in the doctrine of virtue in the _Nicomachean Ethics_ there is nothing which could lead the individual to place his life at the service of the community.

Plato and Aristotle cherish undoubtedly the ancient conviction that the individual ought to devote himself to the State, but they cannot find a foundation for it in their world-view. Like Epicurus and the adherents of the Porch, they are under the spell of an ethic in which there is present no will to attempt a transformation of the world.

How much greater than the two Greeks is Mencius, when he is thinking out the ideal of the civilized State! He can make it as large as he likes and take men into its service with their best thoughts, because it results in the most natural way from a large-scale world-view of ethical activity.

Plato and Aristotle, lacking such a world-view, can do no more than guess at the nature of a civilized State, and invent one for themselves. Plato's _Republic_ is a mere [pg 052] curiosity. Aristotle's _Politics_ is valuable, not on account of the theory of the civilized State which is there presented, but only for his magnificent practical analysis of the advantages and disadvantages of the various State-constitutions, and of their economic problems.

The decadence of antiquity does not begin, then, with the suppression of the individual by the Empire, and its destruction of the normal mutual relations between the individual and the community. It sets in immediately after Socrates, because the ethical thinking which started with him cannot really lead the individual beyond himself, and set him as an effective force in the service of the moralization and the perfecting of social relations.

There is no middle term between the ethic of enthusiasm and that of resignation. But an ethic of resignation cannot think out, much less bring into existence, a system of social relations which can be called really civilized.

Seneca, Epictetus, and Marcus Aurelius

"In imperial times Stoicism shrivels up into a moralizing popular philosophy" is what we are usually told in treatises about ancient philosophy. As a matter of fact what we have to deal with is by no means a shrivelling up, but a serious struggle for a living ethic which begins unexpectedly in the later period of Græco-Roman thought, and leads to an optimistic-ethical nature-philosophy.

The pillars of this movement are L. Annæus Seneca (4 B.C.—A.D. 65), Nero's teacher, who at the command of his pupil had to open his veins; the Phrygian slave, Epictetus (born _c_. A.D. 50), who in A.D. 94 was with all philosophers banished from Rome by Domitian; the Emperor Marcus Aurelius (A.D. 121-180) who, brought up by pupils of Epictetus, defends the Empire at a time of great danger, and writes his philosophical _Meditations_ while in camp._(_8_)_

[pg 053]

In their classical period Greek ethics offer us either egoistic considerations of advantage, or cold doctrines of virtue, or ascetic renunciation of the world, or resignation. In whichever direction they turn, they never lead men out beyond themselves.

In Seneca, Epictetus, and Marcus Aurelius, they lose this self-regarding character. Renouncing the spirit of the earlier time they develop to an ethic of universal brotherhood, and busy themselves with the immediate, altruistic relations of man to man.

Whence comes this understanding for humanity, which is never seen in classical antiquity?

The older Greek moralists are concerned with the State. Their interest is absorbed in the maintenance of the organization of society which is embodied in the city-republic, so that the free citizens can continue to live the life of freedom. The type of complete manhood is to be realized. All around there is the activity of men who receive no consideration except so far as they are means to this end.

But amid the mighty political and social revolutions which lead to the creation of the Empire this mentality ceases to be accepted as a matter of course. The fearful experiences it goes through cause feeling to become more human, and the horizons of ethics are widened. The city-republic, on which ethical thinking had been built up, has disappeared, but an empire now crushes men down just in the same way. Thus the individual man as such becomes the object of reflexion and of ethics. The conception of the brotherhood of all men appears. A disposition to humanity makes itself heard, and Seneca condemns the gladiatorial shows. Nay more: even the [pg 054] inner relationship between mankind and the animal world is recognized.

So now when they have caught sight of mankind as a whole and man as such, ethics reach such a depth and breadth as allows them to try to comprehend themselves in a universal world-will. Henceforth nature-philosophy and ethics can work together. Stoicism had from the very beginning a vision of this, but had not been able to make it a reality, since it had not at its disposal the needful living and universalist ethic.

But there is another reason why optimism and ethics can now in nature-philosophy come into power. The old school of the Porch was crushed down into resignation just in proportion as it submitted to the necessity for critical thinking. But as time goes on, the practical and religious instincts which were always present in its world-view, gain in strength. The antiquity which is passing away is no longer critical, but either sceptical or religious, and therefore the later school of the Porch can let itself be guided by the ethical demands of its world-view much more completely than the old one could. It becomes at once deeper and more simple than the latter, and, like Chinese ethical monism, rises to such freedom from limitations as to be able to interpret the world-will as ethical. So now Stoics appear who, like Confucius, like Mencius, and like Chwang-tse, and indeed, like the Rationalists of the eighteenth century, preach ethics as something grounded in the nature of the universe and of mankind. They cannot prove the truth of this world-view any better than could Zeno and his pupils, who also resorted to it, but they announce it with an inner conviction which the former could not command, and produce their results by means of an enthusiasm which was denied to their predecessors.

When the later school of the Porch reaches the stage of exalting the world-principle more and more to become a personal and ethical god, it is following laws which are at work also in Hinduism.

[pg 055]

Yet the world-view of resignation, which it has inherited from the older school, it never succeeds in rendering entirely impotent. In Seneca and Epictetus this is still strongly maintained side by side with the ethical conception of the universe. It is only in Marcus Aurelius that the optimistic motives sound victoriously through.

Stoicism was from the beginning a multiform elemental philosophy, and it is because it ventured to be this in such comprehensive measure that the later Stoicism is so rich and so full of life.

Moral Sayings of Seneca

No man is nobler than his fellow, even if it happen that his spiritual nature is better constituted and he is more capable of higher learning. The world is the one mother of us all, and the ultimate origin of each one of us can be traced back to her, whether the steps in the ladder of descent be noble or humble. To no one is virtue forbidden; she is accessible to all; she admits everyone, she invites everyone in: free men and freedmen, slaves, kings, and exiles. She regards neither birth nor fortune; the man alone is all she wants.

It is a mistake to think that the status of a slave affects the whole of a person's nature; the nobler part of it is not touched thereby.

Every single person, even if there is nothing else to recommend him, I must hold in regard, because he bears the name of man.

In the treatment of a slave we have to consider not how much we can do to him without being liable to punishment, but how much the nature of right and of justice allows us to, seeing that these bid us treat gently even prisoners and purchased slaves. Although in the treatment of a slave everything is allowed, there is nevertheless something which through the common right of every living being is stigmatized as not permissible in the treatment of a man, because he is of the same nature as thyself.

This, in fact, is the demand which is laid upon each man, viz. that he works when possible, for the welfare of many; if that is impracticable, that he works for the welfare of a few; failing that, for the welfare of his neighbours, and if that is impossible, for his own.

It is through untiring benevolence that the bad are won over, and there is no disposition so hard and so hostile to loving treatment ... as to refuse love to the good people whom it will in the end have to thank again for something more. "Not a word of thanks did I get! What am I now to begin to do?" What the gods do, . . . who begin to shower benefits on us before we are aware of it, and continue them even though we do not thank them.

Moral Sayings of Epictetus

Nature is wonderful, and full of love for all creatures.

Wait upon God, ye men. When He calls you, and releases you from [pg 056] service, then go to Him; but for the present remain quietly in the position in which He has placed you.

You carry a god about with you, and do not know it, unhappy one! You have him within yourself, and do not notice it when you defile him with unclean thoughts or foul deeds.

Cultivate the will to satisfy yourself, and to stand right before God. Strive to become pure, one with yourself and one with God.

Think silence best; say only what is necessary, and say it shortly. Above all, do not talk about thy fellow-men, either to praise them, or to blame them, or to compare them with others. Do not swear; never, if possible, or at any rate as seldom as possible. Your bodily wants—food, drink, clothing, housing, service—satisfy in the simplest way. Avoid unseemly joking, for there is always a danger of becoming vulgar, and joking away the respect of your fellow-men.

As you are careful when walking not to tread on a nail or to sprain your ankle, so take care not to let your soul get hurt.

Moral Sayings from the Meditations of Marcus Aurelius

Everything that happens, happens right, and if you can observe things carefully, you will recognize that it is so. I do not mean only in accordance with the course of nature, but much more that they happen in accordance with the law of righteousness, and as if controlled by a Being who orders all things according to merit.

If I am active, I am so with due regard to the general welfare. If anything happens to me, I accept it and consider it in relation to the gods and the universal source from which, in close connection, come all our happenings.

He who commits unrighteousness is godless, for universal nature created rational beings for one another; to help each other where there is need, but never to injure one another.

Love mankind; obey the godhead.

If thou art unwilling to get up in the morning, reflect thus: I am waking in order to go and work as one of mankind.

Seek all thy joy and contentment in advancing, mindful always of God, from one generally useful deed to another.

The best way to avenge oneself on anyone is to avoid returning evil for evil.

It is a privilege of man to love even those who do him wrong. One can reach this level by reflecting that all men are of one family with oneself; that their shortcomings are due to ignorance, and against their will; that in a short time both of you will be dead.

What is good is necessarily useful, and that is why the good and noble man must be concerned about it.

Nobody gets tired of seeking his own advantage. But doing so procures us an activity which is natural. Never get tired, then, of seeking thine own advantage, provided thou procurest thus the advantage of others also.

[pg 057]

Treat as befits a man endowed with reason, that is magnanimously and nobly, the animals which are not so endowed, and indeed all creatures whatever that can feel but have no reason. But other men, since they are endowed with reason, treat with friendly affection.

Thou has existed till now as a fragment of the universe, and wilt some day be absorbed in thy producer, or rather, thou wilt suffer a transformation and reappear as a new germ of life.

Many grains of incense are destined for the same altar. Some fall soon into the flame, others later, but that makes no difference.

The Optimistic-Ethical World-View of the later Stoicism

In their optimistic-ethical world-view the later Stoics find those impulses to effort which were not available for the ancient ethics of the classical age. Marcus Aurelius is an enthusiastic utilitarian like the Rationalists of the eighteenth century, because, like them, he is convinced that nature itself has bound up together what is ethical and what is advantageous to the individual and to the community.

That being so, the classical question of ancient ethics whether the thinking man is to busy himself with public affairs or not must again be discussed. Epicurus taught that "the wise man has nothing to do with State affairs unless exceptional circumstances arise." Zeno's decision was that "he will take part in the business of the State unless obstacles prevent it." Both schools leave the retirement into oneself to the decision of the Wise man, only one lets the grounds for the decision be given somewhat earlier, the other somewhat later. The thought of a devotion to the general good which is to be kept active for its own sake and under all circumstances is outside the circle of vision of their ethic.

With the later Stoics it emerges, because the conception of "mankind" has come in sight. Man, as Seneca works out in his treatise on Leisure (_De Otio_), belongs to two republics. One is a large and universal one, extends as far as the sun shines, and embraces both gods and men; the other is that into which through the fate assigned us by our [pg 058] birth, we have been adopted as citizens. Circumstances may bring it about that the wise man cannot dedicate himself to the service of the State, but, to escape the storm, must "take refuge in the harbour." It may happen—and Seneca has in mind his own time—that not one of existing States is of such a character as to put up with the activity of the wise man. Nevertheless, the latter does not wholly withdraw into himself, but he serves the great republic by working to improve the general outlook of mankind, and to hasten the coming of a new age.

In Epictetus also this deepened and widened notion of duty is to be found. Marcus Aurelius does not even consider any impossibility of taking part in public life. In him there speaks the ruler who feels himself to be the servant of the State. His ideal is the citizen who "from one activity which makes his fellow-citizens happier goes on to another, and undertakes with alacrity anything whatever that the State lays upon him." "Do what is needed, and what is bidden by the reason of a being who is destined by nature to membership of a State, and do it as it is bidden."

In the middle of the second century A.D. ancient thought arrives at an optimistic-ethical world-view which holds within itself living ideals of civilization, and therefore anticipates those which later on in the eighteenth century will bring into activity so mighty and universal a movement of civilization. But for the men of the Græco-Roman world it comes too late. It does not permeate the masses, but remains the private possession of an _élite_.

It cannot permeate the masses, because there are forces at work among them with which it cannot combine. It is true, indeed, that the ethic of the later Stoicism is so near akin to the universal charity of the Christian ethic, that by the tradition of later times Seneca is declared to be a Christian, and that the Church father, Augustine, holds up the life of the heathen emperor, Marcus Aurelius, as an example for Christians.

Yet the two movements cannot amalgamate, but have [pg 059] to fight each other. Marcus Aurelius is responsible for most terrible persecutions of Christians, and Christianity on its side declares war to the knife against the Porch.

Why this strange fatality? Because Christianity is dualistic and pessimistic, the ethic of Stoicism is monistic and optimistic. Christianity abandons the natural world as evil, the later Stoics idealize it. It helps not at all that their ethical teaching is almost identical. Each appears as part of a world-view which is irreconcilable with that of the other. All contradictions in the world may be concealed, but not that between two world-views, and the struggle ends with the annihilation of the optimistic-ethical world-view of the Stoics, which is defended by officers without an army. The attempt that was undertaken as the ancient world was coming to an end, to restore the Empire and make it an empire as wide as mankind, was a failure.

The horizons of the philosophy of the ancient world had remained narrow too long. No ethical thinkers had appeared who at the right time might have led that world to an ethical optimism about reality. It was a calamity, too, that the natural sciences, which had started in such a promising way, came to a standstill, partly through the fault of fate, partly because philosophy turned away from them, before mankind discovered the law of the uniformity of nature, and obtained thereby control over it. Hence the men of antiquity never acquired that self-consciousness which in their descendants of modern times has kept alive, even through the darkest periods of history, the belief in progress—even though it be sometimes progress of the most superficial kind. This psychological factor is of great importance.

It is true that artistic ability, which in the Greek spirit meets us in such abundant measure, is also control over the material, but this creative power was unable to draw the man of antiquity up to a higher life-affirmation and to belief in progress. It served only to let him express himself, in words and in form, in the antagonism between primitive [pg 060] world- and life-affirmation, and thinking world- and life-denial. It is the puzzling intermixture of serenity and melancholy which produces the tragic charm of Greek art.

From every point of view, then, a strong ethical world- and life-affirmation is made difficult for the ancient world. It therefore falls more and more a prey to pessimistic world-views, which draw its thoughts away from reality, and celebrate the liberation of the spiritual from its bondage to the material in a succession of cosmic dramas. Gnosticism, Oriental and Christian, Neo-Pythagoreanism, which arose as early as the first century B.C., the Neo-Platonism which originated with Plotinus (A.D. 204-269), and the great Mystery-religions, all come to meet the religious, world-shunning disposition of the masses during the breaking-up of antiquity, and offer it that deliverance from the world of which it is in search. In this chaos of ideas Christianity emerges victorious because it is the most robust religion of redemption, because as a community it possesses the strongest organization, and because beneath its pessimistic world-view it has at its disposal living ethical ideas.

The optimistic-ethical monism of the later Stoics is like a sunbeam breaking through in the evening of the long, gloomy day of antiquity while the darkness of the middle ages is already drawing on, but it has no power to waken any civilization to life. The time for that is past. The spirit of antiquity, having failed to reach an ethical nature-philosophy, has become the prey of a pessimistic dualism in which no ethic of action is any longer possible; there can only be an ethic of purification.

The thoughts of Seneca, Epictetus, and Marcus Aurelius are the winter seed of a coming civilization.

[pg 061]

CHAPTER VI

OPTIMISTIC WORLD-VIEW AND ETHICS IN THE RENAISSANCE AND POST-RENAISSANCE PERIODS

Belief in Progress and Ethics

THE essential characteristic of the modern age is this, that it thinks and acts in the spirit of a world- and life-affirmation which has never before shown itself with such active strength.

This world-view breaks through in the Renaissance, first at the end of the fourteenth century, and it arises as a protest against the mediæval enslavement of the human spirit. The movement is helped to victory by the increasing knowledge of Greek philosophy in its original form which is the result of the migration to Italy about the middle of the fifteenth century of learned Greeks from Constantinople. Among the thinking men of that time there arises the belief that philosophy must be something more elemental and more living than Scholasticism made it.

But the thought of antiquity would not have been sufficient by itself to keep alive this new world- and life-affirmation which appealed to it. It has not, in truth, the mentality required. But another kind of fuel is in time brought for the fire. Taking refuge from book-learning in nature, the men of that time discover the world. As seamen they reach countries whose very existence was not suspected, and they measure the size of the earth. As inquirers they press on into the infinite and the secrets of the universe, and learn by experience that forces governed by uniform laws are at work in it, and that man has power to make them serviceable to himself. The knowledge and power won by Leonardo da Vinci (1452-1519), Copernicus [pg 062] (1473-1543), Kepler (1571-1630), Galileo (1564-1642), and others are decisive for the current world-view.

As a movement which draws its life solely from spiritual forces, the Renaissance passes its bloom-time comparatively quickly, and without forming much fruit. With Paracelsus (1493-1541), Bernardino Telesio (1508-1588), Giordano Bruno (1548-1600), and others, an enthusiastic nature-philosophy announces itself. It does not, however, reach full growth. The Renaissance has not strength enough to bring to birth a world- and life-affirming philosophy corresponding to their spirit. Here and there their thought surges for a time, like a rough sea, against the world-denying world-view of the Church. Then all is still. What we know definitely as the philosophy of modern times begins almost without any reference to the Renaissance. It springs not from any nature-philosophy, but from the problem of the theory of knowledge which was raised by Descartes, and from that starting-point philosophy has once more had laboriously to seek its way to a nature-philosophy.

It is not, then, because it was enlarged during the Renaissance into a fully thought out world-view that world- and life-affirmation made good its position in the modern age. If it was able to hold out right into the eighteenth century, when it triumphs against the world- and life-denial which mediæval thought and Christianity kept working in opposition to it, it owed this to the circumstance that progress in knowledge and power never ceased. In them the new mentality had a support which never gave way, but became continually stronger. Since the new scientific knowledge cannot be suppressed nor its progress arrested, belief in the power of truth becomes firmly established. Since it becomes more and more evident that nature works with a uniformity which never misses its aim, there grows up a confidence that the circumstances of society and of mankind generally can be so organized as to secure definite objects. Since man is ever obtaining [pg 063] greater power over nature, he takes it more and more as self-evident that the reaching of perfection in other spheres also is only a question of a sufficiency of will-power and a correct way of grappling with problems.

Under the steadily working influence of the new mentality the world-view of Christianity changes, and becomes leavened with the leaven of world- and life-affirmation. It gradually begins to be accepted as self-evident that the spirit of Jesus does not give up the world in despair, but aims at transforming it. The early Christian conception of the Kingdom of God, which was born of pessimism and, thanks to Augustine, prevailed through the Middle Ages, is rendered impotent, and its place is taken by one which is the offspring of modern optimism. This new orientation of the Christian world-view, which is accomplished by a slow and often interrupted process of change between the fifteenth century and the end of the eighteenth, is the decisive spiritual event of the modern age. During this period Christianity takes no account of what is happening to itself. It believes that it is remaining unchanged, whereas in reality, by this change from pessimism to optimism, it is surrendering its original character.

The man of modern times, then, becomes optimistic, not because deepened thought has made him understand the world in the sense of world- and life-affirmation, but because discovery and invention have given him power over it. This enhancement of his self-appreciation and the consequent strengthening of his will and his hopes, determine his will-to-live in a correspondingly pronounced and positive sense.

In the ancient world man's natural disposition to world- and life-affirmation could not be worked out to a complete world-view of the same, because at that time deep thought about the world and life pressed resignation upon him as a necessity of thought. In the man of the modern age the mentality produced by discovery and invention unites with his natural disposition to world- and

life-affirmation, and establishes him in an optimistic world-view [pg 064] without leading him to deeper thought about the world and life.

The spirit of the modern age is not the work of any one great thinker. It wins its way gradually by reason of the unbroken series of triumphs won by discovery and invention. Hence it is not a result of chance that an almost unphilosophic and moreover somewhat antiquated personality like Francis Bacon, Lord Verulam (1561-1626), is the man who drafts the programme of the modern world-view. He founds it upon the sentence: "Knowledge is power." His picture of the future he develops in his _New Atlantis_, in which he describes how the inhabitants of an island, through the practical application of all known discoveries and inventions and all possible rational reflexion on the purposive organization of society, find themselves in a position to lead the happiest possible lives._(_9_)_

Christian and Stoic Elements in Modern Ethics

What is the relation between ethics and the mentality of belief in progress, and how were they influenced by it?

When the ethical thought of antiquity wanted to come to clearness about itself, it fell a victim to resignation, because it tried to determine the moral as that which is rationally profitable and pleasurable to the individual. It remained shut up within the circle of the egoistic, and never reached the thought of social utilitarianism. From such a fate modern ethics are protected in advance. They have no need to produce from their own resources the thought that the ethical is action directed to promoting the welfare of others, for they find it as something already accepted as true. That is the gift of Christianity. The thought of Jesus that the ethical is the individual's active self-devotion to others has won its way to acceptance. Ethics, [pg 065] which are making themselves independent of religion, keep, as a result of their passage through Christianity, a pronouncedly active and altruistic mode of thought. What they have to do now is to provide this possession with a rational foundation.

It is extraordinarily significant that to meet modern ethics there comes in the Late Stoicism a philosophical ethical system in which there appear, as the result of rational thinking, thoughts which run side by side with Christian morality. There is now coming up for the benefit of modern times the seed sown by Seneca, Epictetus, and Marcus Aurelius. Cicero, too, counts with modern times for so much, because its thinkers find in his writings noble morality based upon thought. The discovery of Late Stoicism's ethic of humanity is for modern times akin to their discovery of nature. They identify it with the real Christian ethic, and contrast it with the scholastic, in which Jesus is expounded according to Aristotle. It is through Late Stoicism that modern times become aware that the moral is something direct. Because Seneca, Epictetus, and Marcus Aurelius speak to such an extent just as Jesus did, they help to spread the conviction that the truly rational ethic and the ethic of the Gospels coincide with one another.

When antiquity came to an end, Late Stoicism and Christianity, in spite of the identity of their moral teaching, had torn each other to pieces. In modern times they unite in order to produce together an ethical world-view. Why is that now possible which before was impossible? Because the chasm which lay between their respective world-views has been bridged. Christianity now treats world- and life-affirmation as valid.

But how could this volte-face of Christianity be brought about? Because of the fact that in spite of its pessimistic world-view it upholds an ethic which, so far as it touches the relation of man to man, is an activist ethic. The pessimistic world-view, if it thinks itself out to a consistent conclusion, must end with a purely world-denying ethic, [pg 066] divorced from action, as it has in India. The peculiar character, however, of the world-view of Jesus which is determined by the expectation of the end of the world and the coming of a supernatural kingdom of God, together with the directness of his ethical feeling, entail his proclaiming of an ethic of active devotion to one's fellow-Man in spite of his pessimistic attitude towards the natural world. This activist ethic is what is wanted to provide the cardinal-point of an evolution from a Christian-pessimistic world-view to one of Christian optimism. The modern age, following its instinct, assumes it as self-evident that an ethic which deals with the active relations of man to man is pre-supposed to be an ethic which assigns a positive value to action as such, and, further, that such an ethic of action belongs to a world-view which is optimistic and which wills and hopes for a transformation of relationships.

It is, then, the ethic of active self-devotion taught by Jesus which makes it possible for Christianity to do what is suggested by the spirit of the modern age, and modulate from the pessimistic to the optimistic world-view. This result finds expression in the way the new conception of Christianity, when it has to come to an understanding with the old one, contrasts itself as "the religion of Jesus" with "the Christianity of dogma."

A way is prepared, then, in Erasmus and individual representatives of the Reformation, shyly at first but then more and more clearly, for an interpretation of the teaching of Jesus which corresponds to the spirit of modern times, an interpretation which conceives the teaching as a religion of action in the world. Historically and in actual fact this is a wrong interpretation, for the world-view of Jesus is, so far as concerns the future of the natural world, thoroughly pessimistic. His religion is not a religion of world-transforming effort, but the religion of awaiting the end of the world. His ethic is characterised by activity only so far as it commands men to practise unbounded devotion to their fellow-men if they would attain to that inner perfection [pg 067] which is needed for entrance into the supernatural kingdom of God. An ethic of enthusiasm, and therefore presumably focused upon an optimistic world-view, forms part of a pessimistic world-view! That is the magnificent paradox in the teaching of Jesus.

But the modern age was right in overlooking this paradox and in assuming in Jesus an optimistic world-view which corresponded to an ethic of enthusiasm and met with a welcome the spirit of Late Stoicism and of modern times. For the progress of the spiritual life of Europe this mistake was a necessity. What crises the latter must have gone through, if it had not been able without embarrassment to place the new world-view under the authority of the great personality of Jesus!

The mistake was such a natural one that till the end of the nineteenth century it was never seriously shaken. When historical criticism, at the beginning of the twentieth century, proclaimed its discovery that Jesus, in spite of his activist ethic, thought and acted under a pessimistic world-view dominated by the expectation of the end of the world, it aroused indignation. It was accused of degrading Jesus to a mere enthusiast, while it after all only put an end to the false modernising of his personality._(_10_)_

What we at the present time have to do is to go through the critical experience of being obliged to think as modern men under a world-view of world- and life-affirmation, and yet let the ethic of Jesus speak to us from out of a pessimistic world-view.

Of this problem which is disclosing itself to-day the early period of the modern age suspects nothing. Jesus and the moralists of Late Stoicism together are its authorities for an ethical world- and life-affirmation.

What the Late-Stoic ethic is for the modern age is shown by Erasmus of Rotterdam (1466-1536), Michel de [pg 068] Montaigne (1533-1592), Pierre Charron (1541-1603), Jean Bodin (1530-1596), and Hugo Grotius (1583-1645), and that whether their ideas run predominantly on Christian or on freethinking lines. To the Later Stoics Erasmus owes it that he can understand the simple gospel of Jesus which was being discovered behind the Church's dogmas, as being the essence of all ethical philosophizing. It is by finding support in them that Montaigne in his _Essays_ (1580) is saved from falling into complete ethical scepticism. Because he is inspired by the Later Stoics, Bodin in his work _De la république_ (1577), puts forward an ethical ideal of the State to combat the ideas of Machiavelli's _Prince_ (_Principe_) (1515). Because he draws from the same source, Pierre Charron in his work _De la sagesse_ (1601), ventures to assert that ethics are higher than traditional religion, and can maintain themselves in an independent position in face of it without losing anything of their essential nature or of their depth. Because the work of Marcus Aurelius has preceded him, Hugo Grotius is able in his famous work, _De jure belli ac pacis_ (1625) to lay so securely the foundations of natural and international law, and thereby to champion the claims of reason and humanity in the domain of jurisprudence.

Other considerations apart, it would have been the first task of the rising power of natural science to restore to currency the world-view of Epicurus, and Pierre Gassendi (1592-1655)_(_11_)_ attempts it. He fails, however, to accomplish his purpose. By its inward belief in progress the mentality of the modern age is driven in elemental fashion beyond scepticism and sceptical ethics. What is great in Epicurus, viz. that in obedience to the deepest demands of truth he tries to think ethically within a nature-philosophy which does not interpret nature as embodying any purpose, can neither be comprehended nor be put before his own age by the philosopher's all too clever modern prophet.

[pg 069]

For the weighty questions of absolute truth that time is by no means ripe. Its capacity is only that of the uncritical. Typical for its spirit is Isaac Newton (1643-1727), who in his investigation of nature is purely empirical, and in his world-view remains simply Christian.

Against the difficulties which crop up for ethics and world- and life-affirmation out of a nature-philosophy which works without any presuppositions, the Renaissance and the Post-Renaissance are secure. The belief in progress which arises from the achievements of discovery and invention, and the joy felt in action itself are their world-view.

Thanks to belief in progress, new life streams into ethics. The inner relations between ethics and world- and life-affirmation begin to have their effect. The elementary impulses to activity which are embodied in the Christian ethic are set free, and the belief in

progress gives them an aim and object: the transformation of the circumstances of society and of mankind.

It is not any really deeper ethical thinking that brings the modern age in, but the influence exerted by the belief in progress, which arose out of the achievements of discovery and invention, on the ethic which drew its life from Stoic and Christian thought. The cart is drawn by the belief in progress, and at first ethics have only to run along beside it. But as the cart gets heavier and the road more difficult to negotiate, so that ethics ought to lend their strength to help, they refuse, because they have no strength of their own. The cart begins to run backward, and carries belief in progress, and ethics with it, down the hill.

The task before philosophy was to change the world- and life-affirmation which arose out of enthusiasm over the attainments in discovery and invention into a deeper, inner one arising out of thought about the universe and the life of man, and on that same foundation to build up an ethical system. But philosophy could do neither.

About the middle of the nineteenth century, when it has become perfectly clear that we are living with a world- and [pg 070] life-affirmation which has its source merely in our confidence in discovery and invention and not in any deeper thinking about the world and life, our fate is sealed. The modern optimistic-ethical world-view, though it has done so much for the material development of civilization, proves to be like a building erected already to a considerable height but on rotten foundations, and has to collapse.

[pg 071]

CHAPTER VII

LAYING THE FOUNDATION OF ETHICS IN THE SEVENTEENTH AND EIGHTEENTH CENTURIES

Hartley, Holbach. Devotion as Enlightened Egoism

MODERN times find world- and life-affirmation so self-evident that they feel no need to give them a sure foundation, and to deepen them, by thought about the world and life. Pessimism they brush aside as reactionary folly, without suspecting how deep down into thought it has sent its roots.

They do, however, see the necessity of establishing the nature of the ethical. How do they proceed to do this?

That the ethical means action directed to promoting the common good is their firm belief from the first, and they are safe from the fate of ancient thought, viz. sticking fast in the mud of resignation while trying to give the ethical a proper foundation. Instead of that they have to answer the question how the unegoistic makes it appearance beside the egoistic, and in what inner relation they stand to each other.

A performance now begins like that which went on after the appearance of Socrates, only the task is proposed this time not by an individual but by the spirit of the time. Another attempt is made to consider the ethical problem in isolation, as if it consisted in reflexions on the relation of the individual to himself and to society, these having no need to settle their position with regard to ultimate questions of the meaning of the world and of life. The ethical problem seems, too, to be a much easier one than it was then, because world-affirmation and activity directed towards the general welfare no longer have to be proved, but appear among the presuppositions which are taken for granted.

[pg 072]

There are three ways in which the relations between the egoistic and the altruistic can be made clear. Either one assumes that the egoistic in the thought of the individual is automatically converted into the altruistic by consistent meditation. Or one supposes the altruistic to have its beginning in the thought of society and thence to pass over into the convictions of the individual. Or one retires to the position that egoism and altruism are both among the original endowments of human nature. All three explanations are attempted, each with most varied arguments. They are not always carried to a conclusion without intermixture, and with many thinkers there is interplay of one with another.

The attempt to deduce devotion to the common welfare from egoism by psychological considerations is made in the most systematic way by David Hartley (1705-1757)_(_12_)_ and Dietrich von Holbach (1723-1789)._(_13_)_

Hartley, a theologian who betook himself to the practice of medicine, claims to see in altruism a purposive ennoblement of original selfishness which comes into play under the influence of rational thought. The much-reviled Holbach ascribes its origin to the fact that the individual, if he rightly understands his own interest, will always form his conception of it in connection with the interest of society, and therefore direct his activities to the latter as well.

Both attempt to carry up their building, so far as it goes, with materialistic considerations and then to roof it with idealist ones. But neither with the coarser nor with the finer considerations nor with both together can the psychological derivation of altruism from egoism produce any convincing result.

The coarser ones do not carry us very far. It is acknowledged, [pg 073] of course, that the prosperity of society depends upon the moral disposition of its members and that the better the moral condition of society the better is the individual's expectation of prosperity. But it does not follow that the individual becomes more moral, the better he understands his own interests. The mutual relation between him and society is not of such a character that he derives benefit from the latter just in proportion as he himself by his moral conduct helps to establish its prosperity. If the majority of its members are with short-sighted egoism intent only on their own good, then the man who acts with wider outlook makes sacrifices from which there is no prospect of gain for himself, even if the best happens and they are not lost without benefiting the community. If, on the other hand, through the moral conduct of the majority of its members the condition of society is favourable, the individual profits by it even if he fails to behave towards it as morality demands. By conduct which disregards both past and future, he will carve for himself an unduly big share of personal prosperity out of the prosperity of the community, milking the cow which the rest feed. The influence of the individual on the prosperity of the community and the reaction of social prosperity on that of the individual do not stand in a simple relation to each other which acts equally in both directions. The consideration, therefore, that egoism, rightly understood, will oblige the individual to resolve on activity which is directed to promoting the common good, is a ship which sails well, but leaks.

The psychological derivation of altruism from egoism must, then, in some way or other, make an appeal to the self-sacrifice of the individual. This it does by inducing him to consider that in happiness there is a spiritual element as well as a material. Man needs (it is said) not only external prosperity, but to be respected by others and to be satisfied with himself, and he can have this double experience only when he concerns himself about the [pg 074] prosperity of others. Even Holbach, who tries to be inexorably matter-of-fact, lets these considerations speak loudly.

The attempt is made, therefore, above the prolonged bass note of the conception of happiness derived from ordinary egoism, to modulate into the spiritualized conception of it.

The path which this attempt has to follow runs parallel to that which led the successors of Socrates into the abyss of the paradoxical. In order to get from egoism into altruism and so think out to a conclusion the ethic of the rationally-pleasurable, the Epicureans wished to use the same scale of values for spiritual and material pleasure alike. The only result was that their ethic transformed itself into resignation. Now again, in modern times, and again for the sake of ethics, spiritual happiness is to be regarded as happiness in the same way as material happiness is, and here again the result is a paradox.

Material and spiritual happiness are not so related that the one can find its continuation in the other. If the second is for the sake of ethics called in with the first, it does not strengthen the first, but paralyses it. The man who does earnestly try to guide himself by the light of spiritual as well as material happiness, ends by finding that the recognition accorded him by his fellow-men, which at first seemed to him to make almost the whole of spiritual happiness, becomes more and more meaningless. It is to him a miserable lump of solder which drops down between material and spiritual happiness without being able to fasten them together. More and more exclusively he experiences spiritual happiness as the condition in which he is at one with himself and therefore can justifiably accord himself a certain amount of self-appreciation.

Spiritual happiness is sufficient unto itself. Either the man is led to resolve on ethical conduct because he expects from it a moulding of the outward circumstances of his being which will bring him profit and pleasure; or he chooses it because he finds his happiness in obeying his inner compulsion to ethical action. In the latter case he [pg 075] has left far behind him all calculations about the interdependence of his morality and his material happiness. The fact that he is a moral man is in itself his happiness, even though it land him in the most disadvantageous situations.

But if spiritual happiness can never be welded into union with material, it is useless trouble to try to depict altruism as an ennobling of egoism.

If the ordinary conception of pleasure, that it may be brought into union with ethics, is submitted to a process of refining, it ends by being refined away. In ancient ethics, in which the refining is done under the influence of an ethical system which is definitely egoistic, it transforms itself into the pleasure of being without pleasure, and allows ethics to end in resignation. In modern ethics, in which the pleasure to be refined is under the influence of altruism, it works itself up into an irrational and immaterialistic enthusiasm. In both cases there is the same paradoxical proceeding, only that in one case it goes in the negative direction, in the other in the positive.

Whenever, then, thought wishes to conceive ethics as springing from pleasure or happiness, it arrives at resignation or enthusiasm, at spiritualised egoistic or at spiritualised expansive conduct.

There is no way in which natural pleasure can, in really deep thinking, be brought into connexion with ethics.

Hobbes, Locke, Helvetius, Bentham

The explanation that altruism is a principle of action which the individual takes over from society is to be found expressed in characteristic ways by Thomas Hobbes (1588-1679),_(_14_)_ John Locke (1632-1704),_(_15_)_ Adrien Helvetius (1715-1771)_(_16_)_ and Jeremy Bentham (1748-1832)._(_17_)_

[pg 076]

Hobbes represents the State as commissioned and empowered by the majority of the individual citizens to engage the whole body in action for the common advantage. In this way alone, he asserts, is it possible to realise the common good in which the egoism of individuals finds the highest possible degree of prosperity. Left to themselves, men would never be able to get free from their short-sighted egoism, and would, therefore, miss prosperity. Their only possible course, then, is to join in setting up an authority which will drive them into altruism.

With external means only, however, organized society cannot engage the individual in all the activities which are needed for the common good. It must strive to ensure its power over him by means of spiritual conviction as well. Locke takes this need into consideration. According to him it is God and society together who force altruism upon the individual by appealing at the same time to his egoism. These two authorities have, that is to say (as our reason enables us to recognize), so ordered the course of things that actions beneficial to society are rewarded, and those injurious to it are punished. God has at his disposal rewards and punishments of endless duration. Society works in two different ways: through the power given to it by the criminal law, and through the law of public opinion in which it uses praise and blame as spiritual means of compulsion. Man being guided both by pleasure and absence of it, he manages to accommodate himself to those rules which defend the general good so effectually, and he thereby becomes moral.

In spite of all their differences on single points, Hobbes and Locke agree in having this external conception of ethics. The essential point of distinction between them is [pg 077] that with Hobbes society alone plies the whip, while with Locke God and society handle it together.

Helvetius, who belonged to a family which had migrated from the Palatinate into France, is more refined and more inward. In his life as a farmer of taxes and a property-owner, he always tried, along with his noble-minded wife, to act with kindness and justice as he explains them in his book. It is clear to him that ethics means somehow or other enthusiastic action, that is, action which springs out of feeling._(_18_)_ Society cannot, therefore, force these virtues into the individual; it can only educate him into them, and it does in fact apply all the means and devices which are at its disposal to influence his egoism in their direction. Above all it makes good use of his striving to win recognition and fame. The praise which it pours on that which is “good” in its own sense of the word is for the mass of men the strongest inducement to take up work for its interests. Helvetius would perhaps have offered a less external conception of how ethical action is realized, if he had not, with the best intentions, taken so much trouble to depict morality as something which can be taught.

In the view that morality is enthusiastic action to which the individual is roused by society, Bentham agrees entirely with Helvetius, but he carries it through in a much deeper way. Out of the _Romanza_ he makes a hymn.

The part played by society in bringing morality into existence cannot, according to Bentham, be emphasized too strongly. In vehement words he opposes the view that the human conscience can decide between good and evil. Nothing can be left to subjective feeling. Man is truly moral only when he receives his ethics at the hand of society and works them out with ardour.

But if society is to decide about ethics, it must first bring order into its own ethical views, and therefore, says Bentham, must learn to combine clear and definite notions [pg 078] with its presentation of the general good. That done, it must make up its mind to apply this principle with absolute consistency as a foundation for legislation and the establishment of ethical standards, excluding all considerations of a different character. A "moral arithmetic" should be constructed which allows the calculating in correct utility values of all decisions that have to be made.

Dealing in a dry, practical way with all cases of penal legislation, and of establishment of standards by the moral law, Bentham then shows that the principle of the greatest good of the greatest number is applicable in all of them, and guides us safely and accurately in questions of good and evil.

"Moral philosophy, in its general meaning, is the theory underlying the art of so directing the actions of men that there is produced the greatest possible amount of happiness."

It is legislation that decides what moral actions the community can order to be performed, and if it is to exert an educative influence it must be humane through and through.

"But there are many actions which, though useful to the community, legislation may not command. There are even many injurious actions which it may not forbid, although moral philosophy does so. Legislation is, in a word, a circle with the same centre as moral philosophy, but its circumference is smaller."

When law ceases to be available, there is nothing that society can do except be continually putting before the individual personally how greatly he contributes to his own welfare by furthering that of others. Bentham does not make it do this with educative guile as does Helvetius. Society appeals to his feeling for truth. It throws itself at his feet and entreats him for the sake of the general welfare to listen to the voice of reason. Thus the dry way in which Bentham writes about ethics has in it something peculiarly impressive, and explains the powerful influence which this [pg 079] eccentric member of the House which looks across the Park at Westminster has exercised all over the world through the individuals who were inspired by him.

The most influential parts of his work are those in which he intensifies the seriousness of men and sharpens their outlook by leading them to reflect not only on the immediate but also on the more distant consequences of anything done or left undone, and, further, not only on the material consequences but on the spiritual ones. It does one good to note the courage with which this fanatic for utility ventures to represent material blessings as the foundation of spiritual ones.

Bentham is one of the most powerful moralists who have ever appeared in the world, but his mistakes are as great as his insight. The latter is shown in this, that he conceives morality as a kind of enthusiasm. His mistake is that he thinks he must guarantee the rightness of this enthusiasm by making it nothing higher than a judgement of society which is taken over by the individual.

This compels us to rank Bentham with Hobbes, Locke, and Helvetius, although in other respects he stands high above them. He, like them, makes morality arise outside the individual. He, like them, in order to find his explanation of the altruistic, puts out of action the ethical personality which is in man, and, to compensate for this, raises society to an ethical personality that he may then by a transmission of energy connect individuals with this central power-station. The difference is only that with the other commonplace moralists the individual is a marionette directed by society on ethical principles, whereas in Bentham he carries out with deep conviction the movements suggested to him.

Ethical thought falls from one paradox into another. If, as in antiquity, it thinks out a system in which the activity that must be directed to the common good is not sufficiently represented, it arrives at ethics which are no longer ethics, and ends in resignation. If it assumes and starts from such an activity directed to the common good, [pg 080] it arrives at an ethic in which there is no ethical personality. It is, strange to say, unable to mark out the middle course and let an activity which is directed to the promotion of the common good spring out of the ethical personality itself.

Altruism as a natural quality. Hume, Adam Smith

The explanations of altruism as an ennobling of egoism which has a spontaneous origin through the activity of reason, or which is brought into existence through the influence of society, are obviously unsatisfying both psychologically and ethically. Utilitarianism must therefore necessarily come to admit that altruism is somehow or other given independently in human nature side by side with egoism. It is true that it always appears there as the backward twin-brother who can be reared only with the most careful nursing, and therefore the upholders of the third alternative given above appeal to the considerations used for the first two. They continually

allow the capacity for altruistic feeling to be exposed to the influence of considerations which seem calculated to let egoism discharge its waters into altruism. The two first views are taken into service as wet-nurses for the third. David Hume (1711-1776)_(_19_)_ and Adam Smith (1723-1790)_(_20_)_ must be named here.

Hume agrees with the other utilitarians in allowing that the principle of seeking to promote the common good must be accepted as the dominant principle of morality. Whether actions are good or bad is decided solely by whether they are directed towards the production of general happiness [pg 081] or not. There is nothing which is in itself ethical or unethical.

To the idea that ethics can have as their object the self-perfecting of the individual as little weight is given by Hume as by the other utilitarians. Like them, he opposes asceticism and other life-denying demands of Christian ethics, because he cannot discover in them anything profitable for the general welfare.

But what makes men decide to work together for the common good? Consistent utilitarians answer: Reflexion about what the common good means. Of this one-sidedness Hume is not guilty, because he does not find it to be in accord with psychological facts. It is not out of high-minded reflexion, he asserts, but out of direct sympathy that the emotions and actions of benevolence arise. The virtues which serve the common good have their origin in feeling. We can resolve on acts of love only because there is in us an elementary feeling for the happiness of men, and a dislike of seeing them in misery. We become moral through sympathy.

It would not have been a big step further to explain this sympathy as a form of the egoistic need of happiness, more or less through the assumption that in order to be really happy a man must see happiness all round him. But Hume does not use such roads as that. He does not aim at constructive thought but at stating facts, and it is enough for him that direct sympathy with other men be proved to be a principle inherent in human nature. We have to stop somewhere or other, he says in one place, in our search for causes. In every science there are certain general principles beyond which there is no more general principle still for us to discover.

Among the elements which are effective in developing moral feeling, Hume attributes great importance to the love of fame. This keeps us considering ourselves in the light in which we wish to appear in the eyes of others, for the effort to secure the respect of others is a potent educator in virtue. On this point he thinks like Frederick the Great, from whom comes the sentence: "The love of fame [pg 082] is innate in noble souls; you have only to arouse it and urge it on, and men who till then merely vegetated, will seem to you, when explained by this happy instinct, to be changed into demi-gods."_(_21_)_

Adam Smith wishes to trace out the idea of sympathy in all its manifestations, and in doing so he discovers that our capacity for sympathy covers more than participation in the weal or woe of others. It brings us, he says, to a community of thought with those who are doing something. We feel ourselves directly attracted or repelled by the actions of others and the motives at the back of them. Our ethics are the product of these sympathetic experiences. We come in time to take care that an impartial third party can justify and sympathise with the mainspring and the tendency of our actions. Innate sympathy not only with the actions but also with the experience of others is thus the beneficent regulator of the behaviour of men to one another. This feeling God has implanted in human nature that it may keep men faithful to work for the common good.

How far this somewhat artificial extension of the notion of sympathy through the doctrine of the impartial third party really means a step forward beyond Hume we may leave undiscussed.

In his famous work, _An Inquiry into the Nature and Causes of the Wealth of Nations_ (1776), Adam Smith founds this prosperity purely upon the entirely free and intelligent activity of egoism. About the part to be played by ethics in economic questions he says nothing. Economic development he leaves to be determined by its own internal laws, and is confident that, if these are left a free course, the result will be favourable. Adam Smith, the moral philosopher, is also, because he is endowed with a rationalistic optimism, the founder of the _laissez-faire_ form of economic [pg 083] doctrine, that of the Manchester school, as it is called. He led industry and commerce in their struggle for liberation from the petty and injurious tutelage of authority. To-day, when economic life among all peoples is again delivered over to the most short-sighted ideas of authorities who never think in terms of economics, we can measure the greatness of his performance.

Like Adam Smith, Bentham also is an adherent of the principle of freedom in economic life. At the same time he has an ethical conception of society, and demands from it that in a spirit of progress it shall help to level out as far as possible the differences between rich and poor.

What, then, do Hume and Adam Smith mean for ethics? They introduce into the treatment of them the element of empirical psychology. They believe that through the value they give to the significance of sympathy they are giving a natural foundation to

utilitarianism, though in reality this psychology begins to correct it and to undermine its position. There hovers before the mind of utilitarianism the great conception that ethics are a result of reflexion. It thinks to make men moral by keeping their attention fixed on the deep nature of ethics and the necessity of the ends at which it aims.

This conception draws its life from the conviction that thought has been given complete control over the will. The absolute rationality of the ethical is the foundation on which it builds, and if it is not to get quite bewildered about its own nature, it cannot allow itself to recognize as presuppositions of the ethical, facts which are given it by psychology and cannot be verified independently.

With Hume and Adam Smith, who trace ethics back to something given in human nature which resembles instinct, there crops up the problem how ethics can be something natural, and at the same time something subordinate to thought, for that they are subordinate to thought has to be assumed even by the champions of this psychological utilitarianism. If they were nothing but the exercise of an instinct, they would not be capable of widening and [pg 084] deepening, nor could they be imparted to all and sundry with convincing force. Yet how is it conceivable that thought influences the sympathetic instinct? What have the two in common that the work of one can be carried further by the other?

If Hume and Adam Smith had suspected the far-reaching character of this great problem of ethics which they brought into the field of discussion, they would have had to go on and settle the extent and the depth of this sympathy which they adopted in their scheme, in order to understand how it continues to function in the domain of thought.

But they fail to notice the far-reaching character of what they lay down, and believe they have done nothing but give by means of psychology an explanation of altruism which is superior to these currents. The spirit of the time, in its wonderful capacity for holding various ideas side by side, takes possession of their view, and the popular utilitarianism now confidently appeals to it as declaring that altruism is to be conceived as a rational ennobling of egoism, as a result of the influence of society, and in addition as a manifestation of a natural instinct.

It is, really, only in appearance that the psychological conception of ethics imparts new life to utilitarianism. It is rather a consumption germ which the latter absorbs. The establishment of a natural element in ethics, when the consequences of it begin to make themselves felt, can only end in its devouring rationalist utilitarianism, as becomes evident in the nineteenth century when biological thought becomes influential in ethics. The funeral procession of rationalist utilitarianism begins to assemble with Hume and Adam Smith, though it is a long time before the coffin is taken to the cemetery.

The English ethic of self-perfecting

Against the utilitarians, who would derive from the content of the moral the essential nature of it, and the [pg 085] obligation to morality, the “Intellectualists” and the “Intuitionists” enter the lists. The empirical derivation of ethics seems to them to be an endangering of the majesty of the moral. Morality—this is the thought before their minds—is a striving after perfection, and this develops itself in us because it is implanted in us by nature. Action for the common advantage does not by any means constitute ethics; it is only a manifestation of the struggle after self-perfecting.

To this deeper and more comprehensive conception of ethics, however, the Intellectualists and Intuitionists do not give correct expression. For that they are still too much entangled in a lifeless and semi-scholastic philosophizing.

Their chief strength lies in their showing up of the weaknesses of the foundation which Hobbes and Locke give to ethics, and to these they principally devote themselves, bringing to their task a great deal that is correct about the directly and absolutely binding character of the moral law. That the meaning of the moral is not to be found merely in the useful character of the actions inspired by it but also in the self-perfecting of the agent which is effected by them, and that morality presupposes a moral personality, is emphasized by them in many happy turns of expression.

When, however, the task before them is to describe exactly in what way men carry in them the idea of the good as a force which works effectively upon their character, the Intellectualists and the Intuitionists land themselves in a psychologizing which is sometimes ingenious, but often artificial and commonplace. They occupy themselves with logical distinctions instead of investigating in a practical fashion the nature of man. Instead of really developing the problem in answer to the innovators, they work at it with data taken from an out-of-date philosophy. They hark back largely to Plato, and again they argue largely, anxiously or unconsciously, not as philosophers, but as theologians.

On individual points they diverge from each other, and [pg 086] attack each other's positions according as they would have the foundations of the ethical more intellectualist, or more sentimental and mystical, or more theological.

The majority of these anti-utilitarians belong to the Cambridge Platonizing school. We must name here Ralph Cudworth (1617-1688),_(_22_)_ Henry More (1614-1687),_(_23_)_ the Rev. Samuel Clarke (1675-1729),_(_24_)_ Bishop Richard Cumberland (1632-1718),_(_25_)_ and William Wollaston (1659-1724)._(_26_)_

According to Cudworth the truths of morality are just as evident as these of mathematics. For More the ethical is an intellectual power of the soul meant for the control of natural impulses. Cumberland finds the moral law given in the reason which has been bestowed upon man by God. Clarke, living in the thought world of Isaac Newton, sees it as the spiritual phenomenon which corresponds to the law of nature. Wollaston defines it as that which is logically right.

Pressed back to their fundamental meaning, these thinkers do nothing but amplify the statement that the ethical is ethical. They assert that the utilitarian view of ethics is pitched too low, but they do not succeed in establishing, in contrast to it, a more exalted principle in such a way that a higher and more comprehensive content of ethics can be derived from it. As to content their ethic does not really differ from that of the utilitarians. It merely lacks the great enthusiastic driving-force which shows itself in the latter. To establish a living ethic of self-perfecting is beyond the capacity of the Intellectualists and the Intuitionists.

What is the inner connexion between the struggle for self-perfecting and action for the common advantage? That [pg 087] is the weighty question of ethics which crops up in the settlement of differences between the utilitarians and their conservative opponents. At first it remains veiled, and it does not come to clear expression till we reach Kant.

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A peculiar position in the ethical thought of the eighteenth century is held by Anthony Ashley Cooper, Earl of Shaftesbury (1671-1713)._(_27_)_ He opposes not only the utilitarians, but the Intellectualists and the Intuitionists as well, and tries to secure a mediating position between them. That the content of ethics is utilitarian he openly admits, but he derives the ethical neither from considerations of usefulness nor from the intellect; he places its origin in feeling. At the same time he emphasizes, as does Adam Smith also a few years later, its relationship to the æsthetic.

But the important thing is that he puts forward a living philosophy of nature which connects itself with ethics. He is convinced that harmony reigns in the universe and that man is meant to experience this harmony in himself. Æsthetic feeling and ethical thinking are for him forms of a growing union with the divine life, which struggles to find expression in the spiritual being of man as it does in nature.

With Shaftesbury ethics descend from a rocky mountain range into a luxuriant plain. The utilitarians know as yet nothing of a world. Their ethic is contained in considerations about the relation of the individual to society. The anti-utilitarians have some idea of a world, but not a correct one. They elaborate ethics with a formal theology and a formal philosophizing about the All, but Shaftesbury plants ethical thought in the universe of reality, which he himself contemplates through an idealising optimism, reaching thereby a direct and universal notion of the moral.

[pg 088]

A mysticism based on a philosophy of nature begins to spin its magic threads through European thought. The spirit of the Renaissance rules again, no longer, however, like a raging storm, as in Giordano Bruno, but as a gentle breeze. Shaftesbury thinks pantheistically, more pantheistically than he confesses to himself, but his is not a pantheism which throws his age into struggles about world-views, and comes into conflict with theism. It is the pantheism which rules in Hinduism and in Late Stoicism also; one which is not dangerous, and raises no question of principle, desiring only to be regarded as a vivifying of belief in God.

Shaftesbury exerts also a liberating influence on the spiritual life of his time by giving ethics a much freer attitude towards religion than anyone had ventured to do up to that time. Religion, according to him, has not to give decisions about ethics, but on the contrary must test its own claims to be true by its relation to pure ethical ideas. He even ventures to represent the Christian teaching about rewards and punishment as not consistent with pure ethical considerations. Morality, he says, is pure, only when good has been done simply because it is good.

His optimistic-ethical philosophy of nature is offered by Shaftesbury only as a sketch. He throws out his ideas without proving that they are well founded, and without feeling any necessity for thinking them out to a conclusion. He steps with an easy stride across

all problems. What a difference between his philosophy of nature and Spinoza's! Yet his meets the needs of his time. He offers what is new to it, and what inspires it: ethics bound up with a living world-view.

The belief in progress now clothes itself in a living world-view which really suits it. This is the process which, thanks to Shaftesbury, began in the first decades of the eighteenth century and went on developing till the end of it. Hence the appearance of his writings, which were immediately spread abroad through the whole of Europe, [pg 089] is the great event for the spiritual life of the eighteenth century. Voltaire, Diderot, Lessing, Condorcet, Moses Mendelssohn, Wieland, Herder, and Goethe too, are under his influence, and he dominates popular thought completely. Hardly ever has any man had so direct and so powerful an influence on the formation of the world-view of his time as the invalid whose life ended at Naples when he was only forty-two.

Direct continuators of Shaftesbury's ethic are found in Francis Hutcheson (1694-1747)_(_28_)_ and Bishop Joseph Butler (1692-1752),_(_29_)_ but they take from it just that soft indefiniteness which gives it its charm and its strength. Hutcheson, who strongly emphasizes theology's independence of ethics, the relationship of the latter to the æsthetic, and their utilitarian content, stands nearer to his teacher than does Butler, who does not go as far in his welcome of utilitarianism, and also opposes, from the Christian standpoint, the optimism of Shaftesbury's world-view.

But Shaftesbury's true successor is J. G. Herder (1744-1803). In his _Ideas on the Philosophy of Human History_ (4 vols., 1784-1791), he carries the optimistic-ethical nature-philosophy on into a corresponding philosophy of history.

[pg 090]

CHAPTER VIII

LAYING THE FOUNDATIONS OF CIVILIZATION IN THE AGE OF RATIONALISM

The Mentality and the Achievements of the Ethical Belief in Progress

THANKS to the fully worked out optimistic-ethical world-view with which the belief in progress surrounds itself in the course of the eighteenth century, these generations prove capable of thinking out the ideals of civilization and advancing towards their realization. The fact that all attempts to give ethics a foundation in reason have turned out on the whole unsatisfactory does not move them, if indeed they give the point any consideration at all. By the conviction that they have formed a rational conception of the world which gives it an optimistic-ethical meaning, they are carried on over all the inner problems of ethics. The alliance which belief-in-progress and ethics have in the course of modern times contracted with one another is sealed by means of their world-view, and now they set to work together. Rational ideals are to be realized.

The ethical and the optimistic come into power, therefore, in the world-view of the eighteenth century, although they have not yet received any real foundation. Scepticism and materialism range around the fortress like hordes of unconquered enemies, though at first without being dangerous; as a rule they have themselves absorbed no small amount of belief-in-progress and of ethical enthusiasm. Voltaire is an example of the sceptic who stands under the restraint exercised by the prevalent optimistic and ethical thought.

So far as its elements are concerned the world-view of rationalism hides itself under the optimistic-ethical monism [pg 091] of Kungtse (Confucius) and the Later Stoics, but the enthusiasm which supports it is incomparably stronger than any felt by them. The circumstances, too, amid which it appears are far more favourable, and so it becomes an elemental power throughout a whole people.

In a world-view which springs from a noble faith, but is remarkable also for the extent of its knowledge, the men of the eighteenth century begin to think out ideals of civilization and to realise them in such measure that the greatest epoch in the history of human civilization now dawns.

The great feature of the mentality of this belief in progress which is ever showing itself in works is its magnificent want of respect for all existing things, whether belonging to the past or the present. These are to it in all their various forms the imperfect, which is destined to be replaced by a perfect.

The eighteenth century is thoroughly unhistoric. In what is good as in what is bad it cuts itself loose from whatever was or is, and is confident of being able to put in its place something that is more valuable, because more ethical or more in accordance with reason. In this conviction the age feels itself so creative that it has no understanding for creations of original genius. Gothic

buildings, early painting, J. S. Bach's music, and the poetry of earlier ages, are felt by these generations as art which was produced at a time when taste had not yet been purified. Activity which follows rules in accordance with right reason will, they think, introduce a new art which will be superior in every respect to any that has preceded it. Full of this self-confidence, a mediocre musician like Zelter in Berlin works over the scores of Bach's Cantatas. Full of this self-confidence, honourable poetasters re-write the texts of the wonderful old German chorales and replace the originals in the hymn books with their own wretched productions.

That they so naïvely push forward right into the sphere [pg 092] of art the boundaries of the creative faculties with which nature endowed them is a mistake made by these men for which they have often been laughed at. But mockery cannot do them much harm. In those departments of life in which the important matter is the shaping of things according to ideals given by reason—and work done upon such things means for the establishment of civilization very much more than any work spent in the promotion of art—they are as creative as any generation ever has been, and as scarcely any will be in the future. They are frightened by nothing which has to be undertaken in this sphere, and in every department they make the most astonishing advance.

They venture also to deal with religion. That religion should be split up into various antagonistic confessional bodies is to them an offence against reasonable reflexion. Only a relative, not any absolute authority, they maintain, can be allowed to the belief which is handed down in historical formulas. Finding expression in so many and such varied forms it can, of course, be nothing but a more or less imperfect embodiment of the ethical religion taught by reason, which must be equally intelligible to all men. The right thing is, therefore, to strive after the religion of reason, and to accept as true only such parts of the various confessions as are in harmony with it.

The churches, naturally, put themselves on the defensive against this spirit, but against the strong general convictions of the age they are unable in the long run to hold out. Protestantism succumbs first, because the elements already within it allow such considerations to find easy access. It carries within itself impulses to rationalism, inherited from Humanism, from Huldreich Zwingli (1484-1531) and from the Italians Lælius (1525-1562) and Faustus Socinus (1539-1604), and these impulses, hitherto suppressed, now find themselves set free._(_30_)_

[pg 093]

Catholicism shows itself more capable of resistance. Nothing in its past makes it inclined to enlist under the banner of the spirit of the age: its strong organization serves as a protection against this. Yet it, too, has to yield considerably, and to allow its doctrines to pass, so far as may be, for a symbolic expression of the religion of reason.

While utilitarian ethics are on the whole the product of the English spirit, the whole of Europe takes part in the expounding of the religion of reason. Herbert of Cherbury (1582-1648), John Toland (1669-1722), Anthony Collins (1676-1729), Matthew Tindal (1655-1733), David Hume (1711-1776), Pierre Bayle (1647-1706), Jean-Jacques Rousseau (1712-1778), Voltaire (1694-1778), Denis Diderot (1713-1784), Hermann Samuel Reimarus (1694-1768), Gottfried Wilhelm Leibniz (1646-1716), Christian Wolff (1679-1754), Gotthold Ephraim Lessing (1729-1781), Moses Mendelssohn (1729-1786), and a host of others, whether standing nearer to or further from the Church, and whether or not going further than others in systematic criticism, all bring stones for the erection of the great building in which the piety of illuminated mankind is to live._(_31_)_ The researches in the history of religion made by the Germans, like Johann Salomo Semler (1725-1791), Johann David Michaelis (1717-1791), and Johann August Ernesti (1707-1781), provide scientific data which throw light upon the division between eternal truths and the time-conditioned convictions of religion.

The creed of the religion of reason is simply the optimistic-ethical world-view reproduced in a Christian phraseology, that is in one preserving within it the Christian theism, and the belief in immortality. An all-wise and wholly benevolent Creator has produced the world, and he upholds it in [pg 094] corresponding fashion. Men are endowed with free will, and discover in their reason and their heart the moral law which is meant to lead individuals and mankind to perfection, and to accomplish in the world God's highest purposes. Every man has within him an indestructible soul, which feels his moral life as the highest happiness, and after death enters a state of a pure, spiritual existence.

This belief in God, in virtue, and in immortality was held to have been taught in its purest form in previous ages in the teaching of Jesus, but it was acknowledged that elements of the same beliefs were to be found in all the higher religions._(_32_)_

If the eighteenth century attained to an optimistic-ethical world-view which preached itself so confidently and was so widely accepted, the reason is that it was able to re-interpret Christianity—which had by that time got rid of the world- and life-denial that

was originally inherent in it—in that sense. Jesus was to it a teacher who even in his own age and then through all the intervening centuries had been misunderstood, and was now first rightly accepted as a revealer of the religion of reason. Let anyone read a rationalistic Life of Jesus, such as those of Franz Volkmar Reinhard (1753-1812) or Karl Heinrich Venturini (1768-1849)._(_33_)_ They hold Jesus up to admiration as the champion of enlightenment and of blessings for the common people. This transformation of the historical picture is made easier for them by the fact that the chief component element of the Gospel narrative is ethical teaching, while the late-Jewish pessimistic world-view which it presupposes is hardly more than hinted at.

[pg 095]

As an immediate result of the wiping out of confessional differences the middle of the eighteenth century sees the beginning of a period of tolerance in place of the persecution of all rejecters of orthodoxy which had been common till then. The last serious act of confessional intolerance was expulsion of all evangelicals from the Salzburg district by the Archbishop of that town, Count von Firmian, in the years 1731 and 1732.

About the middle of the century there begins also the movement of opposition to the Jesuits, who were recognized as the enemies of tolerance, and this led to the suppression of the order in 1773 by Pope Clement XIV._(_34_)_

But the religion of reason fought superstition as well as intolerance. In 1704 the philosopher and jurist of Halle, Christian Thomasius (1655-1728), published his essays condemning trial for witchcraft,_(_35_)_ and about the middle of the century the law courts in most of the States of Europe refused to concern themselves any longer with the crime of magic. The last death sentence on a witch was passed in 1782 at Glarus, in Switzerland.

About the end of the century it became good form to detest anything which had even a remote connexion with superstitious convictions.

Again, the will-to-progress of the eighteenth century deals with nationalist prejudices in the same way as it deals with religious ones. Above and beyond individual nations it points to mankind as the great object towards which ideals are to be directed. Educated people accustom themselves to see in the State not so much an organ of national feeling as a mere organization for legal and economic purposes. Cabinets may carry on war with each other, but in the thought of the common people there grows up a recognition of the brotherhood of nations.

In the sphere of law, too, the will-to-progress acquires [pg 096] strength. The ideas of Hugo Grotius get accepted. The law of reason is exalted in the convictions of the men of the eighteenth century to a position above all traditional maxims of jurisprudence. It alone is allowed to have permanent authority, and legal decisions have to be in harmony with it. Fundamental principles of law, but principles equally indisputable everywhere, have to be deduced from human nature. To protect these and to ensure to every human being a human value with an inviolable measure of freedom of which he can never be robbed, is the first task of the State. The proclamation of "the Rights of Man" by the States of North America, and the French Revolution, do no more than give recognition and sanction to what, in the convictions of the time, had already been won.

The first State in which torture was abolished was Prussia, and this was secured by an administrative order of Frederick the Great's in 1740. In France a certain amount of torture was practised down to the Revolution— and somewhat later, for the thumb-screw was used under the Directory during the examination which the royalist conspirators had to undergo._(_36_)_

Side by side with the fight against absence of law and the existence of inhuman laws, go efforts to adapt law to circumstances. Bentham raises his voice against laws which tolerate usury, against senseless customs duties, and against inhuman methods of colonization.

There dawns an age in which the purposive and the moral are the ruling authorities. Officialdom acquires during these generations familiarity with the notions of duty and honour, which later become natural to it. Far-reaching beneficial reforms are introduced into administration without any outcry.

The education of mankind in citizenship makes splendid progress. The general good becomes the criterion of [pg 097] excellence both for the commands of rulers and the obedience of their subjects, while at the same time a beginning is made of securing that everyone shall be educated in a manner corresponding to his human dignity and the needs of his personal welfare. The war against ignorance is begun.

The way is prepared, too, for a more rational method of living. Houses are built so as to be more comfortable, and the land is better cultivated. Even the pulpit uses its influence to promote improvements of this kind. The theory that reason has been given to man to be used consistently and in every department of life plays at this time an important and beneficent part in the preaching of the Gospel, even if the way in which this is done often makes queer demands on our belief. Sermons, for example, often treated incidentally of the best methods of manuring, irrigating, and draining the fields. That Jenner's discovery of vaccination was so readily adopted in many districts was due to the enlightenment which was spread abroad by the clergy.

Characteristic of the age of rationalism are the private societies formed to promote the moral and utilitarian progress of mankind. In 1717 members of the higher ranks of society in London reorganize as "The Order of Freemasons" the brotherhood which in earlier times had been built up by the union in a single body of the members of the mediæval building-lodges, but was now in a state of decay, and to this new organization was assigned the duty of labouring to build up a new humanity. About the middle of the century this order had spread all over Europe, and reached the zenith of its success. Princes, officials, and intellectuals alike joined it in great numbers, and were inspired by it to the achievement of a huge amount of reform.

Similar aims were pursued by the "Order of the Illuminate" (or enlightened) which was founded in Bavaria in 1776, but was suppressed in 1784 by the reactionary Bavarian Government, which was still under the influence [pg 098] of the Jesuits. It is said to have been the intellectual counterpart of the Jesuit order, on the model of whose organization it was formed.

That private societies aiming at the rational and moral perfecting of mankind should work effectively seemed to the men of the eighteenth century so much a matter of course that they assumed them to have existed in earlier times. In a series of rationalist descriptions of the life of Jesus it is assumed that the sect of the Essenes, near the Dead Sea, of whom we learn from Josephus, the Jewish writer of the first century A.D., was such an order, and that it was in touch with similar brotherhoods in Egypt and India. Jesus, it is said, was trained by them, and then helped by them to carry through the _rôle_ of the Messiah, in order that with the authority given by a holy yet popular personality he might work to spread true illumination. The famous _Life of Jesus_ by Karl Venturini carries this assumption out in complete detail. According to him, the miracles of Jesus were staged by brothers of this secret association.

Be that as it may, the fact that the will-to-progress of the eighteenth century created for itself in these private societies organizations which spread throughout Europe, contributed much to its ability to influence the age.

It must be admitted indeed that the men of the rationalistic period were smaller than their achievements. True, they all possessed personality, but it did not reach very deep. It was produced by the enthusiasm which they found in the mentality of the time and which they shared with all their contemporaries. The individual imbibed personality through the taking over of a ready-made world-view, which gave him firm standing-ground together with ideals. His own contribution was really nothing more than the capacity for enthusiasm. That is why the men of this age are so remarkably like one another. They all graze side by side in the same nourishing pasture land.

Nevertheless, the ideas of the purposive and the ethical [pg 099] have never exercised so much influence over reality as they did among these men of shallow optimism and sensitive morale. No book has been written yet which fully describes their achievements, doing justice to their origin, their character, their number, and their significance. We can then only really comprehend what they accomplished when we recognize the tragic fact that the most valuable part of it is lost to us, while we do not feel in ourselves any ability to reproduce it. They were masters of the facts of life to an extent which we are to-day quite unable to realize.

Only a world-view which accomplishes all that rationalism did has a right to condemn rationalism. The greatness of that philosophy is that its hands are blistered.

Obstacles to the reform movement. The French Revolution

The great work of reform is never completed, partly because external circumstances arise which check it, but also because the world-view of rationalism becomes convulsed from within. In its confidence in the enlightening power of all that is in accordance with reason the will-to-progress was inclined to underestimate the resisting power of the traditional, and to wish to carry through reforms where minds had not been sufficiently prepared for their reception. On these unsuccessful advances followed reaction which permanently injured the work. This was the case in south-eastern Europe. Joseph II. of Austria, who was emperor from 1764 to 1790, is the type of the reforming prince. He discontinued the use of torture, opposed the infliction of the death penalty, abolished

serfdom, gave the Jews full civic rights, introduced a new method of legislation and a new system of legal administration, took away all class privileges, contended for the equality of all before the law, protected the oppressed, founded schools and hospitals, guaranteed the freedom of the Press and freedom of domicile, abolished all State monopolies, and promoted the development of agriculture and industry.

[pg 100]

But he is a ruler in the wrong place. He decrees these reforms and then similar shocks, one after another, in countries which, being in spiritual things still wholly under the dominion of the Catholic Church of that time, are not prepared for them, and moreover in other things as well display a specially backward attitude, because they belong to the zone in which the Europe of that day passed over into Asia. The Emperor is therefore unable to count upon either any willingness to make sacrifices in the classes which are to give up their privileges, or upon any understanding of his ideas in the common people. In his attempts to organize the monarchy as a unity and in an effective way for practical purposes, he comes into conflict with the nationalities themselves of which it is composed. The reduction in the number of the religious houses, which he undertakes out of economic considerations, with the introduction of the freedom of the Press and of a system of State education, bring on him the hostility of the Church. Finally, because he is a ruler in the wrong place, this noble reforming emperor dies of a broken heart, while Europe, because the will-to-progress in Austria can accomplish nothing even at the time of its greatest strength, owing to unfavourable circumstances, is condemned to a period of the deepest misery over the problems of that huge State, which have in this way been rendered insoluble, and over the portion of Asia beyond it along the southern Danube.

In France, too, the wrong men are in control. There the spread of the new ideas prepares the way splendidly for reform, but the reforms are not undertaken, because its rulers cannot understand the signs of the times, and allow the State to collapse in ruin. Consequently the reform movement has to take the road of violence, whereby it slips away from the guidance of the educated, and falls into the hands of the mob, from which it is taken by the powerful genius of Napoleon. Native of an island in which the Europe of that day passed over into Africa, and lacking all [pg 101] deeper education, he is uninfluenced by the valuable convictions of his time. Guided solely by the force of his own personality, he decides what is to happen in Europe, and hurls it into wars through which it sinks into misery. Thus from East and from West alike disaster overtakes the work of the will-to-progress.

The French Revolution is a snowstorm falling upon trees in blossom. A transformation which promises great things is in progress, but everywhere softly and slowly. Extraordinarily valuable results are being prepared in the thoughts of men. Provided that circumstances remain even tolerably near the normal, there stands before humanity in Europe an extraordinarily desirable development. But in place of that there sets in a chaotic period of history in which the will-to-progress has to cease more or less completely from its work, and becomes a bewildered spectator. The first stage of the advance of reforming thought, thought bent with full consciousness of its aims on securing the practical and the ethical, comes to a complete stop.

An experience for which it was in no wise prepared now falls to the lot of the will-to-progress. Up to this time it had always been a more or less obsolescent reality with which it had had to come to terms. In the French Revolution, however, and in the following period, it becomes familiar with a reality which has at its disposal elemental forces. Up to this time the only factor to be reckoned with had been the force of originality exercised by rational thought. In Napoleon it has to learn to recognize as power a personality with creative genius of its own.

By his reorganization of France, a magnificent work but concerned only with the technical matters of administration, Napoleon creates a new State. His work, too, has had the way prepared for it by the labour of rationalism, so far as this upset the equilibrium of the old and made current the idea of something new but necessary. But the new State which now comes into existence is not the State [pg 102] which is ethical and in harmony with reason, but merely the State which works well. Its achievements compel our admiration. In the nursery garden which the will-to-progress was laying out in order to plant it with noble flowers an individual ploughs for himself a piece of ordinary arable land which at once produces an excellent crop. With the elemental creative forces of reality revealing their power in so imposing a fashion, the noble but unoriginal spirit of the age, with all its higher aims, finds itself in a state of instability from which it never completely recovers. Hegel, who saw Napoleon ride past after the Battle of Jena, tells us that he then saw the World-spirit on horseback. In these words we can hear all the confused spiritual experience of that time expressing itself.

The undermining of the rationalistic world-view

There now sets in a development which works against the spirit of the times, and the hitherto unopposed authority of the rational ideal is undermined. Forces in reality which are not guided by it, obtain recognition.

While the will-to-progress remains an amazed spectator of events, respect for what is historical recovers itself, though it seemed to have been banished for ever. In religion, in art, and in law, men begin, though at first only quite shyly, to look again with other eyes on the traditional. It is no longer reckoned as merely something which is to be replaced, but men venture to admit to themselves that it conceals within itself original values. The forces of reality, which had been taken by surprise, now begin everywhere to act on the defensive, and a guerilla warfare develops against the will-to-progress.

The various religious bodies revoke the abdications which they had made before the religion of reason. The law which has grown up in the course of time begins to set itself in opposition to the law laid down by reason. In the atmosphere of passion produced by the Napoleonic wars, [pg 103] national thought takes on a new character, directing on itself, and beginning to absorb, the universal enthusiasm for ideals. The struggles carried on no longer by chancelleries but by whole nations are fatal to the ideals of cosmopolitanism and national brotherhood, and by this awakening of national thought a whole series of political problems affecting the whole of Europe are rendered insoluble. Just as the organization of Austria as a unified modern State has now become impossible, so also has the civilizing of Russia, and the destiny of Europe, viz. to be shipwrecked over these territories which are in it but not of it, begins to reveal itself.

At the close of the Napoleonic era the whole of Europe is in a condition of misery. Far-seeing ideas of reform can be neither thought out nor worked out; only extemporized palliative measures suit the time. The will-to-progress is therefore unable to recover its former vigour.

It is fatally affected, too, by the fact that everybody with any capacity for independent thought feels himself attracted by this new valuation of things and facts, and thereby drawn on to irritation at the one-sided, doctrinaire character of the rationalist way of looking at life.

Nevertheless, the position of the will-to-progress is far from being a critical one. The first attacks are made by Romanticism and the feeling for reality, but are mere outpost-skirmishes, and for a long time yet the will-to-progress remains master of the field. Bentham remains still the great authority. Alexander II. of Russia, Tsar from 1801 to 1825, instructs the legislative commission which he sets up to obtain on all doubtful points the opinion of the great Englishman. Madame de Staël expresses the opinion that the fateful period she has lived through will one day be called by posterity not the Napoleonic age but the Benthamite._(_37_)_

The noblest men of the period still live in the unshaken [pg 104] conviction that nothing can delay the speedy and conclusive victory of the purposive and moral. The philosophically minded mathematician and astronomer, the Marquis Marie Jean de Condorcet (1743-1794), though put by the Jacobins upon the list of the proscribed, writes, while living in concealment in Paris in a dismal room in the Rue des Fossoyeurs, his _Historical Sketch of the Progress of the Human Spirit_._(_38_)_ Then, having been betrayed, he wanders about the Clamart quarries, is recognized by the labourers, in spite of his disguise, as an aristocrat, and while confined in the prison of Bourg la Reine, puts an end to his life by poison. The document in which he gave his exposition of the ethical belief in progress concludes with a forward glance at the time, now soon to appear, when reason, having attained a position of permanent sovereignty, will put every human being in possession of the rights which belong to man as man, and will establish purposive and ethical relations in every department of life.

There is one thing, it must be admitted, which Condorcet and those who share his views overlook. Their belief that the final result will be good might be considered justifiable if the will-to-progress had been endangered only through unfavourable outward circumstances, the revival, that is, of the higher estimation of reality, and the romantic idealizing of the past. But it is threatened far more seriously by something else than it is by them. The assurance displayed by rationalism rests on the fact that it regards the optimistic-ethical world-view as something proved to be correct. But it is not that. It rests like the world-views of Confucius and the Later Stoics on a naïve interpretation of the world. All deeper thought, therefore, even if it is not directed against rationalism, or even if it aims at strengthening its position, must in the long run have a damaging effect upon it. Hence Kant and Spinoza mean doom to it. Kant undermines it by his attempt to [pg 105] provide a deeper foundation for the essence of the ethical. Spinoza, the thinker of the seventeenth century, brings it to confusion when his nature-philosophy begins, a hundred years after his death, to occupy people's attention.

It is about the beginning of the new century, the nineteenth, just when the pressure exerted by material and spiritual circumstances alike begins to make itself felt, that the optimistic-ethical world-view begins to suspect the existence of the serious problems which

are cropping up within it.

[pg 106]

CHAPTER IX

THE OPTIMISTIC-ETHICAL WORLD-VIEW IN KANT

Kant's ethics, deepened, but lacking content

SO far as the general tendency of his thought goes Immanuel Kant (1724-1804) lives entirely in the optimistic-ethical world-view of rationalism._(_39_)_ He has, however, a feeling that its foundations are not deep and firm enough, and he regards it as his task to put them on ground which is in every respect more secure. For this purpose a deeper ethic, and a less naïve positiveness in assertions about world-view which touch upon the supra-sensible, seem to him desirable.

Like the English intellectualists and intuitionists, Kant is offended by the idea that the ethic in which the modern age finds satisfaction and its impulse to activity is rooted merely in considerations of the universal advantage of morally good actions. Like them, he feels that it is something more than this, and that in the ultimate analysis it has its origin in the compulsion which men experience to strive for self-perfecting. But while his predecessors stick fast in the matter provided by semi-scholastic philosophy and theology, he attacks the problem along the lines of pure ethical thought. It follows for him that the fundamental origin and the exalted character of the moral can be preserved only if we always consciously make it an end in itself, and never merely a means to an end. Even if moral conduct prove itself to be always advantageous and practical, our motive to it must nevertheless always be a [pg 107] purely inward compulsion. The utilitarian ethic must abdicate before that of immediate and sovereign duty. That is the meaning of the doctrine of the categorical imperative.

The English anti-utilitarians had in common with the utilitarians the thought that the moral law was related in its essence to empirical natural law. Kant, however, asserts that it has nothing to do with the order of nature, and has its origin in supra-natural impulses. He is the first since Plato to feel, like him, that the ethical is the mysterious fact within us. In powerful language he proves in the _Critique of the Practical Reason_ that ethics are a volition which raises us above ourselves, makes us free from the natural order of the world, and attaches us to a higher world-order. That is his great discovery.

In the development of it, however, he is not happy. Whoever asserts the absoluteness of moral duty, must also give the moral an absolute and completely universal content. He must specify a principle of conduct which shows itself as absolutely binding, and as lying at the foundations of the most varied ethical duties. If he does not succeed in doing this, his work is only a fragment.

When Plato announces that ethics are something supra-natural and puzzling, his world-view provides him with a basic principle of the ethical which corresponds to these qualities, and also has a definite content. He is in a position to define ethics as a process of becoming pure and free from the world of sense. This, his own special ethic, he develops in the passages where he is consistent with himself. Then, when he cannot complete his argument without an active ethic, he has recourse to the popular theory of virtue.

Kant, however, as a child of the modern spirit, cannot let world- and life-denial rank as an ethic. Therefore, since he can go only a part of the way with Plato, he sees himself faced with the confusing task of letting a purposive, activist ethic which is directed on the empirical world originate in impulses which are not determined by any adaptation to the empirical.

[pg 108]

He can find no solution of the problem thus set. In the form which he gives it it is in fact insoluble. But he never even realises that he has arrived at the problem of finding a basic principle of the moral which is a necessity of thought. He is content with formally characterizing ethical duty as absolutely binding. That duty, unless a real content is at once given to it, remains an empty concept, he is unwilling to admit. For the exalted character of his basic principle of the moral he pays the price of having it devoid of all content.

Beginnings of an attempt to establish a basic moral principle which has a content are to be found in his treatise, _Prolegomena to a Metaphysic of Morals_ (1785), and again later in _A Metaphysic of Morals_ (1797). In the 1785 volume he arrives at the dictum: "Act in such a way that you use every human being both in your own person and in everyone else's always as an end, never merely as a means." But instead of seeing how far the totality of ethical duties can be developed out of this principle, he prefers in the 1797 treatise to set before ethics two ends to be aimed at, viz. the perfecting of oneself and the happiness of others, and to enlarge upon

the virtues which promote them.

In his investigation of the ethic which aims at personal perfecting, he drives his gallery with sure instinct towards the recognition that all virtues which contribute thereto must be conceived of as manifestations of sincerity and of reverence for one's own spiritual being. He does not, however, go the length of comprehending these two as a unity, just as little does he concern himself to make clear the inner connexion between self-perfecting and effort directed to the common good, and in that way to dig down to the roots of the ethical as such.

How far Kant is from understanding the problem of finding a basic moral principle which has a definite content can be seen from the fact that he never gets beyond an utterly narrow conception of the ethical. He persists obstinately in drawing the boundary of his ethic as close [pg 109] as possible, making it concerned with no duties beyond those of man to man. The relation of man to non-human existences he does not draw within it. It is only indirectly that he includes in it the prohibition of cruelty to animals, putting this among the duties of man to himself. By inhuman treatment of animals, he says, sympathy with their sufferings is blunted in us, and thereby "comes a weakening of a natural disposition which is very helpful to our morality in relation to other men, and it gradually dies out."

Again as to the vandalism of the destruction of what is beautiful, in the form, that is, of natural objects which are viewed as entirely without feeling, this is said to be unethical only because it violates the duty of man to himself by undermining the desire—itself a support to morality—of having something to love without regard to utility.

If the sphere of the ethical is limited to the relations of man to man, then all attempts to reach a basic principle of the moral with an absolutely binding content are rendered hopeless beforehand. The absolute demands the universal. If there really is a basic principle for the moral, it must be concerned in some way or other with the relations between man and life as such in all its manifestations.

Kant, then, does not essay the task of developing an ethic which corresponds to his deepened conception of the ethical. On the whole he does nothing more than put the current utilitarian ethic under the Protectorate of the Categorical Imperative. Behind a magnificent façade he constructs a block of tenements.

His influence on the ethics of his time is twofold. He furthers it by challenging it to profounder reflection on the nature of the ethical and the ethical destiny of man. At the same time he is a danger to it in that he robs it of its simplicity. The strength of the ethic of the age of reason lies in its naïve utilitarian enthusiasm. It directly enlists men in its service by offering them good aims and objects. Kant makes it insecure by bringing this directness in question and calling for an ethic which is derived from much less elementary considerations. Depth is gained at [pg 110] the cost of vitality, because he fails to establish at the same time a basic moral principle with a content, a principle which compels acceptance from deep and yet elementary considerations.

Several times Kant actually makes it his object to block the natural sources of morality. He will not, for example, allow direct sympathy to be regarded as ethical. The inner feeling for the suffering of another as if it were one's own is not to count as duty in the real sense of the word, but only as a weakness by which the evil in the world is doubled. All help to others must have its source in a reasoned consideration of the duty of contributing to the happiness of others.

By taking from ethics their simplicity and directness, Kant also loosens the connexion which they and the belief in progress had formed with one another, and through which the two together had proved so productive of good. The disastrous separation between them which later on, in the course of the nineteenth century, became complete, was partly due to him.

In consequence of his wishing to drive out the naïve rationalistic conception of the ethical in favour of a deepened one without at the same time being in a position to establish a basic principle of it which has been correspondingly deepened, has a definite content of its own, and is directly convincing, Kant brings the ethics of his time into danger. He labours at the provision of new foundations without remembering that the house will develop cracks, if it is not propped up sufficiently.

Kant's attempt to reach an ethical world-view

Kant passes by the problem of finding a basic principle of the moral with a definite content, because, while attempting to deepen the concept of the ethical, he pursues an object which lies outside ethics. He wishes to bring ethical idealism into connexion with an idealistic representation of the world which has its source in a theory of knowledge. But [pg 111] from that source he hopes there will come an ethical world-view able to satisfy critical thought.

Why has Kant with a rigorism which intentionally depreciates ordinary moral experience ventured forward to the discovery that the moral law has nothing to do with the natural world-order, but is something super-sensible? Because he refuses, similarly, to let the sensible world which is experienced by us in space and time be accepted as anything more than a manifestation of something nonsensible which makes up true reality. The concept of a moral which contains none but inward and spiritual duties is for him the expanding ladder which he draws out so as to reach by means of it the region of Being in itself. He has no feeling of dizziness when in company with ethics, he mounts above all empirical experience and all empirical aims and objects. He is determined to go right up with her, and she can never be sufficiently _a priori_ for him, because he sets up another ladder of the same length, that of epistemological idealism, and tries to lean one against the other, so that they may give each other mutual support.

How does it come about that the theoretical assumption that the world of sensible phenomena has a non-sensible world of Being lying behind it, has any importance for world-view? Because within the notion of absolute duty which man experiences at work within himself there lies a fact of the world-order of that same non-sensible world. Hence arises the possibility, so Kant thinks, of raising to certainty by means of ethics those great elements in the non-sensible world which are of value for the optimistic-ethical world-view, viz. the ideas of God, of the ethical freedom of the will, and of immortality, which otherwise would always remain merely problematical.

So far as rationalism affirms unhesitatingly from the standpoint of theoretical knowledge the ideas of God, of the ethical freedom of the will (_i.e._, of virtue), and of immortality, which make up its optimistic-ethical world-view, it builds upon a foundation which cannot bear the weight of critical thought. Kant wishes, therefore, to erect the [pg 112] optimistic-ethical world-view as a lake-dwelling upon piles rammed into place by ethics. These three ideas are to be able to claim real existence for themselves as necessary postulates of the ethical consciousness.

This plan, however, of thus securing the position of the optimistic-ethical world-view cannot be carried out. It is only the idea of the ethical freedom of the will that can be made a postulate of the moral consciousness. To establish the ideas of God and immortality as equally "postulates," Kant has to abandon all honourable logic and argue with bold and ever bolder sophisms.

There is no way of uniting epistemological and ethical idealism, however enticing the undertaking looks at first sight. When they are set side by side, the happenings which take place according to a law of causation subordinate to freedom, and become conscious in man through the moral law, become identified with the happenings which are universal in the world of things in themselves. There ensues a disastrous confusion of the ethical with the intellectual. If the sensible world is only a manifestation of an immaterial world, then all the happenings which come about in the space and time sphere of causation produced by necessity are only parallel appearances of the events which are brought about in the intellectual sphere of causation produced by freedom. All happenings, therefore, human activity just as much as natural happening, are, according to the point of view, at once intellectual and free, and at once natural and necessary. If ethical activity produced by freedom is represented as analogous with the results of epistemological idealism, then either everything that happens in the world, conceived as intellectual happening, is ethical, or there is no such thing as an ethical happening. Because it has chosen to put side by side these two things, human activity and natural happening, Kant's way of looking at the question has to renounce all ability to maintain the difference between them. But the very life of ethics depends on this difference being there and effective.

[pg 113]

Epistemological idealism is a dangerous companion for the ethical. The world-order of immaterial happening has a supra-ethical character. From the setting side by side of ethical and epistemological idealism there can never result an ethical world-view: it will always be a supra-ethical one.

From epistemological idealism, therefore, ethics have nothing to expect, but everything to fear. By its depreciation of the reality of the empirical world the ethical world-view is not helped: it is injured.

Ethics have materialist instincts. They want to concern themselves with empirical happenings and transform the circumstances of the empirical world. But if that world is only "appearance," derived from an intellectual world which functions within it or behind it, ethics have nothing on which to act. To wish to influence a self-determined play of appearances has no sense. Ethics can therefore allow validity to the view that the empirical world is mere appearance only with the limitation that activity exerted upon the appearance does at the same time influence the reality lying behind it. But thereby they come into conflict with all epistemological idealism.

Kant is defeated by the same fate which rules in Stoic, Indian, and Chinese monism alike. As soon as thought tries in any way to comprehend ethics in connexion with the world-process, it falls at once, whether it is conscious of it or not, into the supra-ethical manner of regarding it. Fully to shape ethics to an ethical world-view means letting them come to terms with nature-philosophy. Ethics are thereupon, as a matter of fact, devoured in one way or another by that philosophy, even if they are in word saved from that fate. The coupling of ethical idealism with epistemological is only bringing ethics and nature-philosophy into relation with one another in a roundabout way by which it is hoped to outwit the logic of facts. But this logic cannot be outwitted. The tragical result lies in the identification which has been made of the ethical with the intellectual.

[pg 114]

The ethical is not something irrational which becomes explicable when we betake ourselves from the world of appearance to the region of immaterial Being that lies behind it. Its intellectual character is of a peculiar kind, and rests upon the fact that the world-process, as such, comes in man into contradiction with itself. It follows that the ethical will and ethical freedom of the will are not explicable by any theory of knowledge, and cannot, moreover, serve as a support to any such theory.

As a result of conceiving the moral law and empirical obedience to natural law as in absolute opposition to each other, Kant finds himself on the road which leads to a dualistic world-view. Afterwards, however, in order to satisfy the claims of the unitary and optimistic world-view which the spirit of the age prescribes to him, he manages with the stratagems which are provided for him by the combination of ethical and epistemological idealism, to work himself back on to the road which leads to the monistic point of view.

Kant is great as an ethical thinker, great too with his theory of knowledge, but as shaper of a world-view he is not in the first rank. By his deepened conception of the nature of the ethical, a conception which lands him in dualistic thought, the problem of the optimistic-ethical world-view is unfolded in an entirely new way. Difficulties reveal themselves which till then no one could have imagined to exist. But he does not deal with them. He is blinded by his ambition to be the Copernicus of the optimistic-ethical world-view, believing that he can show the difficulties inherent in that view to be misunderstandings which explain themselves away as soon as, by means of his epistemological idealism, actual circumstances and relations take the place of these which are apparent but inexplicable. In reality he does nothing but replace the naïve optimistic-ethical interpretation of the world which was the basis of action for the rationalists by an artfully contrived one.

He does not take the trouble to ask in what the optimistic [pg 115] ethical world-view consists, to what final items of knowledge and demands it leads, and how far these are confirmed by experience of the moral law. He takes it over without examination in the formula: "God, Freedom (or Virtue), and Immortality," which was supplied to it by rationalism, and wishes to raise it in this naïve form to a certainty.

There is thus in Kant's philosophy the most terrible want of thought interwoven with the deepest thinking. New truths, weighty in their novelty, make their appearance in it. But they get only half-way on their journey. The absoluteness of ethical duty is grasped, but its content is not investigated. Experience of the ethical is recognized as the great secret by means of which we comprehend ourselves as "other than the world"; but the dualistic thinking which goes with it is not worked out any further. That the final items of our knowledge of our world-view are assertions of the ethical will is admitted, but the consequences of this supremacy of the will over knowledge are not thought out to a conclusion.

Kant stimulates powerfully the men of his time, but is unable to make secure for them the optimistic-ethical world-view in which they have lived. His mission is, although both he and they are content to deceive themselves in the matter, to deepen it, and ... to let it become less secure than before.

[pg 116]

CHAPTER X

NATURE-PHILOSOPHY AND WORLD-VIEW IN SPINOZA AND LEIBNIZ

Spinoza's attempt to reach an optimistic-ethical nature-philosophy

JUST when Kant is beginning to influence men's minds, the entirely different ideas of a thinker who had now been dead for a century, Baruch Spinoza (1632-1677),_(_40_)_ begin to interest those who are searching for a world-view. The _Critique of Pure

Reason_ appears in 1781. In 1785 F. H. Jacobi in his letters addressed to Moses Mendelssohn, _Concerning the Teaching of Spinoza_, draws attention once more to the philosopher whom hitherto everyone had attacked without making any effort to understand him.

Spinoza desires to obtain an ethic from a real nature-philosophy. He makes no attempt to give an optimistic-ethical interpretation of the universe, or to refashion it with any theory of knowledge. He accepts it just as it is in every respect. His philosophy is therefore elementary nature-philosophy, but his method of expounding it is by no means elementary. Acquiescing in the way Descartes puts the problem and the language he uses, he makes his own thought about the universe proceed "in geometrical fashion" in a series of axioms, definitions, precepts, and proofs. Nature-philosophy is embodied in his philosophizing in a magnificent way, but it is as stiff as an ice-bound landscape.

His chief work—published after his death, because he could not venture to publish it himself—he entitles _Ethics_. The [pg 117] title is confusing, because the nature-philosophy in it is developed almost as completely as the ethics. It is only when the reader has shaken himself free of all naïve conceptions in his thought about the universe that he can be permitted, according to Spinoza, to begin upon ethics. The fact that ethics too are broken up into precepts which are given as proved is very prejudicial to their exposition.

In his attempt to found ethics upon nature-philosophy, Spinoza proceeds as follows. Everything that exists, he says, is given in that infinite Being, which may be called either God or Nature. For us, and to us, it presents itself in two forms: as thought (spirit) and as corporeity (matter). Within this divine nature everything, human activity included, is determined by necessity. There is no such thing as doing, there are only happenings. The meaning of human life, therefore, cannot consist in action, but only in coming to an ever clearer understanding of man's relation to the universe. Man becomes happy when besides belonging to the universe naturally, he also surrenders himself to it consciously and willingly, and loses himself spiritually within it.

Spinoza demands therefore a higher experience of life. With the Stoics and the thinkers of India and China, he belongs to the great family of the monistic and pantheistic nature-philosophers. Like them, he conceives of God merely as the sum-total of nature, and accepts as valid only the notion of God which makes him in this way an independent unity. The attempts, made in the interests of the ethical world-view, to allow God to be at the same time an ethical personality standing outside the universe, are to him an offence against thought. Their only object is, of course, to obtain with the help of a confessed or unconfessed dualism a starting-point for an optimistic-ethical world-view. They are striving to reach along naïve-religious by-roads the goal for which the rationalistic optimistic-ethical interpretation of the universe is making along the direct, but not less naïve, main-road.

[pg 118]

The tragic result of monistic thinking in the Stoic, the Indian, and the Chinese philosophies is that nature-philosophy, when consistent, arrives only at resignation, not at ethics. Has Spinoza escaped this fate?

Like Lao-tse, Chwang-tse, Lie-tse, and the Chinese thinkers as a body, Spinoza champions an optimistic monism without suspecting that under a far-away heaven and in a far-off age, he had such great predecessors._(_41_)_ His resignation is of a world- and life-affirming character. He conceives of infinite Being not as something devoid of qualities, as the Indians do, but as life with a full content. The self-perfecting, therefore, for which man is to strive is not for him, as it is for them, in any way an anticipation of a state of death, but a living out of life which is guided by deep reflexion. An elegantly egoistic world- and life-affirmation speaks through him, as through Chwang-tse.

The efforts of the man who refuses to deceive himself about himself are not directed, therefore, to any sort of action which is recognized as serviceable, but are concerned with maintaining his own Being and giving it the fullest possible experience of life. Whatever good he does to others he never does for their sakes, but always for his own.

Spinoza rejects the achievement of modern ethics as influenced by Christianity, viz. the regarding of altruism as something that belongs to the essence of ethics, and confines himself to the thought that in the last resort all ethical action aims at our own interests, though it may be at our highest spiritual ones. In order to avoid thinking anything which is not a necessity of thought, he goes back of his own free will into the captivity in which ancient ethics lived.

If he could let himself go, he would, like Chwang-tse, conduct a campaign against the morality of love and duty. But since he already has as thoroughgoing opponents the [pg 119] authorities, the theologians, whether Jewish or Christian, and almost every philosopher, he has to speak cautiously and offer mankind without attracting notice the life-view which advocates profound and

thinking egoism.

Just as God, the totality of universal Being, acts not with any aim or object but from an inner necessity, so also does the man who has attained to insight. He does only what contributes to complete experience of life, nothing else. Virtue is capacity for self-maintenance at the highest level, and this self-maintenance is attained to when reason is the highest motive to action, and efforts after knowledge and freedom from passion take possession of the man and make him free, that is, allow his conduct to be determined by himself alone and on purely inward grounds. The ordinary man is unstable, moved hither and thither in all sorts of ways by outward causes, with no idea of his future fortune or his final fate, like a ship that is tossed about, now here, now there, on a stormy sea. Ethics, therefore, consists in living our life more in the form and fashion given it by thought than in bodily actuality.

Acting, therefore, with a deep, enlightened egoism and purely from intellectual impulses, a man behaves nobly in every relation of life. He strives to requite hatred, indignation, and contempt with love and noble feeling, because he knows that hatred causes him discomfort. He seeks at any price to create around him an atmosphere of peace. He never acts deceitfully, but always straightforwardly. He has no need to feel sympathy. Since he lives entirely under the guidance of reason, he does good whenever the opportunity offers, on principle, and therefore does not need to be roused to noble feeling by any experience of discomfort. In fact he avoids sympathy. Again and again he makes it clear to himself that everything that happens is brought about by some necessity in the divine nature and in obedience to eternal laws. Just as he finds nothing in the world which deserves hatred, mockery, and contempt, so he finds in it nothing to evoke sympathy. [pg 120] Man must be ever striving to be virtuous and happy, and if he is conscious of having done good within the limits of what is commanded him, he can with an easy mind leave his fellow-men and the world to their fate. Beyond the possibilities of his own immediate activities he need have nothing to do with them.

The wise man who practises the higher life-affirmation possesses power. He has power over himself, power over his fellow-men, and power over circumstances. How very similar is the tone of Spinoza's thought to that of Lao-tse, Chwang-tse, and Lie-tse!

Spinoza lives out his own ethic. In contented independence he passes his life, till consumption brings it to an early close. He declines an invitation to be lecturer in philosophy at Heidelberg University. He is strict with himself, but his resignation is lighted up by a mild trait of considered humanity and friendliness. The persecutions to which he is exposed fail to embitter him.

Intent though he is on thinking only in accordance with pure nature-philosophy, Spinoza does not concern himself so exclusively with the two natural entities, nature herself and the individual man, as do many of his Chinese predecessors, but maintains an interest in organized society. He is convinced that it betokens progress when men change, from the "natural" stage of society to the "civic." Being formed for living with his fellows, man is freer if he settles by general agreement what belongs to each, and what the relations are to be between himself and society. The State must, therefore, have power to issue general orders as to how people are to live, and to secure respect for its laws by means of penalties.

A real devotion of oneself to the common weal appears, however, to Spinoza not to be called for. According to him the perfect human society appears of itself just in proportion as its individual members live according to reason. In contrast, therefore, to his contemporary, Hobbes, Spinoza looks for the progress of society not to the [pg 121] measures taken by the authorities, but to a growth towards perfection in the dispositions of their subjects. The State is to educate its citizens not to submissiveness, but to the right use of freedom. In no way must it do any injury to their sincerity, and it must therefore tolerate all religious views.

Far as Spinoza goes to meet the spirit of the age, there is one point on which he cannot agree with it, viz. that there are ethical aims and objects, aims and objects practical and purposive, to be realized in the world.

Advancing far ahead of his contemporaries, he reaches a universal notion of ethics, and recognizes that from the standpoint of consistent thinking, every ethical relation is nothing but an expression of the relation of the individual to the universe. When, however, ethics have in this way become universal, they are faced by the question how the relation of the individual to the universe is conceivable as producing an effect upon the universe. On the answer to this question it depends whether a real activist ethic can be established, or whether the ethical is only so far present as resignation can be explained as ethical.

That is the reef which threatens danger to all nature-philosophy, and whenever a thinker imagines that with clever seamanship and a favourable wind he can sail round it without coming to grief upon it, he is nevertheless finally driven upon it, as by submarine currents, and suffers the same fate as his predecessors. Like Lao-tse and Chwang-tse, like the Indians, the Stoics, and all self-consistent thinkers before him, Spinoza is unable to furnish what ethics demand, viz. that the relation of man to the universe

shall be conceived of as not merely a spiritual relation, but as active devotion to it in the world of sense. The opponents of this solitary thinker are instinctively conscious that with the re-establishment of an independent nature-philosophy there appears something which means danger to the optimism and the ethics of their world-view. Hence [pg 122] we find in the seventeenth and eighteenth centuries everyone uniting to suppress Spinoza's philosophy.

It is on behalf of optimism that the age is most troubled. The terrible earthquake which in 1755 destroyed Lisbon, sets the mass of men asking whether the world is really ruled by a wise and kindly Creator. Voltaire, Kant, and many other thinkers of the age seize on the occurrence as a topic for discussion, partly confessing their perplexity, partly seeking new ways out of the difficulty for their optimism.

Leibniz's optimistic-ethical world-view side by side with nature-philosophy

How little optimism and ethics have to expect from a real nature-philosophy is shown not only in Spinoza, but also in Gottfried Wilhelm Leibniz (1646-1716)._(_42_)_ In his _Theodicée_ (1710) he tries to be fair to the optimistic world-view. He is helped in this by the fact that his nature-philosophy is much more living and adaptable than Spinoza's. He is also determined to employ every possible device to attach an optimistic meaning to reality. He nevertheless gets no further than a laborious establishment of the conclusion that the actually existing world is the best of all possible ones.

Moreover, so much of optimism as he rescues is useless for his world-view because it contains no energies which can be directed to ethical action upon the world. When he is consistent with himself he remains, like Spinoza, a prisoner within nature-philosophy. All the difficulties for ethics which Spinoza's deterministic nature-philosophy contains within itself, are to be found also in his. Owing to the fact that he does not put the union of thought (spirit) and extension (matter) far away in the Absolute, but allows it to be realized in countless tiny individualities [pg 123] which in their totality constitute the universe—he calls them monads—his nature-philosophy corresponds to the multiform character of reality much better than Spinoza's does. He anticipates to a considerable extent the modern nature-philosophy which is based on the cell-theory of matter. Yet he, too, remains under the spell of the way the problem is put by Descartes. He does not allow the individualities in which thought and extension are united, to enter into living relations with each other, but limits their existence to being merely forces with powers of conception. Their being consists in being conscious of the universe, more clearly some, more confusedly others, but each independent of the rest.

In Spinoza there is a possibility of reaching an ethic, inasmuch as an attempt can be made to give an ethical interpretation to the mystical relation between man and the Absolute. Leibniz bars this path against himself in that he does not recognize such an abstract Absolute as the content of the universe. It is, therefore, not the result of chance that he nowhere philosophizes searchingly about ethics. In no way can an ethic be deduced from his nature-philosophy.

Instead of admitting to himself this result and unfolding the problem of the relation between ethics and nature-philosophy, he weaves into his philosophy traditional dicta about ethics, and defines the Good as love to God and man.

In nature-philosophy Leibniz is greater than Spinoza, because he deals with living reality more thoroughly than the latter does. In the struggle for a correct world-view, however, he is far behind him, because Spinoza, a man with a simpler mental endowment than his, recognizes the reconciliation of ethics and nature-philosophy as the central problem of world-view, and proceeds to deal with it.

If Leibniz had remained consistent, he would have ended in atheism, as does the Indian Samkhya philosophy, which similarly makes the world consist of a multiplicity of [pg 124] eternal individualities. Instead of that, he introduces into his nature-philosophy, in order to rescue for himself a satisfactory world-view, a theistic notion of God, and by giving it an optimistic, ethical, and theistic expression, he makes it acceptable to the eighteenth century. His philosophy, popularized till it is almost unrecognizable by Christian Wolff (1679-1754), helps to lay the foundations of German rationalism.

But in spite of the treason of which he is thus, though with the best intentions, guilty against nature-philosophy, Leibniz cannot undo the fact that thinking on nature-philosophy lines awoke at that time to activity through him. Without wishing it, he too contributes to making Spinoza an influence.

But to let oneself be mixed up with nature-philosophy is for the spirit of the time to step into the dangerous unknown. It therefore resists as long as possible. At last, however, since Kant and Spinoza together are undermining the optimistic-ethical world-view of rationalism which has been built upon the real world and so conveniently fitted up, it has to make up its mind to rebuild, and attempt the process of arriving at a conception of optimism and ethics by direct thinking on the essential nature of the world. For the

carrying out of this undertaking the German speculative philosophy offers its services.

[pg 125]

CHAPTER XI

J. G. FICHTE'S OPTIMISTIC-ETHICAL WORLD-VIEW

Speculative philosophy and Gnosticism

THE vision of an optimistic-ethical philosophy cast in one mould hovers in front of speculative philosophy, which hopes to discover the meaning of the world by the most direct route. It will have nothing to do with analysing the phenomena of the universe in order to deduce its nature from them. It proceeds deductively, not inductively. In pure abstract thinking it hopes to learn for itself how the real world has evolved out of the notion of Being. It is imaginative nature-philosophy in a logical dress.

The right to deal with the world in this fashion is derived by speculative thought from the results of the theory of knowledge, according to which the world as we observe it is more or less our own representation of it. We have, somehow or other, a creative share in its coming into existence. It follows that the logic which is the rule with the finite ego is to be conceived as an emanation of that which holds good with the Absolute. The individual is therefore entitled to disclose in his own thinking the motives and the process of the emanation of the empirical world out of the notion of Being. Speculation, or in other words constructive logic, is the key to the secret door into knowledge of the world.

Generically, speculative German philosophy is essentially related to the Græco-Oriental Gnosticism, which in the first centuries of the Christian era advances its views concerning the emergence of the sensible world from the world of pure Being._(_43_)_ The Gnostic systems aim at establishing a world-view [pg 126] of redemption. They concentrate on the question how the spiritual individualities which find themselves in the material world came there, and how they can return from it into the world of pure Being. Speculative German philosophy on the other hand tries to obtain such a knowledge of the world as shall give a meaning to the activities of the spiritual individualities in the world. Speculative thinking at the beginning of the Christian era is dualistic and pessimistic; that at the beginning of the nineteenth is monistic and optimistic. In both cases, however, the method of obtaining the world-view is the same.

Among the representatives of the speculative philosophy the most eminent are: Johann Gottlieb Fichte (1762-1814), Friedrich Wilhelm Joseph Schelling (1775-1854), and Georg Wilhelm Friedrich Hegel (1770-1831). It is only Fichte and Hegel, however, who produce world-views with a characteristic stamp of their own. Schelling gets no further than a nature-philosophy, and stands almost completely aside from the struggle for an optimistic-ethical world-view with which his age is occupied. Kept in a perpetual state of flux, his thinking makes use of all possible starting-points one after another and is now more concerned with natural science, now more akin to Spinoza's thought, and now to Christian. He never makes a definite, conscious attempt to found an ethic.

Fichte's speculative founding of an ethic and of optimism

Fichte begins as the antipodes of Spinoza._(_44_)_ He aims at extracting from the universe a confession that it is a purely [pg 127] optimistic ethical one, by thinking Kant's thoughts out to a conclusion.

Kant, according to him, made the mistake of not bringing his two discoveries, viz. epistemological idealism and the ethic of the categorical imperative into that inward connexion with one another in which they really stand.

What is the meaning of the fact that the moral law and the sensible world both become actual in me? That is the starting-point of Fichte's philosophizing.

Through the categorical imperative I experience that my particular ego is a self-determined will to activity. Correspondingly, every "thing in itself" which I assume to exist behind phenomena as the real on which they are based, is similarly a self-determined will to activity. The essential nature of infinite Being also can consist of nothing else. The universe is, therefore, the phenomenal form of an infinite, self-determined will to activity.

Why does the absolute Ego appear as a phenomenon in a sensible world? Why is Being revealed as Becoming? If I understand this, I have comprehended the meaning of the world and of my own life.

Now the absolute Ego, because it is infinite will to activity cannot persist in being merely an Ego. It establishes a non-Ego to be a limit to itself in order that it may again and again overcome it, and thereby become conscious of itself as will to activity. This proceeding takes place amid the multiplicity of finite rational beings. In their power of intuition the sensible world becomes actual, and in their overcoming of it they recognize a duty which makes itself mysteriously felt within them and unites them with the world-spirit. This is the meaning of the philosophy of the identity of Ego and non-Ego.

It is not only, then, that the world exists merely in my mental creation of it: it is, further, only produced in me in order that I may have something on which my will to fulfilment of duty can exercise itself. The phenomena of becoming and disappearing which I project out of myself [pg 128] exist only that I may through them comprehend myself as an ethical being. In this way epistemological idealism and the categorical imperative, when they act together and one climbs on the shoulders of the other, can look behind the curtain which hides the secret of the world.

Kant protests against the idea that Fichte's system is to be considered the completion of his philosophy. As a matter of fact, however, Fichte does with ingenious art continue the lines which were begun in the _Critique of Pure Reason_ and the _Critique of the Practical Reason_, and think out the ideas of the philosopher of Königsberg to a self-contained world- and life-affirming ethical world-view. He presents them in a generally intelligible form in _The Destiny of Man_, published in 1800. This book is one of the most powerful documents produced by the struggle for an ethical world-view.

Fichte gives a content to the abstract, absolute duty of Kant, making it consist in this, that man, as the instrument of the ever-active absolute Ego, assigns to himself the destiny of working with the latter "to bring the whole sensible world under the sovereignty of reason."

Since his fundamental moral principle possesses a content, Fichte is able to deduce particular demands from it, but that content is so general and vague that the code of duty which is drawn out from it has but little vital force. Nothing can really be got out of this fundamental principle beyond the demand that man shall in every situation of life fulfil the duties which from time to time fall to him as a result of his destiny of having to help forward the sovereignty of reason over nature. Fichte therefore distinguishes the general duties which man, as such, has to fulfil, and the special ones which are incumbent on him according to his natural gifts, his social position, and his profession. The latter are emphasized as specially important.

By defining ethics as activity which aims at subjecting the sensible world to reason, Fichte gives a cosmic formulation to the utilitarian ethic of rationalism, and thus [pg 129] produces a comprehensive and deep foundation for the ethical enthusiasm which was a discovery of his time. In this matter also he carries through something which hovered before the mind of Kant.

Thereby he opposes the representatives of the popular philosophy of the Illumination, and in a polemical pamphlet he criticizes very severely Christoph Friedrich Nicolai. At bottom, however, the only reproach he can level at them is that they wish to go on housing ethics and belief in progress in the naïve world-view arrived at by the healthy human reason instead of accepting both of them from the world-view produced by the union of epistemological idealism and the categorical imperative. To persist in imperfect rationalism when the perfect has been made a reality by Kant and himself is, in his opinion, a crime against truth. To him the beginning of wisdom is insight into the paradox that "consciousness of the world of actuality springs from our need of action and not, _vice versâ_, our need of action from our consciousness of the world."

The spirit of Fichte's world-view, then, is completely that of rationalism, only that it believes it has found itself at home with him in the real nature of Being, and now comes forward with still stronger conviction and a still more burning enthusiasm. In Fichte's writings, men are positively driven with the lash to work for the improvement of the world. With impressive pathos he teaches them to obey the inner voice which urges them on to activity, and indicates to them their definite duty whatever may be the special circumstances of their existence, and to recognize in so doing that they are thus fulfilling the highest, and indeed the only destiny of their lives.

It is as the result of this inner urge to activity that we long for a better world than the one which we see around us, and belief in that better world is the food by which we live. Fichte makes confession of unbounded optimism. "All those outbreaks of untamed force before which human power is annihilated, those devastating hurricanes, [pg 130] those earthquakes, those volcanic eruptions, can be nothing else than the last wrestlings of the wild mass of nature against the uniformly progressive, purposive, and life-promoting course to which, in opposition to its own tendencies, it is being compelled." . . . "Nature is to become to us more and more transparent and capable of examination even to its innermost secret, and enlightened human power, armed with its own inventions, is destined to master it without trouble, and then to exploit peacefully its once for all made conquest."_(_45_)_ Here Fichte gives us

the triumphant pagan of the belief in progress which the spirit of the modern age, that lives on the achievements of its knowledge and power, has been composing since the Renaissance. He is as thoroughly convinced as the staunchest rationalist that nature is the buffalo which has remained refractory so long, but will at last be brought beneath the yoke.

That mankind will perfect itself and reach a condition of unbroken peace, is to him as certain as the perfection that nature will one day arrive at. At present, it is true, we are in a period of arrested progress with temporary setbacks, but when this is past, and all useful things which have been discovered at one end of the world, get known to and distributed to all, then mankind, using its powers in complete co-operation and marching forward in step, will raise itself uninterruptedly, without arrest of progress or setback, to a culture of which we can form no conception.

To the State Fichte assigns in his early writings a not very important _rôle_, but in his later ones a great one. In _The Foundations of the Law of Nature_ (_Grundlage des Naturrechts_) (1796), it is for him only the maintainer of law and order. In his work _The Complete Commercial State_ (_Der geschlossene Handelsstaat_), which appeared in 1800, he allows it to organize industry and to take over social duties. In his _Addresses to the German Nation_ (_Reden an die deutsche Nation_, 1808), he makes it a moral educator and a protector of the virtue of humanity.

[pg 131]

The man who, with the help of epistemological idealism, has made his way through to the higher rationalism, is safe from losing his optimism, even though he goes through the cruellest experiences. He has grasped the fact that the sensible world is only the limit which the infinitely active will has created on purpose to be overcome. This lends him inward independence in the face of all happenings. He has no need to understand them individually. He can let a large proportion of them be put aside as puzzling to his finite spirit. What is essential he knows: viz. that what is real in the world is not matter, but spirit only.

Partaking of the eternally active spirit, man is raised above the world, and is eternal. The sufferings he meets with afflict nature only "with which he is connected in a marvellous way," but not himself, the being who is exalted above the whole of nature. Of death he has no fear. He does not die to himself, but merely to those who survive him. . . . "All death in nature is birth. . . . Nature is throughout nothing but life. It is not death which kills, but the living life which, concealed behind the old one, now begins and proceeds to develop. Death and birth are nothing but the struggle of life with itself in an effort to reveal itself more and more clearly and more and more like its real self." It is in similar words that the Chinese monist, Chwang-tse, announces that life is eternal and the dying of an individual only means that one existence is being re-cast to form another. .

Fichte's mysticism of activity incapable of being carried through

Fichte's philosophy of absolute activity is the expression of his own strong ethical personality, which with impetuosity and self-sacrifice takes problems in hand, and uses itself up in the strain involved. But even he is unable to make a genuine combination of epistemological idealism and ethical so as to produce an ethical world-view which is a [pg 132] necessity of thought. The impossibility of the undertaking reveals itself everywhere.

In order to conceive ethics as a part of the normal course of world-happenings, Fichte, like all others who make the same attempt, gives up as hopeless any differentiation between human action and world-happenings. The world-spirit's impulse to activity, he says, experiences itself in man as will to ethical action. But, indeed, the whole world is filled with this will to activity which is for ever surging against the limitations it has set up for itself. Everything that happens is only an expression of it. What difference, then, is there between natural happenings and ethical? Between activity in itself and ethical activity? Purposive activity directed with knowledge and intention to the subjection of the sensible world to reason is ethical, decides Fichte. But what does that mean, when closely examined? It means that the finite spirit becomes moral by entering into and taking seriously the play of the infinite spirit which aims at overcoming its own self-created limitations. Looking in this way at Fichte's thought, we see clearly that with the world-view which results from the combination of ethical and epistemological idealism, ethics have no longer any meaning.

Again, what is the meaning of "bringing the whole of the sensible world under the sovereignty of reason"? This conception of the ethical is not only too wide, but fantastic also. To a limited extent man is able to harness the forces of nature for his service, and with a little stretching of language he can, with Fichte, describe such action as not purposive merely, but also in the widest sense ethical. Upon this terrestrial globe he has some "influence," but upon the world none. That he gives names to the mighty heavenly bodies and can calculate the orbits of many of them, cannot mean that he brings them under the sovereignty of reason. Upon deep-sea life, too, he exercises no other influence than catching specimens of it and giving them names.

That he may be able to assert that there is such a thing [pg 133] as an ethical purpose in the world, Fichte falsifies the world's birth certificate, and gives it the categorical imperative for father and epistemological idealism for mother. But this is of no use. The ethical purpose thus produced cannot satisfy ethical thought.

By conceiving the infinite spirit, in which the finite spirit has a share, as will to activity, Fichte tries to make possible a world-view of ethical world- and life-affirmation. In reality, however, this takes him no further than a more emphatic world- and life-affirmation, into which, with the help of speculative thought, he smuggles the idea of duty, thereupon proclaiming it to be ethical. It fares with him just as with the Chinese philosophers, who similarly exert themselves in vain to produce an ethic out of world- and life-affirmation.

Absorption in the Absolute by means of action is, as Fichte thinks, something prodigious, but, just like its counterpart, absorption in the Absolute which is effected by an act of thought, it is not ethical but supra-ethical. The element which is needed by the mysticism of absorption in the Absolute to make it ethical cannot be secured either by enhancing or by depreciating the will to activity.

Fichte's mysticism of activity in which man lets loose his energy in the world is related to the ethic of deed, just as Spinoza's mysticism of knowledge in which man is absorbed in the world is related to that of self-perfecting, but it is only very incompletely that either can develop itself into a real ethic.

The absorption in the Absolute which comes into actuality in an act of thought lies nearer to nature-philosophy than that which completes itself in an active deed. The Brahmans, the Buddha, Lao-tse, Chwang-tse, Spinoza, and the mystics of every age, have experienced the becoming one with the Absolute as a coming-to-rest in it. Fichte's mysticism of activity lies more in the path of dualistic thinking than in that of real nature-philosophy. It is something which has been extorted by enthusiasm, but Fichte [pg 134] is devoted to it, and rightly, because he has a feeling that the interests of an active ethic are better guarded by it than by the other. Since, however, he thus once and for all decides for a nature-philosophy, he comes, dominated though he is by the ideal of an active ethic, more and more to the natural quietist consequences of a nature-philosophy. He goes through a process of evolution which brings him nearer to Spinoza's world-view. In his _Instruction Concerning the Blessed Life_, which appeared in 1806, six years later than _The Destiny of Man_, it is to him no longer the ethical which in itself is the highest, but the religious. The ultimate meaning of life, as he now recognizes, is not to act in God, but to be merged in Him. "Self-annihilation is the gateway into the higher life."

He believes, indeed, that he is thereby merely deepening his world-view without diminishing its ethical energy, and he remains himself, right to the end, the fiery spirit which consumes itself in activity for promoting the progress of the world. But his thought has bent under the weight of nature-philosophy. Without clearly admitting it to himself, he recognizes that out of nature-philosophy there can be drawn only an intellectual, not an ethical meaning for the world and life. Spinoza observes with a smile how he retires upon the thought beyond which a nature philosophy cannot advance.

Fichte is the first philosopher to declare plainly that no world-view is ethical which does not enable man to explain that an enthusiastic active devotion to the universe is something grounded in the nature of the world and of life. But the road he takes in order to develop this thought leads him astray. Instead of going more deeply into the question how ethical happenings, though coming from the world-spirit, and directed upon the world, are nevertheless different from normal world-happenings, and investigating the nature of this difference, he employs the trick, which had been made possible by Kant, of declaring, with the help of epistemological idealism, that the ethical world-view is a necessity of thought. Many of his contemporaries [pg 135] believe with him that it has thereby really reached a position of supremacy, and even those who cannot go with him the whole length of the philosophy of the Ego and Non-Ego, are gripped by the force of the ethical personality which speaks from Fichte's writings.

The direct effect, then, of Fichte's philosophy is that the optimistic, ethical spirit of rationalism maintains its position and becomes stronger and deeper. His philosophy is a source of inspiration which produces a mighty impulse to ethics and civilization. But the vessel in which, with a magnificent wind behind him, he starts with his companions on a voyage over the sea of knowledge is a leaky one. A catastrophe is only a question of time.

Fichte's belief that he has obtained from the nature of the universe the living compulsion to ethical duty and ethical work which he feels within himself, is an illusion. The manner, however, in which he conceives the problem of the optimistic-ethical world-view, and perceives that for its solution the ordinary processes of life afford no help, so that more or less violent ones must be allowed to take their turn, reveals him as a great thinker.

[pg 136]

CHAPTER XII

SCHILLER; GOETHE; SCHLEIERMACHER

Schiller's ethical world-view; Goethe's world-view based on nature-philosophy

VERY important is the fact that the deepened optimistic-ethical world-view of Kant and Fichte finds a champion in Friedrich von Schiller (1759-1805), who brings it to the mass of the people with the force, added by poetical language. He is himself philosophically gifted, and undertakes in addition to develop it further. He wishes to broaden the foundation of the ethical by showing its relation to the æsthetic.

In his _Letters Concerning the Æsthetic Education of Mankind_ (1795), he works out the idea that art and ethics belong together as far as this, that man maintains with the sensible world a relation which is free and creative. "The transition from the passive condition of feeling to the active one of thinking and willing comes about in no other way than through an intermediate condition of æsthetic freedom. . . . There is no way of making the sentient man rational other than first making him æsthetic." In what way the capacity for freedom which is built up in man by æsthetic practice really disposes him to morality, Schiller does not work out in further detail. His treatise, in spite of all the notice it attracted and deserves, is more rhetorical than substantial. He has not gone to the bottom of the problem of the relations between the æsthetic and the ethical.

In contrast to Schiller, Johann Wolfgang von Goethe (1749-1832), stands in almost as cold an attitude to the world-view of the deepened rationalism as he does to that of ordinary rationalism. To him it is impossible to share [pg 137] the confidence with which others, looking around, regard optimistic and ethical convictions as well founded. What separates him from Kant, and Fichte, and Schiller, is reverence for the reality of nature. Nature is to him something in herself, not merely something existing with a view to mankind. He does not require from her that she shall fit herself completely into our optimistic-ethical designs. He does no violence to her either through epistemological and ethical idealism or through presumptuous speculation, but lives in her as a human being who looks at existence with wonder and does not know how to bring her relation to the world-spirit within any formula.

Descartes led modern philosophy astray by cutting the world up into objects which have extension and objects which think, and by going on, moreover, to refuse to each of them the possibility of influencing the other. Following in his steps, thinkers rack their brains over the problem of these two parallel kinds of existence, and try to embrace the world in formulas. That the world is life, and that in life lies the riddle of riddles, never enters their minds. Hence they overlook in their philosophizing what is most important. Because Descartes preceded them, the two great spirits who adhere to nature-philosophy, Spinoza and Leibniz, cannot get further than a nature-philosophy which is more or less dead. Being in the line of descent from Descartes, Kant and Fichte renounce all philosophizing over the real world.

Descartes and the ethical belief-in-progress, therefore, agree in a common neglect of nature. Both alike overlook the fact that she is living, and that she exists for her own sake, and it is because he cannot join them in this that Goethe dares to confess that he understands nothing about philosophy. His greatness is this: that in a time of abstract and speculative thought he had the courage to remain elemental.

Overwhelmed by the mysterious individual life in nature, he persists in maintaining a magnificently imperfect [pg 138] world-view. With the spirit of an investigator he looks within into everything; in that of an inquirer he looks around upon everything. He wants to think optimistically. Shaftesbury's thoughts exercise their charm upon him also. But in the chorus of optimism which makes itself heard so loudly around him, he cannot join. World- and life-affirmation is for him not such a simple thing as it is for Fichte and Schiller. He strives to reach an ethical world-view, but admits to himself that he cannot carry it through, and he therefore does not venture to attribute a meaning to nature. To life, however, he will attribute one. He seeks it in serviceable activity. To make the world-view of activity at home in nature-philosophy is to him an inner necessity. The conviction that activity provides the only real satisfaction that is to be found in life and that therein lies the mysterious meaning of existence is shown by him in _Faust_ as something which he has laboriously gained during his pilgrimage through existence and to which he will hold fast, without being able to explain it completely.

Goethe struggles to arrive at a conception of ethical activity, but cannot reach one because nature-philosophy is unable to provide him with any criterion of what is ethical. What that philosophy had to refuse to the Chinese monists and to Spinoza, she cannot give to him either.

The range of this world-view of Goethe's which deals thus with reality remains hidden from his contemporaries. Its incompleteness alienates their sympathies and irritates them. For knowledge of the world and of life which cannot be reduced to a system, but sticks fast in facts, they have no understanding. They hold to their optimism and their ethic.

Schleiermacher's attempt at a nature-philosophy

Daniel Ernst Schleiermacher (1768-1834), stands apart both from the ordinary and from the deepened rationalism because he cannot free himself from the influence of [pg 139] Spinoza._(_46_)_ His life-work is directed to preaching the Spinozan nature-philosophy as being, as far as he can make it so, both an ethic and the Christian religion. Hence he always dresses it up as one or the other of these.

The accepted ethical code, in Schleiermacher's opinion, makes man merely run about the earth as an ethical individual bent on improving the world. Living in this way, in a constant state of enthusiasm, he becomes in danger of losing himself and becoming unpersonal. He forgets that his primary duty is, first of all to be alone with himself, to look within himself, and, instead of being a mere human creature, to make himself into a personality.

This renunciation of rationalism's enthusiasm for activity is to be found in the _Monologues_, those splendid introspective meditations meant for the first New Year's Day of the nineteenth century. One seems to hear in them Lao-tse and Chwang-tse criticising the moralism and the fanaticism for progress of Confucius.

Man's first task is, according to Schleiermacher, to realize his oneness with the Infinite and in the Infinite to see the world. Only that which results from this as action is really significant, and has importance for morality.

Spinoza's ethic consisted in keeping oneself at the highest level and living one's life more after the fashion of a life of thought than after that of a life of corporeal existence. Schleiermacher's ethic has the same objective except that he seeks to combine with it a more comprehensive interest in the world than is to be found in Spinoza. He is helped in this direction by his belief that progress is something immanent.

We have, he says, no other perfecting to bring about in things than that which is inherent in them. Ethics, therefore, are not a setting up of laws, but the recognition and the description of the tendencies working for perfection which appear in the world itself, together with behaviour [pg 140] in accord with their spirits. The moral law is not distinct from the law of nature and pursues no other aims than the latter does. It is only the law of nature arriving in man at the consciousness of itself.

Schleiermacher, therefore, feels that his task is not, as Fichte conceived his to be, the bringing of the universe under the sovereignty of reason; it consists solely in supporting the oneness of nature and reason in the sphere of human action, which is ever striving to realize itself within that universe. "All ethical knowledge is the expression of the ever-beginning but never completed efforts of reason to become nature." Ethics are a contemplative "science." They revolve around the two poles of natural science and human history.

The ethic which results from this fundamental conception is, like those of Lao-tse and Chwang-tse, so toned down that there is no longer any real power in it. However completely Schleiermacher may try to conceal this fact by his wonderful powers of description, it plays only a subordinate _rôle_. What gives a meaning to human existence is something which is independent of deeds; it is the oneness with the Infinite which is experienced in feeling.

With its clever dialectic, but not in reality, Schleiermacher's ethic shows itself finally to be superior to that of Spinoza. His world-view is that of Spinoza, only enriched by his belief in the immanence of the power of progress. Hence his ethic is iridescent with somewhat more brilliant colours.

Thus do a living nature-philosophy in Goethe and a Spinozan one in Schleiermacher undermine the ground on which stand the men of the now beginning nineteenth century, whose thinking is so enthusiastically optimistic-ethical. The crowd pays no attention to their dangerous proceedings. It gazes at the fireworks which Kant and Fichte let off, while Schiller recites his poetry. And now there begin to rise bursts of rockets which throw a peculiarly brilliant light. The past-master in the art of firework display, Hegel, has come into action!

[pg 141]

CHAPTER XIII

HEGEL'S SUPRA-ETHICAL OPTIMISTIC WORLD-VIEW

Ethics in Hegel's nature-philosophy, and in his philosophy of history

IN his speculative philosophy Fichte's first and chief interest was ethical. Hegel, deeper and more objective than he, aims at truth before everything._(_47_)_ While using any helpful considerations which are provided by facts, his aim is to discover the meaning of Being. He therefore cannot join Fichte in the violent procedure, suggested by his ethic, of giving the world the categorical imperative for father and epistemological idealism for mother. Before going so far as to write out a birth-certificate for the world, he undertakes some material investigations. He studies the laws which govern events, as they are revealed in history. He then lays these as the foundation for the constructive operations which are to explain the origin of the world out of the notion of Being. His philosophy, therefore, is a philosophy of history become cosmic. The building, so far as one can measure it externally, is solidly constructed. That is why it is still convincing even where its lines lose themselves in infinity.

What, then, does Hegel discover to be the principle underlying the course of events in history? He discovers that every process of becoming advances with natural progress, and that this progress realizes itself in the occurrence of a consecutive series of contradictions which invariably issue in reconciliation! In thoughts as in facts, [pg 142] every thesis evokes an antithesis. Then these unite in a synthesis which preserves what is valuable in either of them. Every synthesis that is reached becomes again a thesis for a new antithesis. From these there results again a new synthesis, and so on for ever.

With the aid of this scheme Hegel can expound the course of history. From it he is also able to develop the basic principles of logic. Hence he is sure that from it it must be possible to make intelligible how the notional world which can be logically developed out of the notion of Being passes over into being the world of reality. He carries this fancy through to its conclusion in such magnificent fashion, that even we, who are proof against its charm, can understand how it was possible to become intoxicated with it. The Project Gutenberg eBook of The decay and the restoration of civilization

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To MY DAUGHTER KATE RUSSELL

PREFACE

Hypatia was a University lecturer denounced by Church dignitaries and torn to pieces by Christians. Such will probably be the fate of this book: therefore it bears her name. What I have written here I believe, and shall not retract or change for similar episcopal denunciations.

DORA RUSSELL.

January, 1925.

TABLE OF CONTENTS

I JASON AND MEDEA _Is there a Sex War?_ 1

II ARTEMIS _The Early Struggles of Feminism_ 13

III ASPASIA _The Younger Feminists_ 26

IV HECUBA _Feminist Mothers_ 40

V JASON AND ADMETUS _Men_ 71

HYPATIA

I

JASON AND MEDEA _Is there a Sex War?_

A feature of modern life is that matrimonial quarrels, like modern war, are carried on on a large scale, involving not individuals, nor even small groups of individuals, but both sexes and whole classes of society. In the past, Jason and Medea, neither of them quite an exemplary character, measured their strength against one another as individuals; and, though each voiced the wrongs and the naked brutality of their sex, it did not occur to either to seek in politics or in social reform a solution or a compromise. Jason, indeed, as the reactionary face to face with a turbulent and insurgent female, called to his aid the powers of kingship and the State■■to suppress and exile, but not to remedy. Medea, driven mad■■like so many able and remarkable women■■by the contempt and ingratitude of men as individuals or in the mass, and aware that the law was a mockery where she was concerned, expressed herself in savage protest after the manner of a militant suffragette. While I can open my newspaper to-day and read of mothers desperate with hunger, misery, or rage drowning themselves and their children, I cannot bring myself to look upon Medea as some elemental being from a dark and outrageous past. As for Jason, he never did appear to anybody as other than an ordinary male.

During the last twenty or twenty-five years, when women were struggling for their right as citizens to a vote and to a decent education, began what has been called the sex war. No woman would deny that we began it, in the sense that we were rebels against a system of masculine repression which had lasted almost unbroken since the beginning of history. In a similar sense, the proletarian to-day begins the class war. Those who remember the heroic battles of suffrage days know that the sequence of events was as follows: We made our just demands and were met with ridicule. We followed with abuse■■all the pent-up anger, misery, and despair of centuries of thwarted instinct and intelligence. Man retaliated with rotten eggs. We replied with smashed windows; he with prison and torture. People forget so readily, that it is well to remember that this was in the immediate past; it is not a nightmare picture of one of those future sex wars with which our modern Jasons delight to terrify the timorous of both sexes.

Is there a sex war? There has been. It was a disgraceful exhibition, and would not have come to a truce so soon, but that it was eclipsed by the still more disgraceful exhibition of the European War. In 1918 they bestowed the vote, just as they dropped about a few Dames and M.B.E.'s, as a reward for our services in helping the destruction of our offspring. Had we done it after the fashion of Medea, the logical male would have been angry. They gave the vote to the older women, who were deemed less rebellious. Such is the discipline of patriotism and marriage, as it is understood by most women, that the mother will sacrifice her son with a more resigned devotion than the younger woman brings to the loss of her lover. There may be more in this than discipline. If honesty of thought, speech, and action were made possible for women, it might transpire that on the average a woman's love for her mate is more compelling than love for her offspring. Maternal instinct■■genuine, not simulated■■is rarer, but, when found, more enduring.

There was a promise, as yet unredeemed by any political party■■for the politician has yet to be found who will realize that the sex problem is as fundamental in politics as the class war, and more fundamental than foreign trade and imperial expansion■■to extend this franchise on equal terms with men. "Good fellowship" between the sexes as between classes was the key-note of the war. It was held that women had proved their mettle and that mutual aid was to be the basis of all future activities, public and private. The sex question was deemed settled, and everyone was led to suppose that all inequalities would be gradually eliminated. On this partial victory and this promise feminists called a truce, and abandoned the tactics of militarism.

But you never know where you have Jason. He was a soldier, mark you, and a gentleman. Forbidden open warfare, he takes to sniping. He snipes the married women out of those posts for which they are peculiarly fitted■■as teachers or maternity doctors■■although it is against the law to bar women from any public activity on the ground of marriage. He cheats unemployed women out of their unemployment insurance more craftily and brutally than he cheats his fellow-men. Instead of realizing that the competition of women in industry and the professions is a competition of population pressure rather than of sex, he seeks by every means in his power to drive woman back to matrimonial dependence and an existence on less than half a miserably inadequate income; and then he mocks at her when she claims the right to stem the inevitable torrent of children whose advent will but aggravate man's difficulties as well as her own. But worse than all the sniping is the smoke-screen of propaganda. While feminists have, in a large measure, stayed their hand, anybody who has anything abusive to say of women, whether ancient or modern, can command a vast public in the popular press and a ready agreement from the average publisher.

It is a very insidious propaganda. Thus the fashion-papers tell us that grandmamma's ways are coming back into their own; elsewhere we are flattered for the frank honesty of the modern girl and then warned not to ask for equal pay or opportunity.[1] Again, we hear that woman, like the Labour Party when in office, has done nothing with the opportunities given her by the vote; or that the country rejectedThe Project Gutenberg eBook of An essay in defence of the female sex

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A BLACK ADONIS.

by

ALBERT ROSS.

Author of "Out of Wedlock," "Speaking of Ellen," "Thou Shalt Not," "Why I'm Single," "Love at Seventy," Etc., Etc.

"You see!" he answered, bitterly. "Because I am black I cannot touch the hand of a woman that is white. And yet you say the Almighty made of one blood all nations of the earth!"--Page 212.

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CONTENTS.

Chapter Page

I. A Rejected Manuscript 9

II. "Was my story too bold?" 23

III. "Her feet were pink" 35

IV. With Titian Tresses 49

V. Studying Miss Millicent 65

VI. "How the women stare!" 79

VII. A Dinner at Midlands 93

VIII. Holding Her Hand 99

IX. "Daisy, my darling!" 110

X. "Oh, so many, many maids!" 121

XI. Archie Pays Attention 136

XII. Dining at Isaac's 143

XIII. A Question of Color 155

XIV. "Let us have a betrayal" 166

XV. The Green-Eyed Monster 177

XVI. "I've had such luck!" 190

XVII. A Burglar in the House 198

XVIII. Black and White 204

XIX. "Play out your farce" 215

XX. Like a Stuck Pig 226

XXI. "We want Millie to understand" 238

XXII. Where Was Daisy? 246

XXIII. An Awful Night 254

XXIV. "This ends it, then?" 263

XXV. An Undiscoverable Secret 273

XXVI. "I played, and I lost" 282

XXVII. Absolutely Blameless 292

XXVIII. Trapping a Wolf 301

XXIX. "The Greatest Novel" 309

TO MY READERS.

I do not know how better to use the space that the printer always leaves me in this part of the book than to redeem the promise I made at the end of my last novel, and tell you in a few words what became of Blanche Brixton Fantelli and her husband.

But, do you really need to be told?

Could they have done anything else than live in connubial felicity, after the man had proved himself so noble and the woman had learned to appreciate him at his true worth?

Well, whether they could or not, they didn't. Blanche is the happiest of wedded wives. She still holds to her theory that marriage is based on wrong principles, and that the contract as ordinarily made is frightfully immoral; but she says if all men were like "her Jules" there would be no trouble.

In this she proves herself essentially feminine. She is learning, albeit a little late, that man was not made to live alone, and that the love a mother feels for her child is not the only one that brings joy to a woman's breast.

Fantelli does not claim that Blanche is his property. He is her lover still, even though he has gained the law's permission to be her master. He recognizes that she has rights in herself that are inviolable. This is why they live together so contentedly. She would not be his mate on any other terms.

If it is not the ideal existence, it is very near it. As near as a man and woman who care for the world's opinion can live it in these days.

And now, with heartfelt thanks for the continued favor of the reading public, which I am conscious is far beyond my desert, I bid a temporary farewell to American shores. By the time this book is on the shelves of the dealers I shall be on European soil, there to remain, I trust, for the better part of a year. Wherever I am, my thoughts will always turn to you who have made these journeys possible, and there as here my pen will continue devoted to your service.

ALBERT ROSS.

Cambridge, Mass., _June 1, 1895._

A BLACK ADONIS.

CHAPTER I.

A REJECTED MANUSCRIPT.

"A letter for Mr. Roseleaf," he heard his landlady say to the chambermaid. And he was quite prepared to hear the girl reply, in a tone of surprise:

"For Mr. Roseleaf! This is the first letter he has had since he came."

The young man referred to stood just within his chamber door, waiting with some anxiety for the letter to be brought to him. He was about twenty years of age, of medium height, with rather dark complexion, curling hair and expressive eyes, and with a natural delicacy of manner that made him seem almost feminine at first view.

He had the greatest possible interest in the letter that the postman had just brought, but he was far too polite to disturb the landlady or her servant, who were not yet through with it.

"You can see that it is from a publishing house," commented Mrs. Ranning, inspecting the envelope with care. "It is from Cutt & Slashem, who bring out more novels than any other firm in the city. I told you he was some kind of a writer. Perhaps they are going to publish a book for him! If they do he will leave us for finer quarters. Novelists make a mint of money, I have heard. We must do our best to keep him as long as we can. Be very polite to him, Nellie. He appears to be an excellent young man."

Shirley Roseleaf's anxiety to get possession of his letter was not lessened by this conversation. It seemed as if his entire future hung on the contents of that envelope tarrying so long in Nellie's hands. The great publishers, Cutt & Slashem, had had a manuscript of his in their hands for nearly a fortnight. When they had definitely accepted it, his path would be perfectly clear. If they rejected it--but he had not got so far as that.

The manuscript was a romance--a romance of love! Its author had spent a great deal of time upon it. He had rewritten it with care, and finally made a neat copy, of which he was very proud. Then he had thought a long time over the question of a publishing firm. Cutt & Slashem stood at the top of their profession, and they finally received the preference. With the MSS. Roseleaf sent a pretty note, in which he included a delicate compliment on their success. The MSS. and the note were arranged tastefully in a neat white package and tied with pink twine.

After all of those precautions it is no wonder that the novelist felt surprise when days passed and no reply was sent to him. But never at any time was he discouraged. Had they intended to reject the novel, he reasoned, they could as easily have done so in three days as ten.

He pictured the members of the firm hugging themselves over their good fortune, passing the manuscript from one to the other, all eager for a taste of such a marvelous work. He did not think it egotism to believe they did not get stories like that every day.

His thoughts flew rapidly as Nellie slowly climbed the stairs. Now he would be famous, he would be courted, he would be envied! He would also be very, very rich, though that was not of so much account.

As Nellie handed him the letter he responded to her pleasant smile with one of his own, and even pressed a twenty-five cent piece into her hand. Then he closed his door behind him, bolting it in his eagerness to be alone. The morning was foggy, and he sank into a chair by the window, the only part of the room where he could see to read distinctly.

There was an attraction about the envelope. It was light buff in color, bearing the address of Cutt & Slashem in large letter on one side of the front face, besides the names of several of the most famous authors whose publishers the firm had the happiness to be.

"Shirley Roseleaf!" It would not look so badly in print.

So lost was he in the pleasant pictures which these thoughts conjured up that it was some minutes before he tore open the envelope. Then his astounded eyes rested upon these lines:

"Messrs. Cutt & Slashem regret to be obliged to decline with thanks the MSS. of M. Shirley Roseleaf, and request to be informed what disposition he desires made of the same."

Roseleaf read this dizzily. For some moments he could not understand what that sentence meant. "Obliged to decline" was plain enough; but his confused mind found some grains of comfort in the request of the firm to know what he wished done with his manuscript. They must, he reasoned, consider it of value, or they would not respond in that courteous manner. Still, he could not comprehend how they had had the asininity to "decline" it at all.

Were they unwilling to add another star to their galaxy?

Could they actually have read the tale?

A firm of their reputation, too!

When Roseleaf emerged from his temporary stupor it was into a state of great indignation. Why, the men were fools! He wished heartily he had never gone to them. They would yet see the day when, with tears in their eyes, they would regret their lack of judgment. His first act should be to go to their office and express his opinion of their stupidity, and then he would take his MSS. to some rival house. And never, never in the world--after he had become famous, and when every publisher on both sides of the Atlantic were besieging him--never, he said, should these ignorant fellows get a scrap of his writing, not even if they offered its weight in gold!

He was too excited for delay, and donning his hat, he took his way with all speed to Cutt & Slashem's office. At that instant he had more faith in his novel than ever. As he walked rapidly along he compared it with some of the stories issued by the firm that had rejected it, to the great disadvantage of the latter.

"I wish to see Mr. Cutt or Mr. Slashem," he said, imperiously, as he entered the counting room.

"Both are in," said the office boy, imperturbably. "Which will you have?"

"I will see them together."

Had they been tigers, fresh from an Indian jungle, it would have made no difference to him.

The boy asked for his card, vanished with it, returned and bade him follow. Up a flight of stairs they went, then to the left, then to the right, then across a little hall. A door with the name of the house and the additional word "Private" loomed before them.

"Come in!" was heard in response to the knock of the office boy.

Roseleaf entered, something slower than a cannon ball, and yet considerably faster than a snail. The two principal members of the firm were sitting together, with lighted cigars in their mouths, examining a lot of paper samples that lay upon a table. They did no more at first than glance up and nod, not having finished the business upon which they were engaged.

"Is it any better than the last?" asked Mr. Slashem, referring to the sample his partner was examining.

"It's just as good, at least," was the answer. "And an eighth of a cent a pound less. I think we had better order five hundred reams."

"Five hundred reams," repeated the other, slowly, making a memorandum in a little book that he carried. "And the other lot we'll wait about, eh? Paper is not very steady. It's gone off a sixteenth since Thursday."

This conversation only served to infuriate still more the visitor who stood waiting to pour out his wrath. Were these men wasting time over fractions of a cent in the price of stock, just after they had rejected one of the greatest romances of modern times!

With the precision of a duplex machine both partners finally looked up from the table at the young man.

"Mr. Shirley Roseleaf?" said Mr. Slashem, interrogatively, glancing at the card that the office boy had brought.

"Yes, sir!" was the sharp and disdainful reply.

"We need nothing in your line," interrupted Mr. Cutt. "I suppose Mr. Trimm has our other order well under way?"

The look of indignant protest that appeared in Roseleaf's face caused Mr. Slashem to speak.

"This is not Mr. Roseberg," he explained. "My partner took you for an agent of our bookbinder," he added.

The novelist thought his skin would burst.

"I am quite complimented," he said, in an icy tone. "Let me introduce myself. I am the author of 'Evelyn's Faith.'"

The partners consulted each other.

"The similarity of names confused me," said Mr. Cutt. "Is your book one that we have published?"

Saints and angels!

"It is one that was sent to you _for_ publication," replied Roseleaf, with much heat, "and has been returned this morning--_rejected_!"

"Ah!" said Mr. Cutt.

"We have nothing to do with that department," said Mr. Slashem, coming to the rescue. "You should see Mr. Gouger, on the second floor above; though if he has rejected your story a visit would be quite useless. He never decides a matter without sufficient reason."

"Oh, dear, no!" added Mr. Cutt, feeling again of the paper samples.

Shirley Roseleaf listened with wild incredulity.

"Do you mean to tell me," he said, "that you, the members of the firm of Cutt & Slashem, have rejected my story without even reading it?"

The partners glanced at each other again.

"We never read books," said Mr. Cutt.

"Never," said Mr. Slashem, kindly. "We have things much more important to attend to. We pay Mr. Gouger a large salary. Why, my young friend, there are probably a dozen manuscripts received at our office every week. If we were to try to _read_ them, who do you think would attend to the _essential_ points of our business?"

Roseleaf's contempt for the concern was increasing at lightning speed. He did not care to mince his words, for it could make no difference now.

"I should imagine that the selection of the books you are to print would be at least as important as the paper you are to use," he retorted.

Mr. Cutt looked at him in great astonishment.

"You are much mistaken," said he.

"Entirely mistaken," confirmed Mr. Slashem.

The author had no desire to remain longer, as it was evident he was losing his temper to no purpose. If it was Mr. Gouger who had rejected his work, it was Mr. Gouger that he must see.

Bowing with ironical grace to the examiners of printing paper, he took leave of them, and mounted to the sanctum of the man who he had been told was the arbiter of his fate. A girl with soiled hands pointed out the room, for there was nothing to indicate it upon the dingy panel of the door; and presently Roseleaf stood in the presence of the individual he believed at that moment his worst enemy.

There were two men in the room. One of them indicated with a motion of his hand that the other was the one wanted, and with a second motion that the caller might be seated. Mr. Gouger was partly hidden behind a desk, engaged in turning over a heap of manuscript, and it appeared from the manner of his companion that he did not wish to be disturbed.

Somewhat cooled down by this state of affairs, the young novelist took the chair indicated and waited several minutes.

"What d--d nonsense they are sending me these days!" exclaimed Mr. Gouger at last, thrusting the sheets he had been scanning back into the wrapper in which they had come, without, however, raising his eyes from his desk. "Out of a hundred stories I read, not three are fit to build a fire with! This thing is written by a girl who ought to take a term in a grammar school. She has no more

idea of syntax than a lapdog. Her father writes that he is willing to pay a reasonable sum to have it brought out. Why, Cutt & Slashem couldn't afford to put their imprint on that rot for fifty thousand dollars!"

He had finished saying this before he learned that a third person was in the room. Upon making this discovery he lowered his voice, as if regretting having exhibited too great warmth before a stranger. The novelist rose and handed him a card, and as Mr. Gouger glanced at the name a gleam of recognition lit up his face.

"I am glad to see you, Mr. Roseleaf," he said. "I had half a notion to ask you to call, when I felt obliged to send you that note yesterday. There are several things I would like to say to you. Archie, perhaps you would let us have the room for a few minutes."

The last remark was addressed familiarly to the man who occupied the third chair, and who looked so disheartened at the prospect of having to rise therefrom that Roseleaf hastened to express a hope that he would not do so on his account.

"Very well," said Mr. Gouger, abruptly. "You heard what I said about this copy I have just read, though it was not my intention that you should. I supposed I was talking only to Mr. Weil, who is not in the profession and does not expect to be. Now, let me say at once, Mr. Roseleaf, that your contribution is not open to any of the objections I have cited. You have evidently been well educated. Your English is pure and forcible. It is a real delight to read your pages. Every line shows the greatest care in construction. I did with your story what I have not done with another for a long time--I read it through. Why then did I reject it?"

The question was too great for the one most interested to answer, but in the glow of pleasure that the compliment brought he forgot for the moment his bitter feelings.

"Possibly," he suggested, "Cutt & Slashem have more novels on hand than they feel like producing at present."

"No," responded Mr. Gouger, disposing of that theory in one breath. "A house like ours would never reject a really desirable manuscript. If you will reflect that only one or two of this description are produced each year you will the more readily understand me. Your story has a cardinal fault for which no excellence of style or finish can compensate. Shall I tell you what it is, and before this gentleman?"

He indicated Mr. Weil as he spoke. Roseleaf's heart sank. For the first time he felt a deadly fear.

"Tell me, by all means," he responded, faintly.

Mr. Gouger's face bore its gentlest expression at that moment. He was taking valuable time, time that belonged to his employers, to say something that must temporarily disappoint, though in the end it might benefit his hearer.

"Let me repeat," he said, "that your work is well written, and that I have read it with the greatest interest. Its fault--an insuperable one--is that it lacks fidelity to nature. Mr. Roseleaf, I think I could gauge your past life with tolerable accuracy merely from what that manuscript reveals."

The novelist shook his head. There was not a line of autobiography in those pages, and he told his critic so.

"Oh, I understand," replied Mr. Gouger. "But this I have learned: Your life has been marvelously colorless. Yet, in spite of that, you have undertaken to write of things of which you know nothing, and about which, I may add, you have made very poor guesses."

Mr. Weil, leaning back in his chair, began to show a decided interest. Mr. Roseleaf, sitting upright, in an attitude of strained attention, inquired what Mr. Gouger meant.

"Well, for instance, this," responded the critic: "You attempt to depict the sensations of love, though you have never had a passion. Can you expect to know how it feels to hold a beautiful girl in your arms, when you never had one there? You put words of temptation into the mouth of your villain which no real scamp would think of using, for their only effect would be to alarm your heroine. You talk of a planned seduction as if it were part of an oratorio. And you make your hero so superlatively pure and sweet that no woman formed of flesh and blood could endure him for an hour."

The color mounted to Roseleaf's face. He felt that this criticism was not without foundation. But presently he rallied, and asked if it were necessary for a man to experience every sensation before he dared write about them.

"Do you suppose," he asked, desperately, "that Jules Verne ever traveled sixty thousand leagues under the sea or made a journey to the moon?"

Mr. Weil could not help uttering a little laugh. Mr. Gouger struck his hands together and clinched them.

"No," said he. "But he could have written neither of those wonderful tales without a knowledge of the sciences of which they treat."

"He has read, and I have read," responded Roseleaf. "What is the difference?"

"He has studied, and you have not," retorted the critic. "That makes all the difference in the world. He has a correct idea of the structure of the moon and what should be found in the unexplored caverns of the ocean; while you, in total ignorance, have attempted to deal in a science to which these are the merest bagatelles! You know as little of the tides that control the heart of a girl as you do of the personal history of the inhabitants of Jupiter! Your powers of description are good; those of invention feeble. Either throw yourself into a love affair, till you have learned it root and branch, or never again try to depict one."

Mr. Archie Weil smiled and nodded, as if he entirely agreed with the speaker.

"What a novel _I_ could make, my dear fellow!" he exclaimed, "if I only had the talent. I have had experiences enough, but I could no more write them out than I could fly."

"It is quite as well," was the response, "your women would all be Messalinas and fiction has too many now."

"Not _all_ of them, Lawrence," was the quick and meaning reply.

"In that case," said Gouger, "I wish heartily you could write. The world is famishing for a real love story, based on modern lines, brought up to date. I tell you, there has been nothing satisfactory in that line since Goethe's day."

Mr. Weil suggested Balzac and Sand.

"Why don't you include George William Reynolds?" inquired Gouger, with a sneer. "Neither of them wrote until they were depraved by contract with humanity. If we could get a young man of true literary talent to see life and write of it as he went along, what might we not secure? But I have no more time to spare, Mr. Roseleaf. I was sorry to be obliged to reject your story. Some day, when you have seen just a little of the world, begin again on the lines I have outlined, and come here with the result."

Quite dispirited, now that the last plank had slipped from under him, the novelist walked slowly down the stairs. He did not even ask for his manuscript. After what he had heard, it did not seem worth carrying to his lodgings. His plans were shipwrecked. Instead of the fame and fortune he had hoped for, he felt the most bitter disappointment. All his bright dreams had vanished.

A step behind him quicker than his own, made him aware that some one was following him, and presently a voice called his name. It was Mr. Archie Weil, who had put himself to unusual exertion, and required some seconds to recover his breath before he could speak further.

"I want you to come over to my hotel and have a little talk with me," he said. "Gouger has interested me in you immensely. I believe, as he says, that you have the making of a distinguished author, and I want to arrange a plan by which you can carry out his scheme."

Mr. Roseleaf stared doubtfully at his companion.

"What scheme?" he said, briefly.

"Why, of imparting to you that knowledge of the world which will enable you to draw truthful portraits. You have the art, he says, the talent, the capacity--whatever you choose to call it. All you lack is experience. Given that, you would make a reputation second to none. What can be plainer than that you should acquire the thing you need without delay?"

"The 'thing I need'?" repeated Roseleaf, dolefully.

Mr. Weil laughed, delightfully.

"Yes!" he explained. "What you need is a friend able to interest you, to begin with. Pardon me if I say I may be described by that phrase. Come to my hotel a little while and let us talk it over."

It was not an opportunity to be refused, in Roseleaf's depressed condition, and the two men walked together to the Hoffman House, where Mr. Weil at that time made his home.

CHAPTER II.

"WAS MY STORY TOO BOLD?"

"Well, Millie, your letter has come," said Mr. Wilton Fern, as he entered the parlor of his pleasant residence, situated about twenty miles from the limits of New York City. "Open it as quick as you can, and learn your fate."

His daughter started nervously from her seat near the window, where she had been spending the previous hour in speculations regarding the very missive that was now placed in her hands. She was a handsome girl, neither blonde nor brunette, with eyes of hazel gray and hair of that color that moderns call Titian red. She took the envelope that her father gave her, and though she wanted intensely to know the contents she hesitated to open it.

"Read it, Millie," smiled Mr. Fern. "Let us learn whether we have an authoress in our house who is destined to become famous."

But this remark made Miss Millicent less willing than before to open the letter in her father's presence. She slowly left the room without answering and did not break the seal of her communication till she was in the seclusion of her chamber.

And it was quite a while, even then, before she summoned the necessary courage. Some days previous she had sent a MSS. to the great publishing house of Cutt & Slashem. The writing had taken up the best of her time for a year. She had high hopes that it was destined to lay the foundation of an artistic success. Her plot was novel, not to say startling. It was entirely out of the conventional order. It would be certain to arouse talk and provoke comment, if it got into print; and to make sure that it _would_ get into print she had persuaded her father to write a little note, which she enclosed with the MSS., saying that he would pay a cash bonus, if the firm demanded it, to guarantee them against possible loss.

With this note in her mind, Miss Millicent had felt little doubt that her story would be accepted and printed. She only wondered how warmly they would praise her work. It was not enough to have them print it; she wanted something to justify her in saying to her father, "There, you see I was not wrong after all in thinking I could have a literary career!"

At last the envelope was removed, and the girl's astonished eyes lit upon this cold, dry statement:

"Messrs. Cutt & Slashem regret to be obliged to decline with thanks the MSS. of Miss M. Fern, and request to be informed what disposition she desires made of the same."

Millicent felt a ringing in her ears. Her hands grew clammy. A dull pain pressed on her forehead. She felt a faintness, a sinking at the heart. Was it possible she had read aright? Rejected, in this cruel way, without even a reference to her father's offer! It was atrocious, and, girl-like, she burst into a spasm of weeping.

How could she ever face her father? The sacrifices she had made came back to her, sacrifices of which she had thought little at the time, but which now seemed gigantic. There had been nights when she had not gone to bed till three, other nights when she had been too full of her subject to sleep and had risen in the small hours to finish some particularly interesting chapter. Twelve hundred pages there were in all, note size, in her large, round, almost masculine hand. And this time was all lost! She had mistaken her vocation. The greatest publishing house in the country had decided against her.

Gradually she dried her eyes. It would do no good to weep. She read the curt answer that had come in the mail, a dozen times. Why could not the firm have sent her a reason, an excuse that meant something? She wanted to know wherein her fault lay. It might be possible to correct it. Perhaps the state of business was to blame. The more she thought, the more determined she grew to investigate this strange affair, and within an hour she had donned her street clothes and started, without saying anything to the rest of the household of her intention, for the office of Cutt & Slashem in the city.

She knew that each large concern had one or more "readers," on whose judgment they relied in such matters. She, therefore, paused only long enough at the counting-room to get directed to Mr. Gouger. Her knock on the critic's door brought forth a loud "Come in," and as she entered she saw two men standing with hats in their hand, as if about to take their departure.

"I beg your pardon," she said, "but I wish to see Mr. Gouger."

"That is my name," responded one of the men, stepping forward.

"I am Miss Fern."

Mr. Gouger did not seem very glad to hear it. The hour of one had just struck, and he was about to go to his lunch. He recognized the girl's name, as that of the author of the MSS. he had criticized so severely to his friend, Weil, who was, by-the-way, the third person in the room at this moment. Had she sent up her card, as is usual with women, he would have avoided seeing her at any hazard.

Mr. Weil took a long survey of the young lady, and then retired to the vicinity of the front windows. He pretended to interest himself in the rush of traffic that was going on in the street below, but he missed nothing of what was said, and stole from time to time a glance at his two companions, particularly the younger one.

"A mighty pretty girl," was his mental comment. "I hope Lawrence isn't going to be nasty with her."

Mr. Gouger motioned Miss Fern rather stiffly to a seat.

"I do not wish to detain you," she said, with feminine inconsistency, as she accepted it. "I only want to know, if you will be so kind as to tell me, what is the trouble with my story."

The critic was pleased at one thing. Miss Fern's voice was reasonably clear. She had finished her weeping at home. There was to be no scene, something he dreaded, and in the course of his connection with this house he had experienced scores of them. He inspected his caller critically in the few seconds that elapsed while she was asking this question, and when she paused he decided to answer her with as much of the truth as he dared use.

"The fact is," he began, "a firm like ours is unable to use more than one novel out of fifty that is submitted to it. Of our friends who send us manuscripts, the vast majority must, therefore, be disappointed. Now, your story--shall I be frank?"

"By all means," answered Miss Fern.

"Your story, though written with spirit and power, needs a great deal of revision from a--from a rhetorical standpoint. It is, in fact, carelessly put together. That is a cardinal fault in a literary production, and one for which no amount of talent, or even of genius, can compensate."

The girl listened with deep interest. She tried to think where the blemishes alluded to could be, for she had read the story twenty times. To say nothing of several girl friends, who had listened with evident wonder and delight, to various parts of the tale, as it progressed.

"If that is true," answered Miss Fern, slowly--, "could not the trouble be remedied by sending the MSS. to some very competent person and having the errors made right?"

Mr. Gouger smiled.

"Hardly," he said. "A novel is like a painting. The _ensemble_--do you understand?--is the thing. Can you conceive a painting being 'done over'? Your book would lose its quality if subjected to that process."

A look of discouragement crossed the features of the young woman.

"Of course, you know best," she stammered. "What would you advise me--try again?"

Mr. Gouger raised both his hands.

"It is difficult to say, in such a case," he replied. "But--if you want my best opinion--"

"That is just what I want," said the girl, with ill-concealed impatience.

"You are not dependent upon your exertions, I suppose, for a living?"

Millicent shook her head, almost sorry at the moment that she could not reply in the affirmative.

"Then--I should give up the idea of being an authoress."

This was very unpalatable medicine, and the critic realized it as he looked at the sombre face before him.

"Is your rejection of my story based at all," asked Miss Fern, after a pause, "on the--boldness of its subject?"

Mr. Gouger smiled again.

"We publish the works of Hall Caine and George Moore," he said. "I should not consider your story overbold, if there was nothing else against it. It is a wonder to me, and always will be, why such young girls as you choose _risque_ themes, but if the work is well done the public will pay for it."

There was a slight blush on Miss Fern's face, partly at the insinuation and partly at the adverse criticism that had crept thoughtlessly into the sentence.

"For my part," she explained, "I wanted to write something that would attract attention--that would put my name prominently before the public and keep it there. The girls I read it to thought the scenes just lovely, though some said perhaps their mothers would not feel that way. And I told them that the mothers of to-day were very old-fashioned, and that the public taste was changing rapidly. If the story is too bold, there are things I could cut out of it, but if you say that would make no difference, I would rather let them stand. I intend to try some other concern before I give up."

Mr. Archie Weil had abandoned all pretence of looking out the window. He stood with his eyes fastened on the pretty girl, as she made these statements in such a matter-of-fact way. He wondered what the dickens the story was about, and made up his mind that he would try to get possession of it.

"All the same," responded Mr. Gouger, who had apparently forgotten his lunch in his growing interest in the conversation, "I don't see where girls like you obtain such an intimate knowledge of things. You are not over twenty--excuse me, I am old enough to tell you this without offence. It is not you alone, but a hundred others who have made me ask myself this question. As soon as the modern girl gets a bottle of ink and a pen and begins to let her thoughts flow over paper, it transpires that she knows everything--more than everything, almost. Why, I was twenty-five before I was as wise as the heroine of sixteen, in this story of yours!"

Miss Fern reddened again, all the more because she had glanced up and encountered the bright eyes of Mr. Weil fixed upon her.

"Why, Archie," pursued the literary man--he turned toward Mr. Weil--"you remember Lelia Dante, you have seen her here. Five or six years ago I got a letter from that young girl's mother asking me to come to their residence and hear a story she had written. It was her first one, and the child was not a day over seventeen. I couldn't believe it when she came into the room, with her hair tumbled about her shoulders, and began to read to me the first chapter of 'Zaros.' 'Did _she_ write that?' I asked her mother, incredulously. 'Certainly,' she replied. 'Without aid from any one?' 'Absolutely alone.' My hair stood on end. I could not keep it down for the next week with a brush. You know the story. We printed it, and it sold well, and that is all that C. & S. cared about it; but I never understood how that infant could conceive it. No more than I can understand your ability to write this story of yours, Miss Fern," he added, pointedly.

The young woman bridled a little.

"It does not matter much, if you are not going to print it," she said, raising her eyes to his.

He bowed low to express whatever apology might be necessary.

"I would have accepted it if I could," he said. "My entire life is spent in reading manuscripts in the hope of discovering one that will make a hit with the public to whom we cater. When successful I am as pleased as a South African who fishes a diamond of the first water out of the mine. Your story, Miss Fern, shows decided talent. You have a greater knowledge of some of the important things of life, I will wager, than your grandmother had at eighty, if she lived so long. As I am obliged to go now, let me add, without mincing matters, that you are very deficient in English grammar, and that nothing you can write will be acceptable to any first-class house until that fault is remedied. Are you ready, Archie?"

Mr. Weil felt indignant. He could not have spoken to any girl as pretty as this one in such language, and he thought it quite inexcusable on the part of his friend to do so. Mr. Gouger, though feeling that it was best to use little circumlocution, had not meant to wound his caller. But her countenance showed that he _had_ wounded her, and the natural gallantry of his younger companion came to the rescue.

"I am not ready yet," said Mr. Weil, telegraphing at the same time a series of signals with his eyes. "I want a few minutes' talk with Miss Fern, if you will introduce me. I think I can say something she will like to hear."

Mr. Gouger, who now stood in such a position that Miss Fern could not see him, shook his head to imply that he did not fancy this arrangement; but he ended by saying, "Very well." He then abruptly made the presentation, put on his hat, said good-by, and vanished.

Miss Millicent, who had risen, turned with an air of puzzled inquiry toward Mr. Weil.

"Be seated again, for a moment," he said, politely. "I want your permission to read your story."

"Why, I don't know," she answered. "Are you one of the employes of Cutt & Slashem?"

He smilingly denied the imputation.

"I have not that felicity," he added, "but I am much interested in things literary, and have a rather wide acquaintance in this line of business. If I could be allowed to read your MSS. perhaps I should form a milder opinion of its faults than my unbending friend. And in that case a word from me, to another house, would certainly do you no harm."

A brighter light came into Miss Millicent's eyes.

"I shall be only too glad to have you read it," she answered. "It is hard to believe that I have wasted almost a year in something entirely worthless. You may take it with pleasure."

Mr. Weil went to Mr. Gouger's desk, from which he soon came with the parcel in question. He untied the string and for a moment his gaze rested on the handwriting.

"Do you live far from here?" he began; and then added, as he noticed the address on an enclosed card, "Ah, I see! At Midlands."

She explained herself rather more to him, giving the full address of her father, and some particulars about the manner in which she had been drawn into attempting literary work. He listened intently, all the time engaged in rapid thought.

"The best way for me to get a thoroughly correct impression of this novel," he said, when she came to a pause, "is to hear you read it aloud. In that manner," he added, as he saw that she was about to interrupt, "a hundred meanings would come to the surface that a mere inspection of the pages might fail to show. Beside, there would be an opportunity for discussion. If convenient to you I would gladly come to your residence for this purpose."

The eyes of the young girl brightened. She was greatly pleased at the idea and said so without delay.

"Very well," said Mr. Weil, more than delighted with the success of his experiment. "To-day is Tuesday; shall I come for the first time, say, Thursday evening?"

"That would suit me perfectly; or to-morrow, if you wish. I shall put aside everything and have my time free for you."

Mr. Weil nodded.

"Let it be Thursday then. And the hour--shall we call it eight?"

The time was promptly agreed to.

"In the meantime, I will take the MSS. and look it over, to form a general idea of the plot. Here is my card. By-the-way, you will of course arrange it so that we shall not be interrupted during our conference. It disturbs anything of that kind to have people coming in and out. We want to be entirely alone so as to give our full attention to the work in hand."

Miss Fern smilingly acquiesced, saying that it was exactly what she would wish.

"And do you think there may be hope for it yet--that poor little manuscript?" she asked, as she stood by the door ready to take her departure.

"That is a question I can hardly answer," he replied. "I shall be better able to tell you in a week or two, I trust."

She lingered, with her hand on the door knob.

"My father is willing to take all the financial risks," she said. "That ought to make a difference, don't you think so?"

"It would, with many houses," he admitted. "I am glad to know these things. Thursday, then, Miss--Miss Fern."

He wanted to call her "Millicent," for he had read the name on the package he still held in his hand; but on the whole he concluded that this would be a little premature.

CHAPTER III.

"HER FEET WERE PINK."

When Miss Millicent Fern entered the office of Lawrence Gouger, as detailed in the preceding chapter, it will be remembered that she found that gentleman and his friend, Archie Weil, with their hats in their hands. The fact was that Mr. Weil had but just entered the room, and that Mr. Gouger had accepted an invitation to take lunch with him, an arrangement that was by no means an infrequent one between them. The entrance of Miss Fern, and the subsequent proceedings, compelled the literary critic to go out alone, as has been seen. When he returned he found Mr. Weil still there.

"Haven't you been to lunch yet!" exclaimed Mr. Gouger.

"I have not been out of this office," was the reply, "and all appetite for anything to eat has left me. Lawrence, that is one of the most interesting girls I ever met."

Mr. Gouger pursed up his lips, and uttered an impatient, "Pah!" He then remarked that Mr. Weil had a habit of finding such a quality in the latest women of his acquaintance.

"What does she amount to?" he asked. "An overgrown schoolgirl, who did not half learn her lessons. Read that MSS. she left here, and get disillusionized in short order. Why, she doesn't even know how to spell, and her periods and commas are in a hopeless tangle."

His companion eyed him quizzically.

"Are periods and commas, even a correct spelling of the English language, the only things you can see in a bright, handsome girl?" he demanded. "For shame, Lawrence! You are a dried-up old mummy. Your senses are numb. A lively wind will come in at the keyhole some day and blow you out of that chimney."

Mr. Gouger heaved a sigh, as if to say that discussion with such a nonsensical fellow was useless, and took his seat at his desk, where an unfinished pile of MSS. awaited his reading.

"She's given me leave to take her story home," said Mr. Weil, with a mischievous expression.

The critic stared at his friend.

"Given it to you?" he repeated. "How did that happen?"

"I asked her for it, naturally. You were so severe on the poor child, that I couldn't help putting in a cheering word. We talked of the whole business, and she was willing I should see if my opinion agreed with yours."

"_Your_ opinion!" echoed Gouger, testily. "What is that worth? But take the stuff, if you want it, and when you are done, send it to her; it will make less rubbish in this confounded hole. One thing I'll tell you, though, in advance. You'll never be able to make sense of it, unless you get some one to straighten it out."

"That's all right," replied the other. "After I have read it through, I am going to Miss Fern's house, where she will read it to me."

Mr. Gouger started from his chair.

"You don't mean that!" he exclaimed.

"But I do. She asked me, and I'm going. I understand that it's a rather bold tale, and I can conceive nothing more entertaining than to hear that kind of thing from the red lips of such a pretty piece of flesh and blood as has just left here."

There was an uneasy expression on the face of the critic as he heard these words. He liked Weil, although they were as different in their natures as two men could well be. He wanted to please him, but the aspect of this affair was not agreeable.

"Look here, Archie," he said, earnestly, "there are some things that I can't permit, you know. My office must not be made a starting-place for one of your lawless adventures. You met Miss Fern here. Now, I protest against your going to her house, pretending that you are interested in that novel, when your real purpose is of a much more questionable kind."

Mr. Weil put on the air of one whose feelings are lacerated by an unjust suspicion.

"My dear Lawrence--" he began.

"That's all right," growled the critic. "I may or may not be your 'dear Lawrence,' but I know you like--like a book," he added, hitting by accident on a very excusable simile. "You are an old dog that is not likely to learn new tricks. I shall send this MSS. back to Miss Fern, myself, enclosing a letter warning her to have nothing to do with you."

A laugh escaped the lips of Archie Weil at this proposition.

"If you knew the feminine mind half as well as you do modern literature," he answered, "you would see how little that would avail. I have met Miss Fern and made a distinctly favorable impression. Her address is in my pocket, and I have received a pressing invitation to call. If you choose to send the MSS. by another messenger you will relieve me of the task of carrying a bundle, but you will accomplish nothing more."

Mr. Gouger's mouth opened in astonishment at the evident advantage which his friend had gained in so short a time.

"You must have convinced her that your literary opinions are of value," he said, presently. "If I write that you are a charletan and entirely unworthy of attention, what will happen then?"

The smiling gentleman opposite crossed his hands over his left knee, and did not delay his answer.

"I will tell you," he said. "In the same mail she will receive a letter from me, warning her that a certain party, who has given an adverse judgment on her writings, may attempt to influence her against others more likely to decide in her favor. She will be told that, having rejected a book, this certain party does not wish any one else to print it. Send the severest note you can construct, Lawrence. I have few talents, but I know how to write letters."

The critic could hardly believe that fate had thrown so many cords around his neck in the brief space of one hour, but the more he thought the more he became convinced that his best course was to shut his eyes.

"Well, gang your gait," he said, after a long pause, during which the look of triumph deepened on his companion's face. "You will have to answer for your own sins. But I'll tell you one thing, that may save your time. Women who write racy novels are almost without exception remarkably correct in their own lives."

Mr. Weil inquired if his friend was certain of this, and there was a suspicion of disappointment in his tone.

"Absolutely," said Mr. Gouger, refreshing his memory. "I can think of a dozen instances to prove the point. There is Lelia Dante, for instance, who writes like a--like a--well, you know how she writes. She sticks to her mother's apron strings like a four-year-old child. They never are seen apart, I am told. Then there is Mrs. Helen Walker Wilbur, the poetess. We have a volume of her verse that is positively combustible from its own heat. The sheets had to be run off the press soaked in water to keep them from igniting. The room was full of steam all the time the work was going on. Warm! I should say so! Now, that woman is vain, and she dresses foolishly, and she does odd things for the sake of being talked about--but nobody questions her loyalty to her husband. You would think by some of her poems that an East Indian regiment would not suffice for her, and yet she is the straightest wife on Manhattan Island. Oh, I know so many cases. You remember that girl who wrote, 'Love's Extremities,' a work as passionate as Sappho. She is a little Quaker-like maiden,[A] who dresses and talks like a sister of one of the Episcopal guilds. These women are on fire at the brain only. They would repel a physical advance with more indignation than those endowed with less esthetic perceptions. So, see Miss Fern as much as you like. Should you attempt anything improper you will prove the truth of my assertions."

[Footnote A: Now dead, alas!--A. R.]

Mr. Weil changed the knee he had been nursing, but the quiet smile did not leave his countenance.

"What an inconsistent fellow you are, Lawrence," he said. "I could convict you of a hundred errors of logic. Do you remember telling Mr. Roseleaf that a man should have a passion before he attempts to depict one."

"And I say so still," retorted Gouger. "_You_ don't call the ravings of these poetesses and female novelists real life, do you? _You_ know the actual lover isn't content with kissing the hair and the feet of his divinity! There is more about women's _feet_ in these poems and novels than all the rest of their anatomy put together. And what is a woman's foot? Did you ever see one that was pretty--that you wanted to put to your lips?"

"Yes," interrupted Archie, dreamily, "once. At Capri. She was fifteen. Her feet were pink, like a shell. She was walking along the shore in the early evening."

"With the dirt of the soil on them!" exclaimed Mr. Gouger, in disgust.

"No, she had just emerged from her bath. The sand there was clean as a carpet, cleaner, in fact. Gods! They were exquisite!"

The critic uttered an exclamation.

"I waste time talking to you," he said, sharply. "You are like the rest of the imaginative crowd. It is a pity you were not gifted with the divine afflatus, that you could have added your volumes to the nonsense they print."

"And which you are always glad to get," interpolated Mr. Weil.

"Because it will sell. Cutt & Slashem are in this business to make money, and my thoughts must be directed to the saleable quality of the manuscripts submitted. If _I_ was running the concern, though, I would touch the mooney, maundering mess. It makes my flesh creep, sometimes, to read it."

Archie Weil uttered another of his winsome laughs.

"How would you like to be a serpent," he asked, "and have your flesh creep all the time? But before we dismiss this matter of Miss Fern, I want you to clear your mind, if you can, of the haunting suspicions you always have when a woman is concerned. You know there are concerns in the city who would print her book, with a proper amount paid down, if it had neither sense, syntax nor orthography. If she wants it fixed up, I can find tailors to help her out; and if her papa wants it on the market, why shouldn't he be able to get it there? Now, let us talk a little about Roseleaf."

Mr. Gouger brightened at the change of subject. His interest in Mr. Roseleaf was genuine, and he had already learned that Archie had formed a sort of copartnership with the novelist, in the hope of making his future work a success. While the critic could not be said to have any real faith in the arrangement, it certainly interested him.

"What strange freak will you take to next?" he asked. "And do you really expect to make a novelist out of that young man?"

Mr. Weil's eyes had a twinkle in them.

"Didn't you say, yourself, that it could be done?" he inquired. "If I have made any mistake in my investment, I shall charge the loss to you."

The critic reflected a minute.

"I'm not so certain it _can't_ be done," he said. "But that's quite different from investing money in it, as you are doing. A man wants pretty near a certainty before he puts up the stuff."

"You greedy fellow!" exclaimed Weil. "Will you never think of anything but gain? I have to spend about so much money every year, in a continual attempt to amuse myself, and it might as well be this way as another. I have a document, signed and solemnly sealed, by which I am to back him against the field in the interest of romantic and realistic literature, and in return he is to give me a third of the net profits of his writings. I don't know that I have done so badly. Perhaps you may live to see Cutt & Slashem pay us a handsome sum in royalties."

Mr. Gouger looked oddly at his friend, whose face was perfectly serious.

"What are you going to begin with?" he asked.

"Love, of course. It is the A B C, as well as the X Y Z of the whole business."

"What kind of love?"

"The best that can be got," replied Weil, now laughing in spite of himself. "The very finest quality in the market. Oh, we shall do this up brown, I tell you."

"What have you done so far?" asked Gouger.

"You want to know it all, eh?" responded Mr. Weil. "I don't think I am justified in letting you too deeply into our secrets. However, you are too honorable to betray us, and so here goes: I have instructed my protege that he must fall violently under the tender passion before next Saturday night."

"With a lady whom you have selected, of course?"

"By no means. He must catch his own sweethearts."

Mr. Gouger played with his watchchain.

"And this is Tuesday," he commented. "Do you think he will succeed?"

"He must," laughed Weil. "It's like the case of the boy who was digging out the woodchuck. 'The minister's coming to dinner.'"

"You might at least have got an introduction for him," said Gouger, reflectively.

"Not I. There's nothing in our agreement that puts such a task on me. Besides, there's no romance in an introduction. He would write a story as prosy as one of Henry James' if he started off like that."

Mr. Gouger nodded his head slowly.

"That would be something to avoid at all hazards," he assented.

And at this juncture, to the surprise of both the parties to this conversation, the young man of whom they were speaking entered the room.

"I was telling Mr. Gouger of our agreement," said Mr. Weil, as soon as the greetings were over. "How do you get along? Have you discovered your heroine yet?"

Mr. Roseleaf answered, with an air of timidity, in the negative.

"I don't quite know where to find one," he said.

Mr. Weil spread out his arms to their fullest capacity.

"There are thirty millions of them in the United States alone," he exclaimed. "Out of that number you ought to find a few whom you can study. What a pity that _I_ cannot write! I would go out of that door and in ten minutes I would have a subject ready for vivisection."

The younger man raised his eyebrows slightly.

"But, that kind of a woman--would be what you would want--the kind that would let you talk to her on a mere street acquaintance!"

Mr. Weil leaned back in his chair and stretched his legs.

"Oh, yes," he said. "She would do for a beginning. Don't imagine that none of these easy going girls are worth the attention of a novelist. Sometimes they are vastly more interesting than the bread and butter product of the drawing rooms. It won't do, in your profession, to ignore any sort of human being."

Roseleaf breathed a sigh as soft as his name.

"You were right, Mr. Gouger," he said, turning to that gentleman. "I do not know anything. I have judged by appearances, and I now see that truth cannot be learned in that way."

"All the better!" broke in Archie. "The surest progress is made by the man who has learned his deficiencies. You remember the hare and the tortoise. I have read somewhere that the race is not always to the swift. You must treat your fellow men and women as if you had just arrived on this earth from the planet Mars. You must dig through the strata of conventionality to the virgin soil beneath.

The great human passions are lust and avarice, though they take a thousand forms, in many of which they have more polite names. For instance, the former, when kept within polite boundaries, is usually known as Love. As Avarice makes but a sorry theme for the romantic writer, Love is the subject that must principally claim your attention. All the world loves a lover, while the miser is despised even by those who cringe beneath the power of his gold. Study the women, my lad, and when you know them thoroughly begin your great novel in earnest."

Roseleaf listened with rapt attention.

"And the men?" he asked.

"The men," was the quick reply, "are too transparent to require study. It is the women, with their ten million tricks to cajole and wheedle us, that afford the best field for your efforts."

Mr. Gouger, who had never been known to take so much time from his work during business hours, tried to begin his reading, but without success. When at his usual occupation he would not have been disturbed by the conversation of a room full of people, so preoccupied was he with what he had to do; but on this occasion he was too much entertained with his companions to do anything but hear them through.

"Is there no such thing as unselfish love--in a woman--love that sacrifices itself for its object?" asked Roseleaf, with a trace of anxiety in his tone.

"M----m, possibly," drawled Mr. Weil. "A female animal with young sometimes evinces the possession of that sort of thing, and women may have touches of it on occasions. That will be a good point for you to remember when you are deeper in your investigations. However, I ought not to fill your head with ideas of my own. I think what we most desire in our friend," he added, turning to the critic, "is complete originality."

The young man shifted his feet nervously.

"Pardon me," he said, "would it not be well to talk with people and learn their impressions? Then I can compare these with my own experiences, when they come. You would not send a blind man out on the street unled."

Archie Weil laughed deliciously.

"You are ingenious, when you should only be ingenuous," he replied. "You do not act at all like the young man from Mars that I have in mind. Perhaps, nevertheless, you are not wholly wrong, for even my traveler from that planet might have to ask his way to the nearest town. Supposing you had just reached the earth, and had met me with a thousand questions. What could I answer that would be of any use?"

Mr. Roseleaf reflected a moment.

"You could tell me your idea of a perfect woman," he suggested.

"Well, I will," said Weil, glancing meaningly at Mr. Gouger. "The perfect woman is about nineteen years of age. She is neither very light nor very dark. Her eyes are hazel, with a touch of gray in them. She measures, say, five feet, four inches in height, and--about--twenty-two inches around the waist. She has a plump arm, not too fleshy, a well-made leg, a head set on her shoulders with enough neck to give it freedom and grace of movement, but not sufficient to warrant comparison with a swan, or even a goose. Her hands match her feet, being not too slender nor too dainty. Her hips are medium, but not bulging. She weighs in the vicinity of a hundred and twenty-five pounds. And her hair--there is but one color for a woman's hair--is Titian red."

The young man had taken out his note-book and rapidly sketched this list of attractions.

"Every woman cannot have Titian hair," remarked Mr. Gouger. "Would you condemn one with all the other attributes on account of missing that?"

"I would, decidedly," was the reply, "when it is obtained so easily. I think it only costs two dollars a bottle, for the finest shade. Have you written it all down, Mr. Roseleaf?"

The young man ran over his notes.

"I have it--all but the hair," he said. "Of course I could not forget that."

"Very well. And this hair must be long enough, but not too long, remember, for everything unduly accentuated spoils a woman. It should hang about five inches below the waist, when unfastened, and be thick enough to make a noticeable coil. There should be sufficient to hide her face and her lover's when he takes her in his arms."

Mr. Roseleaf started slightly.

"Then she should have a lover?" he remarked, curiously.

"Undoubtedly. Else why the hair and the arms, and the five feet four! It is a woman's business to be loved and to make herself lovable. When you have found this woman, if she has no lover, you will be expected to officiate in that capacity. If she has one, you must supplant him as soon as possible. And when you have fallen desperately, ravingly in love with such a creature, you will not have to come to me for further advice."

The young man surveyed the speaker with the utmost gravity.

"Have _you_ ever been in love?" he inquired.

"Never."

"Why?"

"It was not necessary; _I_ did not intend to write novels," said Archie, with a laugh. "But, come, we have bothered Lawrence enough. Let us go."

He took the package containing Miss Fern's story, and sauntered out, paying no attention to the peculiar glances that his friend, the critic, threw at him as he was leaving.

CHAPTER IV.

WITH TITIAN TRESSES.

Mr. Weil deciphered the MSS. of Miss Fern with some difficulty. Not that the handwriting was particularly illegible, though it did not in the least resemble copperplate engraving; but, as Mr. Gouger had intimated, the sentences were so badly constructed, and the punctuation so different from that prescribed by the usual authorities, that he was continually obliged to go back over his tracks and hunt for meanings. Nevertheless, within an hour from the time when he sat down in his room at the Hoffman House and opened the package he had brought, he had to confess himself deeply interested.

Miss Fern had conceived some entertaining characters, and some very unconventional situations. Her people were virile; her hero was strong if not always grammatical; her heroine did and said things not common in real life, and yet that were quite reasonable when her peculiar nature and environment were considered.

Archie paused once in awhile to wonder how much of all this record was within the direct knowledge of the young authoress; which expressions conveyed her own ideas and which sentiments she would personally endorse. Gouger might be right as to the exceeding purity of most of the ladies who dealt in eroticism, but in this especial case Mr. Weil meant to make an investigation on his own account before he accepted as a universal rule the one his friend had laid down.

He did not go to sleep that night until he had finished his story. Had it been arranged by a competent hand he could have read it in four hours, but as it was he consumed eight in the work. With all its faults, he liked it. There was something breezy about it, and it had a theme that he did not remember had been treated exactly in the same way before. Though, as he himself had said, without much talent for composition, Archie had read a great many books. It is no proof because a person cannot write that he would make a poor critic. Mr. Weil might almost have filled Lawrence Gouger's place at Cutt & Slashem's. He had written fugitive pieces in his time for the papers, in reference to his travels, which had been extensive, and had even contributed occasional book reviews to the magazines. His connection with Gouger enabled him to keep in touch with what was going on in the literary world, and the dozens of new volumes which passed through that office were always at his disposal.

"She's not a fool, by any means," he remarked to himself, when he put down the last sheet of Miss Fern's work. "A fellow who understood his business might put that into such shape that it would be worth using. I mean to find some one who can do it, and suggest the idea to her, when I get to that stage in this affair. Let me see, who do I know that could undertake it?"

He had begun to undress, and was in the act of taking off his collar as he spoke. His mind ran over a list of struggling literary men. Something seemed the matter with most of them. There was Hamlin, but he would be too exacting, and would want to suggest alterations in the story itself, which would never do. There was Insley, whose last three books had been flat failures, and for whom Cutt & Slashem had positively refused to print anything more; but Insley had gone into the country for the summer and nobody knew his address. Then there was--

"_Roseleaf!_"

Archie received this thought like an inspiration. He threw his cravat on the bureau and began tugging at his shoestrings to the imminent danger of getting them into hard knots that no one could unravel. Roseleaf! Why not? The boy would do almost anything he suggested, so great was his confidence that a road to literary preferment could be staked out over that path. Roseleaf would not undertake the work for the sake of pecuniary compensation, but the thing could be presented to him in quite another light. In Miss Fern's story there were living, breathing men and women. In his own there were beautifully drawn marionettes. He could be made to see that the study of the young lady's method was worth his while. And then!

Mr. Weil's shoes lay on the floor, in the disorder of a bachelor who had never in his life taken pains to put anything in the place where it really belonged. He took out the studs of his shirt, pulled that garment over his head, and then sat for some minutes wrapped in active thought.

"They must be introduced to each other!" he exclaimed, at last. "Between them they have every qualification for success; apart they are like the separated wheels of a watch. There is Shirley, with a style so sweetly subtle, a grace so perfect, every line a gem; and with it all not a sign of human emotion. There is Millicent, full of plot and daring and breathing characters, and bold conceptions, and no more able to write good English than an Esquimaux squaw. I have both these interesting persons on my hands, and I must combine them, for their mutual good.

"I wonder what Gouger will say when I unfold my plan. Perhaps I had best not tell him. He actually came near threatening, to-day, to send a line to Miss Fern, warning her against me. He wouldn't have done it, though. Lawrence has a bark that is worse than his bite by a great deal. Yes, I'll bring these young folks together. I'll take them as Hermann does the rabbits, and press them gently but firmly into one. And then sha'n't we get a combination! And won't Mr. Lawrence Gouger hug himself when the product of their joint endeavor comes to him for a reading!"

The muser finished disrobing and donned his night robes, but it was a long time before he felt like slumber. He could think of nothing but his scheme. As he revolved it over in his mind, it took many new forms. At first Roseleaf was to be asked to rewrite the story that Miss Fern had offered Cutt & Slashem. And afterwards there must be an entirely new novel, conceived together and worked out slowly, using the best of what was brightest in both of them.

The last idea Mr. Weil had before he relapsed into unconsciousness contained two novels, worked out at the same time. Roseleaf was all right, if he could only get a glimpse of realism into his work. Miss Fern would have no trouble if her ideas could find a garb that suited them.

There would be a way to make them of service to each other, and the time to cross a bridge is always when you come to it. So thought Archie Weil, as he fell asleep.

In the morning he laughed to think of the description he had given to Shirley, in his offhand way, of "the perfect woman." It was a faithful list of Miss Millicent's charms, so far as they were apparent to him. Shirley had noted them down with great carefulness, and would be sure to notice how fully the authoress met the ideal he now had in mind. It only remained for the schemer to say something to Miss Fern that would suggest Roseleaf to her, whenever they were made acquainted.

It must be plain to the reader that Mr. Weil's principal intention in this whole matter was to dispose of the _ennui_ which idleness brings even to its most adoring devotees. He had a fair fortune, accumulated by a father who had denied himself every luxury to amass it. Drifting to New York, he had found the vicinity of the Hoffman House very agreeable, and his companions, with the exception of Mr. Gouger, were of about as light views of life as himself. The critic was one of those strange exceptions with which most of us come in contact, where persons of entirely opposite tastes and inclinations become attached friends.

Breakfast was served so late to Mr. Weil that he had not finished that repast when the young novelist made his appearance. Seating himself on the side of the table that faced his friend, Mr. Roseleaf responded to the latter's inquiries in regard to his health

by saying that he was quite well. Indeed, he looked it. His eye was bright, his cheek rosy. His attire showed just enough of a negligent quality to be attractive. There was an air about him such as is often associated with an artist of the pencil and brush.

"Never better in health," he said, "but very anxious to begin something definite in the way of work."

Mr. Weil smiled his most affable smile.

"What did I tell you to do, first?" he asked, playfully.

"To fall in love."

"Which you have not yet done!"

The young man shook his head.

"Good Heavens! And you have lost more than a week!"

Roseleaf colored more than ever.

"Isn't there something else--that I could--begin on?" he asked, humbly.

"I don't know of anything. Love is the alphabet of the novelist. You'd best go straight. Aren't there any eligible young women at your lodging house?"

The younger man thought a moment.

"No; only the chambermaid."

Mr. Weil sipped his coffee with a wise expression.

"It may come to that," he said, putting down the cup, "but we'll hope not. We will hope not. What's the matter with Central Park? There are five hundred nice girls there every afternoon."

"But I don't know them," said Roseleaf, desperately. "And--I have been there. Yesterday one of them looked at me and smiled. I walked toward her, and she slackened her speed. When I came within a few feet she almost stopped. Then--I could think of nothing to say to her, and I walked on, looking in the other direction."

Several breakfasters in the vicinity turned their heads to note the couple at the table, from which a laugh that could be heard all over the room came musically.

"Why didn't you say 'Good-morning?'"

"Yes! And she might have said 'Good-morning.' And then it would be my turn, and what could I have done?"

Mr. Weil folded up his napkin and laid it by his plate.

"You coward," he replied, affably, "you could have done a thousand things. You could have remarked that the day was fair, or that you wondered if it would rain. And you could have asked her to stroll over to a restaurant and take a little refreshment. Once opposite to her, the rest would have come fast enough."

The novelist took out a handkerchief and wiped the perspiration from his forehead. It all seemed very easy the way Archie described it, but he was sure it would be very different in practice. How could he know, he demanded, that the young lady would go to the restaurant with him? She might have declined, and then he would have been in a worse position than ever.

"Declined!" echoed Archie. "Declined a lunch? Declined ice cream? Declined champagne frappe! Well, you _are_ ignorant of the sex. My dear boy, it is evident that I shall have to introduce you to the leading lady of your company, and if you will be patient for a very few days, I hope to be able to do so."

Rousing himself with a show of genuine interest, Roseleaf inquired for further particulars.

"Listen," replied the other. "I expect, to-morrow evening, to spend a few hours in the company of one of the most charming members of her sex. She, like you, has an ambition to become a successful writer. Like you, also, she lacks some of the prime

qualities that are needed for that end. It happens, however, that the things wanting are entirely different in each of your cases--that you will, if you choose, be able to supplement and perfect each other. I shall tell her that I know a young man of literary taste who will give her advice on the points in which she is deficient. With such an opening you will be at once on Easy street, and if you cannot fall in love within forty-eight hours, I shall regard you as a case too hopeless to merit further attention at my hands."

The young man's cheek glowed with pleasure.

"That is more like it," he said. "When do you think I shall be able to meet this young lady?"

"Within a week or two, at the latest. I must sound her before I trust you with her, for she is nearly as much a stranger to me, so far, as to you. Of course there is no objection--quite the contrary--to your falling in love elsewhere in the meantime, if opportunity serves."

At this moment Mr. Weil called his companion's attention to a rather corpulent gentleman who had just entered the breakfast room and was stopping near the door to hold a brief conversation with some one he had met there.

"You see that fellow?" he remarked. "Wait a minute, and I will get him over here. If you ever want to put a real character into one of your stories you will only need to take his photograph. In actual life he is as dull as a rusty meat axe, but for literary purposes he would be a godsend."

Catching the eye of the person of whom he was speaking, Mr. Weil motioned to him to come to his part of the room, and as he approached arranged a chair for him invitingly.

"Mr. Boggs, I want to present a young friend of mine to you," said Archie, rising. "Mr. Walker Boggs--Mr. Shirley Roseleaf."

Mr. Boggs went through the usual ceremony, announcing that he was most happy, etc., in the perfunctory style that a million other men follow every day. Then he took the chair that was offered him, and gave an order for his breakfast to a waiter.

"Are you a New Yorker, Mr. Roseleaf?" he asked, when this important matter was disposed of.

"Mr. Roseleaf is staying here for the present," explained Mr. Weil. "He is a novelist by profession, and I tell him there is no better place to study the sensational than this vicinity."

The young man's color deepened. He doubted if it was right to introduce the subject in exactly these terms. Mr. Boggs' next question did not detract from his uneasiness.

"Excuse me--I am not altogether up in current literature, and I must ask what Mr. Roseleaf has written."

Mr. Weil helped his young friend out of this dilemma as well as he could.

"He has written nothing, as yet; at least nothing that has been printed," he said. "He is wise, I think, in laying a deep foundation for his romances, instead of rushing into print with the first thoughts that enter his head, as so many do, to their own subsequent regret and the distress of their readers. I want him to meet men and women who have known what life is by their own experiences. You ought to be worth something to a bright writer, Walker. You have had many an adventure in your day."

Mr. Walker Boggs shrugged his shoulders.

"In my 'day,' yes," he assented. "Enough to fill the Astor and Lenox libraries and leave enough for Charlie Dillingham and The American News Company. But that is nothing but history now. My 'day' is over and it will never return."

He paused and ran his right hand dejectedly across his vest in the vicinity of the waist band. Though he knew perfectly what Mr. Boggs referred to, Archie Weil wanted him to express it in his own words to Shirley.

"You wouldn't think," continued Mr. Boggs, after a pause which seemed filled with strange emotions, "that my figure was once the admiration of every lady who saw it, that they used to stop and gaze at me with eyes of positive envy. And now--look at this!"

He indicated his embonpoint again, and shook his head wrathfully.

"It is simply damnable," he continued, as neither of the others thought best to interrupt him. "When I was twenty-four I had a reputation that was as wide as the continent. When I walked down Broadway you would have supposed a procession was passing,

the crowds gathered in such numbers. If it was mentioned that I would spend a week at Saratoga or Newport, the hotels had not a room to spare while I remained. The next year I married, and as one of the fashion journals put it, two thousand women went into mourning. For a decade I devoted myself entirely to my wife and to business. I made some money, and kept out of the public eye. Then my wife died, and I retired from the firm with which I had been connected. The next twelve months dragged terribly. I did not know what to do. Finally I decided that there was but one course open to me. I must resume again the position I had vacated as a leader of fashion."

Mr. Weil bowed, as if to say that this was a very natural and praiseworthy conclusion; precisely as if he had not heard the story told in substantially the same way a dozen times before. He was watching Roseleaf's interested expression and had difficulty in repressing an inclination to laugh aloud.

"I sought out the best tailor in the city," continued Mr. Boggs. "I went to the most fashionable hair dresser. I spent considerable time in selecting hats, cravats and gloves. When all was ready I took a stroll, as I had done in the old days, from Fiftieth street, down Fifth Avenue and Broadway to Union Square. I met a few acquaintances who stared at me slightly, but did not act in the least impressed. The women merely glanced up and glanced away again. What was the matter? I went home and took a long survey of myself in the mirror, a cheval glass that showed me from crown to toe. My costume was perfect. There was not a wrinkle in my face--this was several years ago, remember. There was not a gray hair in my head then--there are a few now, I admit. 'What is it?' I asked myself a hundred times as I stood there, studying out the cursed problem. My tie was all right, my shirt front of the latest cut, my watch chain straight from Tiffany's, my--ah! I saw it all in a moment!"

Roseleaf, who did not see it even yet, wore such an astonished expression that Mr. Weil had to stuff his napkin into his mouth to prevent an explosion.

"It was this devilish abdomen!" said Mr. Boggs, slapping that portion of his frame as if he had a special grudge against it and would be glad if he could hit it hard enough to bring it to a realizing sense of its turpitude. "My figure had gone to the devil! It was not as large as it is now, but it was large enough to cook my gruel. My waist had increased so gradually that I had never noticed it. I got a tape and took its measure. Forty-two inches, sir! The jig was up. With a heart as young as ever, with a face as good and a purse able to supply all reasonable demands, I was knocked out of the race on the first round by this adipose tissue that no ingenuity could hope to conceal!"

Mr. Weil could wait no longer. His musical laugh rang out over the room.

"Let this be a warning to you, Shirley," he said, "to wear corsets."

"It is no joke," was the indignant comment of Mr. Walker Boggs, as he proceeded to add to his rotundity by devouring the hearty breakfast that the waiter had just brought him. "I am left like a marooned sailor on the sea of life. The only occupation that could have entertained me is gone. It is no time to enter business again, I couldn't have selected a wiser one to leave it. I don't want to marry, once was enough of that. The only women I can attract are those commercially inclined females that any other man could have as well as I. What is the result? My life is ruined. I take no pleasure in anything. I eat, walk about, go to a play, sleep. A _pig_ could do as much; and a pig would not have these memories to haunt him, these recollections of a time so different that I am almost driven wild."

Roseleaf felt a sincere pity for the unfortunate gentleman, and did not see the slightest element of humor in his melancholy recital. But Archie Weil could not be restrained.

"You're right about that pig business," he remarked. "You recall the incident in Mother Goose, where--

'A little pig found a fifty dollar note, And purchased a hat and a very fine coat.'

"There are strange parallels in history."

Mr. Boggs would have replied to this remark in the terms it deserved had he not been too much engaged at the moment in masticating a particularly fine chop. As it was he growled over the meat like a mastiff in bad humor.

"Are there no remedies for excessive accumulation of fat in the abdominal region?" asked Weil, taking his advantage. "It seems to me I have read advertisements of them in the newspapers."

"Remedies!" retorted the other, having swallowed the food and supplemented it with a glass of ale. "There are a thousand, and I have tried them all. I have taken things by the gross. I have paid money to every quack I could find. For awhile I starved myself so nearly to death that I went to making my will. And every day I grew stouter. I don't know what I measure now, and I don't care. A few fathoms more or less, doesn't count, when one falls from a steamer in midocean."

Mr. Weil took occasion to say that there was no need for this extreme discouragement. A little coin in the hand, or a new diamond ring, would still bring youth and beauty to his disconsolate friend.

"That's just it," retorted Boggs. "It's the contrast that's killing me. The only women who would look at me to-day are mercenary ones that wouldn't care if I was black as Othello or big as George IV. Why, I could show you a trunkful of letters, written me by the finest women in this country, when I was at my best. They breathe but one thing--love, love, love! I lived on it! It was the air that kept my lungs in motion. And I thought to go back to it so easily! _Ah!_"

Mr. Boggs commenced upon his fourth chop and emptied the last of the quart bottle into his glass.

"Well, I'm sorry for you," said Weil. "I think the times must have changed, as well as yourself, though. Now, here's a young fellow, with all the qualifications of face, figure and address that you once had, and he claims to be unable to make the acquaintance of a single interesting woman between Brooklyn Bridge and Spuyten Duyvil."

The heavy eyes of Mr. Walker Boggs rested upon the youthful face opposite to him. Under the scrutiny to which he was subjected Roseleaf reddened, in the way he had. He had never looked more handsome.

"This is evidently a jest of yours," said Boggs, turning to Mr. Weil.

"Not in the least, I assure you."

"Then I say he can do what he likes, and I know it," replied the stout man. "If I had his form I'd have to ask the police to clear the way for me. I have seen circulation impeded in front of this very hotel because I was coming out to take my carriage. If he won't look at them, why, of course, the women can't do it all, but it lies with him."

Roseleaf's eyes glistened with a strange mixture of hope and fear. He did not think he would care to be in such great demand as that, but he dearly wished to break through the iron bars that enclosed him. He glanced in a glass that paneled the wall near by. He was good-looking enough, it was no vanity to say so. What he lacked was confidence.

"He is afraid of them, that's his trouble," smiled Weil. "We will cure him of that, and when he gets to know women as they are he will give us a novel that will set all creation by the ears. Gouger--you know Gouger--says he writes the purest English. All he needs is a taste of life."

To this Mr. Boggs gave his unqualified assent. And he added that if he could be of any service in the matter he would only be too glad.

"We thank you for the offer, and may be able later to make use of it," said Mr. Weil. "And now good-morning, for we have important business to attend to."

Roseleaf looked long and earnestly at the person they were leaving. He seemed to him a very ordinary individual. If such a man had won the love of scores of beautiful women, surely he himself could gain the affections of one. When he stood with Weil in front of the hotel, by which an unrivaled procession of ladies and gentleman was already beginning to pass, though it was only eleven o'clock, he felt much encouraged.

"They are looking at you," whispered Archie, "plenty of them. Did you see those two girls in pink in that landau? Why, they nearly broke their necks to get the last glimpse of you. There is another lady who would stop if you asked her, pretty as any of them, though she must be nearly thirty. Your eyes are not open. Ah, here is something better! In that carriage, with the Titian tresses!"

It was Miss Millicent Fern, and she bowed to Mr. Weil. Then her bright eyes lit up with a new lustre as they fell upon his companion.

CHAPTER V.

STUDYING MISS MILLICENT.

When Mr. Weil made his appearance at the residence of Mr. Wilton Fern, the door was opened for him by a young negro of such superb proportions that the caller could not help observing him with admiration. He thought he had never seen a man more perfectly formed. The face, though too dark to suggest the least admixture of Caucasian blood, was well featured. The lips were not thick nor was the nose flat, as is the case with so many of the African race. The voice, as the visitor heard it, was by no means unpleasant. Mr. Weil could not imagine a better model for an ebony statue than this butler, or footman, or whatever position, perhaps both, he might be engaged to fill.

"Yes, sir, Miss Millicent is in, and she is expecting you," said the negro, in his pleasant and strong tones. "Let me take your hat and stick. Now, sir, this way."

Miss Fern came in a few moments to the parlor, where Archie was left, and greeted him most cordially.

"There is a sitting-room on the next floor," she said, "where we shall not be disturbed. I have given Hannibal orders to admit no one, saying that we shall want the evening entirely to ourselves."

"Hannibal?" repeated the visitor. "Is that the name of the remarkable individual who received me just now?"

"Yes," said Miss Fern, rather coldly. "Though I do not know why you call him 'remarkable.'"

"He is so tall, so grand, so entirely overpowering," explained Mr. Weil. "One would think he might be the son of an African king. I never saw a black man that gave me such an impression of force and power."

Millicent elevated her eyebrows a little, as if annoyed at these expressions. She answered, still frigidly, that she had noticed nothing unusual about Hannibal. She did not believe she had looked closely enough at his face to be able to identify him in a court.

"He would make a fine character for a novel," said Mr. Weil, as they walked together up the broad staircase. "I could almost write one myself, around such a personality."

The young lady looked disgusted.

"A negro servant!" she exclaimed. "What kind of a novel could you write with such a central figure?"

"Perhaps I should not put him in the centre," laughed Archie, determined to win her good nature. "Every story needs lights and shades. You can't deny that he would cast a magnificent shadow."

The humor of this observation struck Miss Fern and she joined mildly in her companion's mirth. Then she remarked that the central figure of a novel--the main thing in it--to her mind, should be a being who could be given the attributes of beauty and grace. The minor characters were of less account, and would come into existence almost of their own accord.

"And now, before we do anything more," she said, "I want you to tell me about that excessively handsome young man that I saw with you yesterday in Madison Square."

Weil was delighted at this introduction of his young friend. He began a most flattering account of Shirley Roseleaf, describing him as a genuine paragon among men, both in talent and goodness. He drew heavily on his imagination as he proceeded, feeling that he was "in for it," and might as well do his best at once. And he could see the cheek of the young listener taking on a new and more enticing color as he went farther and farther into his subject.

"If I have to rearrange my novel--the one Mr. Gouger rejected--I shall draw my hero after that model," she cried, when he paused for breath. "I never saw a man who came so near my ideal."

"But--you would have to alter your hero's character, in that case?" he said. "I have read your MSS., and your description does not tally with my young friend at all."

Miss Fern reddened.

"You don't mean to claim, do you," she replied, "that physical beauty and moral goodness always go hand in hand?"

"They should," he answered, in a tone that was meant to be impressive.

"Ah, that is another question! _Do_ they? that is all the novelist needs to know. Did you ever read Ouida's 'Sigma?' There are the two sisters, one as pure as can be, the other quite the opposite, and the beauty belongs to the depraved one. I know Oscar Wilde takes a different view in 'Dorian Grey,' but he is wrong. I am sure that the worst man or woman in the world--reckoning by what are called the 'amiable vices'--might be the most lovely to look upon, the most delightful to associate with. Eve found the serpent attractive, remember."

Where did she learn all these things? Weil looked at her with increasing astonishment. "Amiable vices." He liked the appellation.

"Perhaps you are right," he assented, as if slowly convinced. "If you wish to be acquainted with Mr. Roseleaf, I will bring him here with pleasure. My only fear is that he will not interest you. He seems almost too perfect for earth. Think of a young man who knows nothing of women, who says he has no idea what it is to be in love, who does not understand why the ladies who pass down Fifth Avenue turn their heads to look at him! He, like yourself, is a novelist, but his characters are beautiful images that lack life. He carves marble figures and attempts to palm them off as flesh and blood. He really thinks they _are_, because he has never known the difference. If you could take him, Miss Fern, and teach him what love really is--"

The young lady blushed more than before.

"_I_--" she stammered.

"In a strictly literary way," he explained. "But," he added, thinking he was getting upon the edge of a quicksand, "we must not forget the object of my visit."

He took the parcel containing her MSS. that he had obtained from Mr. Gouger, and began to untie the string. Manlike he soon had it in a hard knot, and Miss Millicent, coming to his rescue, her young hands touched his and made his heart beat faster.

"There," she said, when the knot had given way to their joint endeavors. "It is all right, now. But, before we begin on this, tell me a little more about Mr. Roseleaf. What has he written? Where was it published? I will send to-morrow morning and buy a copy."

Her enthusiasm was agreeable under the circumstances, but the truth had to be explained to her.

"What he has written I will let you see, one of these days," he replied. "As for publishing, he ran upon the same rock that you did--that of Mr. Lawrence Gouger."

The beautiful eyes opened wider.

"So he rejected his work, too! And yet you say that it was well done?"

"Exquisitely. Shirley's lines are as symmetrical as his face and figure. His people are dead, that is all the trouble. Gouger scented the difficulty under which he labors, in a moment. 'Go and fall in love!' he said to him, 'and you will write a story at which the world will marvel!'"

Miss Fern arranged one of her locks of Titian red that had fallen down.

"And hasn't he taken the advice?" she inquired, in a low voice.

"Not yet," smiled the other. "He says, like a very child, that 'he cannot find any one to love.' I walked up the avenue with him to-day, and afterwards rode in the Park. There were hundreds of the prettiest creatures, all looking their eyes out at him. And he hadn't the courage to return one glance, not one. Ah, Miss Fern, it will be genuine love with Shirley Roseleaf, if any. The imitations one finds in the fashionable world will never answer for him."

The young lady breathed a gentle sigh, as her thoughts dwelt on the handsome figure she had seen in front of the Hoffman House.

"You may bring him here--yes, I should be glad to have you," she said, slowly. "But I must ask one favor; do not tell him what I said so thoughtlessly about his being my ideal. Let me talk with him on fair terms. It may be, as you suggest, that we shall be of advantage to each other. When can you arrange it?"

"Almost any day," smiled Weil. "I will let you know, by mail or otherwise. And now, this story of yours," he added, thinking it a shrewd plan to divert her attention from the other matter while it was still warm in her mind. "Though I have read it through, and think I understand it fairly well, I am all the more anxious to hear it from your lips. You will put into the text new meanings, I have no doubt, that have escaped my observation."

Miss Fern flushed pleasantly and inquired with a show of anxiety whether Mr. Weil had found its construction as bad as his friend, Mr. Gouger, had intimated.

"To be perfectly honest, it might be improved," he replied. "But the germ is there, Miss Fern--that necessary thing for a good novel--an interest that will hold the reader in spite of himself. I disagree with Lawrence in his essential point. I am sure that a good writer of English with a taste for fiction could make all the necessary alterations without in the least detracting from the value of the story. For instance, I believe if Mr. Roseleaf would take hold of it I could guarantee to get you a publisher this winter."

"And do you think he would?" she cried.

"I think so."

The authoress was so delighted with this announcement that she conquered the slight wound to her pride. It would be herself still who had drawn the picture, who had put the coloring into it; all that the other would have to do might be described as varnishing. She took up the first sheet of her writing, and turned up an oil lamp that stood upon the table at her elbow, the better to see the lines.

"Are you ready?" she asked.

"Quite ready," smiled Mr. Weil.

In a voice that trembled a little, and yet not unpleasantly to the listener, Miss Fern began to read her manuscript. The opening chapter introduced the heroine and two gentlemen, either one of whom might be the hero. As the book is now so well known it is needless to transfer its features to these pages.

Presently the authoress paused and seemed to wait for her guest's criticism.

"That is one chapter," she said.

"Yes. I remember. And the second one is where Algernon begins to disclose a very little of his true nature. Shall we not have that now?"

"As you like. I thought perhaps you would give me advice as we proceeded, some fault-finding here and there, a suggestion of alterations."

He shook his head affably.

"Not yet," he answered. "Up to this point I see nothing that requires condemnation."

"Nor praise, perhaps?" she said, in a low tone.

"That might be true, also," he replied. "The first chapter of a novel is only the laying of the cloth and the placing of a few dishes. The viands that form the meal are still in the kitchen."

She smiled at the simile.

"But even the laying of the cloth is important," she said.

"Your cloth is laid most admirably," he answered. "And now we will have the castor, which in this case, I believe, contains a certain quantity of mustard and red pepper."

At this she laughed the more, and glanced through a few of the sheets in her hands before she spoke again.

"Did you form any opinion about--about _me_--from this story?" she asked, constrainedly. "Did you, in brief, think it had taken a bold girl to write it?"

He hesitated a moment.

"Yes," he said, at last. "A bold girl, a daring girl, a brave girl. Not one, however, whose own conduct would necessarily be like that of the woman she has delineated."

She was so pleased that she put down the MSS. and leaned toward him with both hands clasped together.

"You are very, very kind," she said, impressively.

"No, merely truthful," he replied. "With your permission I want to retain that last quality in all my conversations with you. When you ask me a question I wish to be perfectly free to answer according to my honest convictions."

"It is what I especially desire," she said, brightening. "No one able to judge has heard anything of this story except your friend, Mr. Gouger. I know it is bold, sometimes I think it is brazen. I can conceive that there are excellent people who would say it never should have been written. To my mind, the moral I have drawn more than justifies the plainness of my speech. You can tell better than I where I have overstepped the proper bounds, if there be such places. You are, of course, a man of the world--"

The protesting expression on the face of her companion arrested her at this point.

"That depends on what you mean by 'a man of the world?'"

"It is a common expression."

"And has many definitions. Before I plead guilty to it, I want to know just how much you intend by it."

Miss Fern put down the page she had taken up and a puzzled look crossed her pretty face.

"You make it hard for me to explain myself," she said. "I suppose I meant--"

"Now, be as honest as you asked me to be," he interrupted.

"Well, then, I suppose you are a man like--like other men."

"But there are many kinds of other men."

The young lady tried several times to make herself clearer, and then asked, with a very pathetic pout, that she might be permitted to proceed with her reading, as the hour was growing later. It was not a very important point, any way, she said.

"I cannot entirely agree with you," replied Archie. "If you are to be a writer of fiction, you should not consider any time wasted which informs you in reference to your fellow creatures. It is from them that you must draw your inspiration; it is their figures you must put, correctly or incorrectly, on your canvas. Don't understand me as dictating to you, my dear Miss Fern. I only wish, as long as you have referred to me, to know of what I am accused."

To this Miss Fern answered, with many pauses, that she had not intended to accuse her visitor of anything. And once more--with evident distress--she begged to be permitted to drop the matter and return to her reading.

"Very well," he assented, thinking he had annoyed her as much as was advisable for the present. "As they say in parliamentary bodies, we will lay the question on the table, from which it can be taken at some more fitting time. I am as anxious as you can be to get into Chapter II."

She read this chapter to the end, and paused a few seconds to see if he had any comments to make, but he shook his head without breaking silence, and she went on with the story. He pursued the same plan till the end of the fifth chapter.

"It is interesting, exciting and true," he remarked, referring to the closing scene. "And I cannot help feeling arise in my brain the question that Mr. Gouger put when he read it: How could a young, innocent girl like you depict that situation with such absolute fidelity."

He had come to the point with a vengeance. But to Miss Fern his manner was far more agreeable than if he had approached it by stealth, or in an insinuating way. She had anticipated something of the sort and had tried to prepare herself to meet it.

"Does not nature teach us some things?" she asked, speaking straightforwardly, though her color heightened in spite of her efforts. "Given a certain condition, an intelligent mind can prophesy results."

He shook his head in mild disagreement with her.

"Gouger is an expert, and he denies this, as a regular rule, at least. You should have heard him argue it with Roseleaf. 'Either throw yourself into a love affair,' he said, 'or never try to depict one.' Excuse me, Miss Fern, you bade me be frank--"

She assented, with a grave nod of her shapely head.

"You may have been in love--I do not ask you whether you have or not--but you cannot have known personally of the sort of love that you have depicted in these pages. I call it little less than miraculous that you should draw the scene so accurately."

She colored again, this time partly with pleasure, for she was very susceptible to compliments.

"Perhaps your statement may explain to you," she said, pointedly, "what I meant a few minutes ago by calling you 'a man of the world.' You recognize at a glance what I had to construct from my imagination."

Archie Weil's face changed as he realized how deftly he had been caught. He had meant to pretend to this girl that he was more than usually ignorant of the nether side of life.

"Don't think too badly of me because I happen to know what is clear to every man," he said, impressively.

"To every one?" she answered. "To your friend, Mr. Roseleaf?"

"Ah! He is an exception to all rules. And yet, Gouger says he can never write a successful book till he is more conversant with life than he is at present."

She looked troubled.

"With life?" she echoed. "With sin, do you mean?"

"With the ordinary things that men know, and that most of them at some time experience."

Her bright eyes were temporarily clouded.

"What a pity!" she exclaimed.

"Yes," he said, for it was his humor to agree with her. "It is a pity."

There was a pause of a minute, and then she asked if she had read enough for one evening. He answered that as it was now past ten o'clock it would not be easy to get much farther and that he would come again whenever she chose to set the time.

"You do not say much about my work," she said, anxiously, as he prepared to go.

"Silence is approval," he responded. "I can talk it over with you better when you have reached the end. I have things to say, and I shall not hesitate to say them then."

"When is it most convenient to you to come?" she inquired.

"Any time," he answered. "I don't do much that is really useful. But wait till you see Shirley. He will atone for the shortcomings you find in me."

She repeated the word "Shirley," as if to test its sound.

"You are your father's only child, are you not?" he asked, thoughtfully.

"No. I have a sister, Daisy, a little younger than I."

"And has she a literary turn, also?"

"Not in the least."

Archie arose, and Miss Millicent accompanied him to the front door. The tall negro came to open the portal, but Miss Fern told him, with the same quality of dislike in her tone which Weil had noticed before, that he need not wait.

"He is really a magnificent piece of humanity," said Archie, when the man had disappeared. "I never saw anything quite like him."

"You admire negroes, then?" said the young lady, almost impolitely.

"I like representatives of every race," he answered, as if not noticing her. "There are interesting specimens in all. I number among my acquaintances several Chinamen, a Moor, a Mexican, Jews, Portuguese and Russians innumerable. If that fellow was not in

your employ I would engage him to-morrow, merely as a study."

Miss Fern took the hand he held out to her and set the next meeting for Saturday evening. Then she said:

"If you want Hannibal, perhaps papa would oblige you. I certainly would do all I could to persuade him."

CHAPTER VI.

"HOW THE WOMEN STARE!"

The next day Archie Weil lunched with Lawrence Gouger. He wanted to talk with his friend about the young author and authoress. Gouger listened with interest to the story he had to relate, and nodded approval when it appeared that Archie had behaved admirably thus far in relation to Miss Millicent.

"Do you know anything about Mr. Fern?" he asked, when the other had reached a period.

"Nothing."

"Well, neither did I, a week ago, but I have taken pains to inform myself. He is a highly respectable elderly party, who deals in wool. He married a very beautiful lady, who has now been dead eight or ten years and he lives altogether in the society of his two daughters. If you succeed in getting Millicent's book on the counters you will earn his everlasting gratitude. They say he is not literary enough himself to be a judge of its merits, and if she has fifty copies to present to the family friends it will probably be all he will ask."

Mr. Weil uttered a low whistle.

"I don't know what the family friends will say of it," he replied, "but I call it pretty warm stuff. If the list includes many prudes they will hardly thank the girl for sending such a firebrand into their houses."

"Pshaw!" said Gouger. "The world is getting used to that sort of thing, and they won't mind it a bit. Besides, they will be so lost in admiration of their cousin's name on the cover that they will think of nothing else. What did you make out of her? Is she as innocent as I predicted?"

Archie poured out a glass of Bass' ale and sipped it slowly.

"Quite," he said, as he put it down on the table. "And she's no dunce, either." He went on to tell of the trap he had fallen into. "I'm dying with impatience to get her and Roseleaf together. They'd make an idealic couple."

Mr. Gouger inquired what he was waiting for.

"Oh, I want to do the thing right," said Weil. "I want to learn her as thoroughly as I can, before I bring him upon the stage. It will take three or four evenings more to hear the rest of her novel, and another to discuss it. I shall get around to him in about a fortnight, at the rate things are going. He will keep. What do you suppose he is doing now? Writing poetry! He sent a piece a few days ago to the _Century_, and they accepted it."

"He will be gray when it appears," said the critic. "It takes a long time for anything to see the light in that publication."

"But in this case an exception will be made," said Weil. "They have assured him that it will come out in their very next issue. He will be so proud to see his name in print that I expect to find difficulty in holding him back. A poet who appears in the Century has certainly stepped a little higher on the ladder."

The critic agreed to this, and remarked that such a man as Roseleaf should give his whole attention to poetry.

"Wait!" cried Archie. "Give him time. See him after he has fallen head over ears in love with charming Millicent Fern. There is something in him, I feel sure, and between that dear girl and myself we will bring it out. By-the-way, there is a character I want you to meet," he added, as Mr. Walker Boggs came into the room. "You have never had the pleasure, I think, though you have heard me speak of him."

Mr. Boggs had his attention attracted by a waiter who was sent for the purpose and came with great willingness to occupy a seat with Mr. Weil and his friend.

"We were talking of a New York merchant just now," said Archie, when the introductions were over, "and it occurs to me that you, who know almost everybody, may have some knowledge of him. He is in the wool business, I hear, and I think you once told me you had done something in that way. His name is Wilton Fern, and he lives at Midlands."

"Do I know anything about him?" echoed Mr. Boggs. "I should say so. He was my partner for seven years, and I still have a little stake left in the concern, on which I am drawing interest."

Mr. Weil showed his astonishment at this statement. What a very small world it was, after all! Then, after pledging his friend not to mention that he had ever discussed the matter with him, he went guardedly into the particulars of Miss Millicent's book, and of his having called at the house for the purpose of passing judgment upon it.

"I didn't know that was in your line," replied Boggs.

"Well, it was this way," answered Archie. "Mr. Gouger's decision didn't exactly suit the young lady, as it was not very favorable. Mine will be quite to her taste, as I view her abilities in a more favorable light. Now tell us all about the family, as the only one of them I have met is Miss Millicent. Why, this is a regular find, old man! You should have told me a week ago that you possessed all this information that I have been aching to get hold of."

Thus adjured, Mr. Boggs entered upon his story. From which it appeared that he knew the Ferns, root and branch, and had dined with them dozens of times.

"What sort of a chap is the pater?" asked Weil.

"A very well-kept man of nearly seventy, with a great deal of what is called 'breeding' in his manner, and a face like the portrait of a French marquis cut out of a seventeenth century frame. He doesn't look like a business man at all, and between ourselves he's not much of a one. All the money he ever made--saving my apparent egotism--was when I was in the concern. I've heard he's got a big mortgage on his residence and is going down hill generally. Too bad; nice fellow; sorry for him; such is life."

Archie asked if Boggs would do him a personal and particular favor, if it would not cause him much trouble; and on being answered in the affirmative, said he would esteem it a great honor if he could be introduced to Mr. Fern by that gentleman's former business associate.

"I suppose I shall run across him at Midlands, some evening," he said, "and get one of those presentations that are the most aggravating things in the world. I don't want that to happen, and the best way, to use an elegant phrase, is to take the bull by the horns, or in this case, the sheep by the tail. Will you make an accidental call on him to-morrow afternoon and let me be of the party?"

Mr. Boggs responded that he would be delighted. And this matter being settled, all parties could give more direct attention to their lunch than they had been doing for the preceding ten minutes.

"You must have heard of my friend Boggs, in the days when he was a figure on the streets of this town," said Weil, presently, returning to what he knew was the favorite subject of that personage. "You've lived here for twenty years, and of course the name of Walker Boggs is familiar to you."

Mr. Gouger looked a good counterfeit of complete mystification for some seconds, and then a gleam as of sudden recollection shot across his face.

"Certainly, certainly!" he said. "Mr. Boggs was what is popularly known as a lady killer, if I am not mistaken. You got married, did you not, Mr. Boggs, some ten or eleven years ago?"

The party addressed acknowledged the practical correctness of the date.

"Why, it comes back as plain as day," said the critic. "The _Herald_ had a page about you, including your portrait and some verses by a well known poet. It said your marriage had cast a gloom over Manhattan Island and some of the up-river counties."

Mr. Boggs gloomily nodded, to show that the statement was true. Then he touched his most rotund portion with a significant look.

"I'm a widower now," he said, "and nothing but this--_this_--stands in my way. As Shakespeare says, 'Tis not as deep as a well, nor as wide as a church door, but--' The ladies never look at me now, and all on account of this d--d flesh, which hangs like a millstone

around my neck."

Cutt & Slashem's critic, ignoring the peculiar character of the metaphor used, remarked politely that he thought no lady of sense would put great stress on such an insignificant matter.

"Insignificant!" echoed Boggs. "I'll bet it's fifty inches around, come! And it's not the 'ladies of sense' I'm after. Quite the contrary."

One of Archie Weil's explosive laughs followed this statement, which caused an expression of mild injury to settle over the countenance of Mr. Boggs.

"You're getting on toward forty, and you ought to quit," said Weil. "Confound the women! Let them go."

"That's well enough to talk about," replied Boggs, gruffly. "How would you like to follow your own advice?"

Weil uttered an exclamation.

"I? I have precious little to do with them, I assure you. For a man of my correct habits I have the worst name of any one I know. Everybody insinuates things about me, and they can prove nothing."

"We'll ask Isaac Leveson about that," sneered Boggs. "By-the-way, that wouldn't be a bad place to take young Roseleaf to, when you get to instructing him in earnest. I met the young fellow on the avenue last night and walked around with him for a couple of hours. He's a darling!"

"Roseleaf?" cried both the other gentlemen, in one breath.

"To be sure. How the women stared at him! I couldn't blame them; his waist isn't over thirty, and he's as handsome as--as I was at his age. I told him he could have all the loveliness in New York at his feet, if he liked."

Weil smiled significantly at Gouger.

"What did he reply to that?" he asked.

"Oh, he had an ideal in his head, and none of those we saw quite came up to it; for I did get him to raise his eyes and look at the prettiest ones. I drew out of him slowly that he would have nothing to do with a girl unless she had red hair; that--"

Mr. Weil uttered a laugh so hearty that it attracted the attention of everybody in the room. Mr. Boggs paused to inquire the cause of this outbreak, but Archie assured him that something entirely out of the present discussion had just occurred to him, which was to blame for his impoliteness.

"A girl must have _Titian_ hair," repeated Mr. Boggs, accepting the explanation, "or he would not consider her. He ruled out all the striking blondes and brunettes, saying that he liked only those of a medium shade. We came across one that answered these descriptions, an exquisite little creature who looked as if she would swallow him could she get the chance. And then there came out another idea. He would not think of this fairy because she was so short. 'I want a woman five feet, four inches tall,' he said, as if the article could be made to order, in case the size did not happen to be in stock. Then, would you believe it, he found a girl embracing every attribute he had mentioned. Her hair was just the right shade, her height must have hit the mark exactly, her complexion was medium. But no. She was too heavy. She would weigh a hundred and forty-five, he said, quite twenty pounds too much. If we had found a girl that filled all his description he would have invented something new to bar her out of the race."

Mr. Weil remarked that he was not so sure of Roseleaf's insincerity. He believed the right woman would yet be discovered, and that a case of the most intense affection would then spontaneously develop.

"In fact," he added, "I have the identical creature in mind. It is clear to us--to myself and Mr. Gouger here--that Shirley will never write a thrilling romance till he has fallen wildly, passionately in love."

Mr. Boggs smiled slightly, and then sobered again.

"Shall you have him marry, also?" he inquired, pointedly.

"Why not?"

"Because it will finish him; that's why. The romance in a modern marriage lasts six weeks. At the end of that time he will be useless for literary purposes, or anything else."

Mr. Weil shook his head in opposition to this rash statement.

"My theory is," said he, "that a novelist should know everything. To write of love he should have been in love; to tell of marriage he should have had a wife--a real one, no mere imitation; to talk of fatherhood intelligently he should become a father. How can he know his subjects otherwise?"

The stout man smiled significantly.

"And if he wishes to write of murder, he must kill some one. And if he wants to depict the sensations of a robber he must take a pistol and ask people to stand, on the highway."

"Now you are becoming absurd," said Archie.

"No more than you," said Boggs. "You go too far, and you will find it out. Let your novelist fall in love. That will do him good. But don't let him marry, or you will lose him, mark my word. Let him contemplate matrimony at a distance. Let him reflect on the glory of seeing his children about his knees. So far, so good. But when you have shelved him with a wife of the present era, when you have kept him up nights for a month with a baby that screams--his literary capacity will be gone. Make no mistake!"

Mr. Weil, half convinced, and much surprised to hear such wisdom from this unexpected source, made an effort to maintain his ground.

"Nearly all the modern novelists _are_ married," he remarked.

"Yes, and nice stuff they write, don't they? Namby-pamby, silly-billy stories, misleading in every line! They are the most unsafe pilots on the shores of human life. They start, without exception, from false premises. Their chart is wrong, their compass unreliable, their reckoning ridiculous from beginning to end. Where did you ever see a bit of real life that resembled these abortions? Do lovers usually fall on their knees when they propose? Is the modern girl an idiot, knowing less of the facts of nature than an oyster? Is the conversation between men and women filled exclusively with twaddle? You would think so, from reading these books; and why? They are written by married people, most of them, people who don't dare step over the line of the commonplace any more than a woman would dare order her dressmaker to put pockets in her gown!"

Archie looked at Mr. Gouger, who nodded a partial approval of these statements. Mr. Boggs betook himself with more interest to his chops. And the other two gentlemen, remarking that time pressed, bade him good-by for the day.

"I see you agree with him that I shouldn't marry Roseleaf?" said Archie, with a rising inflection.

"There is certainly point in what he says," replied Mr. Gouger.

"But--confound it! With the boy's disposition, it will be a delicate business," retorted Weil. "I don't know as I can carry him to the point of passionate love for pretty Miss Fern, and then shut off the steam when it suits me."

This matter was discussed for the next ten minutes, as the friends walked along toward the office of Cutt & Slashem.

"I think you are foolish to delay so long introducing him to her," said Gouger, finally. "I don't see that you are making any progress whatever."

"Ah, but I am," replied Weil. "I am making both of them more and more anxious for the meeting. Shirley walks the street feverishly impatient, and I have no doubt mutters her name in his dreams. Millicent talks about her ideal of manly beauty. When they get together failure will be impossible."

Mr. Gouger laughed at the idea that Roseleaf was "feverishly impatient" to meet any girl, and ventured to predict that the young man would have to be put in irons to get him to the residence of the Ferns when the time came; or at least to keep him there.

"Just the point I am working on," replied Weil. "Under ordinary circumstances I would have to handcuff his wrists to mine, but I am making such a strong impression on his imagination that he is crazy to go. And once she gets him under her influence--I tell you, Lawrence, she is no ordinary girl."

"She certainly does not write like one," smiled the critic, "either in her subject or her English. You may make something of him--I rather think you will--but not of her. Her ideas are wild, and her realism a little too pronounced even for the present age."

"She has truth on her side, you admit," said Archie.

"Yes, to a remarkable degree."

"Well, that ought to be something, if Boggs' estimate of the modern liar is correct. Shirley will help her to style, give her his own, if necessary. I am going to land both of these fish, if only to spite you, Lawrence. You tossed them away with that fine contempt of yours, and you will weep hot tears for it before you die."

At the door of Cutt & Slashem's they met the two members of that firm, who paused to say a word to Mr. Gouger. They were anxious for a new book to bring out as soon as possible, and were regretting with him that nothing worth publishing seemed to present itself.

"You may strain matters, it necessary," said Mr. Cutt. "We can't keep up on reprints forever. I hope you made no mistake in rejecting that book of Mrs. Hotbox. I hear it is selling well."

Mr. Gouger's face was, as ever, immovable before his employers.

"What 'Fire and Brimstone?'" he inquired. "The authorities seized the entire edition this morning."

Mr. Cutt looked at Mr. Slashem, with a startled expression.

"In that case, I am glad we escaped it," he said. "We shouldn't like that sort of an affair, of course."

Mr. Weil, who knew both the gentlemen well, inquired what they thought of Mrs. Hotbox's production.

"I have never seen it," said Mr. Slashem.

"Nor I," said Mr. Cutt.

The partners disappeared into the counting-room, where they had an interview with a binder who had offered to do their work at one-tenth of a cent a hundred copies less than the concern with which they were then dealing. Archie said good-by to Gouger, and went off to find Roseleaf, with whom he had engaged to take, later in the day, a ride through the Park.

"How soon am I to see your paragon?" sighed the young man, as they were making the grand round of that famous drive.

"Within a week, I hope. Are you getting uneasy?"

"I am getting lonesome," was the gloomy reply. "And I want to begin work."

"Well, it will soon pass now. To-morrow evening I am to hear another installment of her novel. Two more sittings after that will finish it, I should say. And the next thing will be--you. But have you seen no one else in all this time that you care for?"

The young man looked aimlessly at the fleecy clouds that hung low on the horizon.

"No," he answered.

"And you think you are ready for a passionate affection, if the right person is found?"

"I will try," he said, simply.

Mr. Weil roused himself and touched his horse with the whip.

"Try!" he echoed. "You will not have to try. She will carry you off your feet, at the first go. Shirley, I have found you a superb woman, that you _must_ love. All I want to feel sure of is, that you can control yourself enough to behave in a reasonable manner."

Roseleaf looked up inquiringly.

"She belongs to an eminently respectable family," explained Archie. "Her father is a gentleman of the most honorable type. She has a young sister, who--"

Roseleaf, slow at all times, had at last begun to comprehend.

"You surely don't think--" he began.

"Ah, that is the question! A novelist must learn so very much--a novelist who is to depict the truth, as you are to do. Where should he stop? What experience should he refuse, provided it may be utilized in his work? A responsibility that is no light one will rest on me, my dear boy, when I have introduced you to this family, and left you to your own devices."

Roseleaf's eyes opened wider at these mysterious suggestions, but he did not like to make any more inquiries. Weil changed the conversation, calling attention to the women they met, who turned their handsome heads to look at the young man, as their equipages almost touched his.

"What an awfully wide swath you are cutting!" was Archie's exclamation, as the throng increased.

CHAPTER VII.

A DINNER AT MIDLANDS.

True to his appointment Walker Boggs met Mr. Weil on the following afternoon, and set out with him for Wilton Fern's office. Though engaged, as has been already stated, in the wool trade, Mr. Fern did not have on the premises to which these worthies repaired a very large assortment of that product. His warehouses were in another part of the city, and all the wool that was visible to his customers was arranged in sample lots that would easily have gone into a barrel. Mr. Weil, notwithstanding the description that Boggs had given of his ex-partner, was not prepared to see such an exceedingly fine specimen of humanity as the one introduced to him. The word "gentleman" was written in large characters on his broad forehead and in every word he spoke. It certainly was not often, said Archie to himself, that one encountered that sort of man in business.

"I have already heard something of you, sir," said Mr. Fern, affably, but with the dignity that was a part of his nature, no more to be discarded than his eyes. "That is, if you are the same gentleman that has kindly offered to assist my daughter in arranging a story she has written."

Mr. Weil admitted the correctness of the supposition, but disclaimed any special credit for what he had done. He explained briefly how he was drawn into the case. The visit lasted upwards of an hour, during which the conversation wandered from literature to business and politics, and all sorts of things.

Mr. Weil could not tell from Mr. Fern's manner of alluding to his daughter's work whether he had a very high idea of its value or not. Indeed, there was very little to be learned from this grave gentleman that was not expressed in the language he used. He was inclined, Archie thought, to reticence, for when there was a lull in the conversation it was always one of the others who had to start it going. The thing that might be counted a substantial gain, out of the whole affair, was an invitation to dinner for the following Wednesday, in which Mr. Roseleaf was included, and Mr. Boggs also.

Before the Wednesday set for the formal dinner at the Ferns', Mr. Weil had heard the whole of Miss Millicent's novel read by the lips of that charming young woman. There was certainly something very strong in it, in spite of its grammatical faults. It would be a very good story when "Dr." Roseleaf had put it into a little better English.

The meeting between Roseleaf and Millicent was most interesting to the one who had been the means of bringing them together. The girl put out her hand with a straightforward motion of welcome, and it was accepted with something resembling timidity by the young man, who did not even raise his eyes to hers. The talk that followed was nearly all her own, Shirley's part in it being largely monosyllabic replies to her statements and suggestions.

When Miss Daisy was presented to both the gentlemen, for the first time--Mr. Boggs she remembered very well--she drew their attention for a few moments from her sister, but soon relapsed into the more insignificant place which she seemed to prefer. She was not as large in any way, as Millicent, and did not seem likely to become so. Her hair was of a soft shade of light brown, and her eyes a decided blue. In the presence of her sister she did not expect to shine, and was evidently relieved when she could go into a corner and talk over times long past with Walker Boggs.

Mr. Fern came in rather late, but still before the hour announced for dinner. He had his habitual look of quiet elegance, but withal an expression of care about his face, that Weil attributed to the business troubles of which Boggs had spoken. The manner of the

daughters toward him was marked by the watchful eyes of the chief conspirator. Millicent merely looked up and said, "Papa, this is Mr. Roseleaf, of whom we have spoken," and then when the greetings that followed were exchanged, went on talking with those about her as if there had been no interruption. Daisy, on the other hand, crept softly to her father's side, and putting an arm around his neck, kissed him when she thought no one observed her.

"You are tired, papa," she whispered.

"No, no!" he said, brightening. "I am very well."

It was at the table that Mr. Fern had his first conversation with Roseleaf, and the two men got along nicely together. Shirley acquitted himself creditably. Weil, who saw everything, noticed that the negro, Hannibal, in superintending the service in the dining-room, lingered more about Miss Daisy's chair than any other, and took extra pains to see that her wants were anticipated. In spite of this, however, Mr. Fern frequently asked his younger daughter to have more of certain dishes, as if his mind was constantly turned in that direction.

"How long do you think it will require to do the work you have so generously undertaken?" asked Mr. Fern of Roseleaf, when the dessert was reached.

"It is impossible to say," stammered the young man. "Some weeks, at least."

"So I supposed," said Mr. Fern. "That being the case I wish to tender you the hospitality of my home. It would be a great deal of trouble for you to come every day from the city, and I know we could make you comfortable here."

Roseleaf was about to decline the offer with thanks, when Mr. Weil spoke to him in a low tone.

"Take it, by all means," he said. "It's a chance in a lifetime. You know nothing of family life. Don't dream of refusing."

The delay allowed Miss Millicent to add her request to that of her father, and fearing to let his protege answer, Mr. Weil boldly spoke for him.

"It is a good idea," he said. "He will have his baggage brought up to-morrow. There's nothing like being on the ground, when there's work to be done. And, with the general permission, I am going to run out pretty often myself, to see how things progress."

The bright, off-hand way of the last speaker seemed to please Mr. Fern, for he heartily seconded this suggestion. When the table was vacated, Mr. Fern asked if he might be excused for a few minutes, while he wrote a couple of important letters, and requested Walker Boggs to show the guests through the grounds, where they could smoke their cigars till he returned.

Accordingly Weil and Roseleaf accompanied their new guide out of doors and across an extensive lawn to an arbor at the further end, where a handsome prospect of the Hudson unfolded itself. As Archie was wishing for some feasible way of getting rid of Boggs, temporarily, that gentleman espied an acquaintance in the adjacent road and went off to speak to him.

"Are you in love yet, you dog?" asked Archie, as soon as he and his young friend were alone. "What! You're not! Don't let an hour pass, then, before you are. The best of all proverbs is, 'Never put off till to-morrow what you can do to-day.'"

"How can I do this to-day?" was the doleful response.

"How can you help it, you mean? There she was at the table--Titian hair,The Project Gutenberg eBook of Narrative of the Life of Frederick Douglass, an American Slave

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Table of Contents ----------

Sojourner Truth, the Libyan Sibyl.....Harriet Beecher Stowe Reconstruction.....Frederick Douglass An Appeal to Congress for Impartial Suffrage..Frederick Douglas The Negro Exodus.....James B. Runnion My Escape from Slavery.....Frederick Douglass The Goophered Grapevine.....Charles W. Chesnutt Po' Sandy.....Charles W. Chesnutt Dave's Neckliss.....Charles W. Chesnutt The Awakening of the Negro.....Booker T. Washington The Story of Uncle Tom's Cabin.....Charles Dudley Warner Strivings of the Negro People.....W. E. Burghardt Du Bois The Wife of his Youth.....Charles W. Chesnutt The Bouquet.....Charles W. Chesnutt The Case of the Negro.....Booker T. Washington Hot-Foot

Hannibal.....Charles W. Chesnutt A Negro Schoolmaster in the New South.....W. E. Burghardt Du Bois The Capture of a Slaver.....J. Taylor Wood Mr. Charles W. Chesnutt's Stories.....W. D. Howells Paths of Hope for the Negro Practical Suggestions of a Southerner.....Jerome Dowd Signs of Progress Among the Negroes.....Booker T. Washington The March of Progress.....Charles W. Chesnutt The Freedmen's Bureau.....W. E. Burghardt Du Bois Of the Training of Black Men.....W. E. Burghardt Du Bois The Fruits of Industrial Training.....Booker T. Washington The Negro in the Regular Army.....Oswald Garrison Villard Baxter's Procrustes.....Charles W. Chesnutt The Heart of the Race Problem.....Quincy Ewing Negro Suffrage in a Democracy.....Ray Stannard Baker

Bibliography of Sources

SOJOURNER TRUTH, THE LIBYAN SIBYL by Harriet Beecher Stowe

Many years ago, the few readers of radical Abolitionist papers must often have seen the singular name of Sojourner Truth, announced as a frequent speaker at Anti-Slavery meetings, and as travelling on a sort of self-appointed agency through the country. I had myself often remarked the name, but never met the individual. On one occasion, when our house was filled with company, several eminent clergymen being our guests, notice was brought up to me that Sojourner Truth was below, and requested an interview. Knowing nothing of her but her singular name, I went down, prepared to make the interview short, as the pressure of many other engagements demanded.

When I went into the room, a tall, spare form arose to meet me. She was evidently a full-blooded African, and though now aged and worn with many hardships, still gave the impression of a physical development which in early youth must have been as fine a specimen of the torrid zone as Cumberworth's celebrated statuette of the Negro Woman at the Fountain. Indeed, she so strongly reminded me of that figure, that, when I recall the events of her life, as she narrated them to me, I imagine her as a living, breathing impersonation of that work of art.

I do not recollect ever to have been conversant with any one who had more of that silent and subtle power which we call personal presence than this woman. In the modern Spiritualistic phraseology, she would be described as having a strong sphere. Her tall form, as she rose up before me, is still vivid to my mind. She was dressed in some stout, grayish stuff, neat and clean, though dusty from travel. On her head, she wore a bright Madras handkerchief, arranged as a turban, after the manner of her race. She seemed perfectly self-possessed and at her ease,--in fact, there was almost an unconscious superiority, not unmixed with a solemn twinkle of humor, in the odd, composed manner in which she looked down on me. Her whole air had at times a gloomy sort of drollery which impressed one strangely.

"So this is YOU," she said.

"Yes," I answered.

"Well, honey, de Lord bless ye! I jes' thought I'd like to come an' have a look at ye. You's heerd o' me, I reckon?" she added.

"Yes, I think I have. You go about lecturing, do you not?"

"Yes, honey, that's what I do. The Lord has made me a sign unto this nation, an' I go round a'testifyin', an' showin' on 'em their sins agin my people."

So saying, she took a seat, and, stooping over and crossing her arms on her knees, she looked down on the floor, and appeared to fall into a sort of reverie. Her great gloomy eyes and her dark face seemed to work with some undercurrent of feeling; she sighed deeply, and occasionally broke out,--

"O Lord! O Lord! Oh, the tears, an' the groans, an' the moans! O Lord!"

I should have said that she was accompanied by a little grandson of ten years,--the fattest, jolliest woolly-headed little specimen of Africa that one can imagine. He was grinning and showing his glistening white teeth in a state of perpetual merriment, and at this moment broke out into an audible giggle, which disturbed the reverie into which his relative was falling.

She looked at him with an indulgent sadness, and then at me.

"Laws, Ma'am, HE don't know nothin' about it--HE don't. Why, I've seen them poor critters, beat an' 'bused an' hunted, brought in all torn,--ears hangin' all in rags, where the dogs been a'bitin' of 'em!"

This set off our little African Puck into another giggle, in which he seemed perfectly convulsed.

She surveyed him soberly, without the slightest irritation.

"Well, you may bless the Lord you CAN laugh; but I tell you, 't wa'n't no laughin' matter."

By this time I thought her manner so original that it might be worth while to call down my friends; and she seemed perfectly well pleased with the idea. An audience was what she wanted,--it mattered not whether high or low, learned or ignorant. She had things to say, and was ready to say them at all times, and to any one.

I called down Dr. Beecher, Professor Allen, and two or three other clergymen, who, together with my husband and family, made a roomful. No princess could have received a drawing-room with more composed dignity than Sojourner her audience. She stood among them, calm and erect, as one of her own native palm-trees waving alone in the desert. I presented one after another to her, and at last said,--

"Sojourner, this is Dr. Beecher. He is a very celebrated preacher."

"IS he?" she said, offering her hand in a condescending manner, and looking down on his white head. "Ye dear lamb, I'm glad to see ye! De Lord bless ye! I loves preachers. I'm a kind o' preacher myself."

"You are?" said Dr. Beecher. "Do you preach from the Bible?"

"No, honey, can't preach from de Bible,--can't read a letter."

"Why, Sojourner, what do you preach from, then?"

Her answer was given with a solemn power of voice, peculiar to herself, that hushed every one in the room.

"When I preaches, I has jest one text to preach from, an' I always preaches from this one. MY text is, 'WHEN I FOUND JESUS.'"

"Well, you couldn't have a better one," said one of the ministers.

She paid no attention to him, but stood and seemed swelling with her own thoughts, and then began this narration:--

"Well, now, I'll jest have to go back, an' tell ye all about it. Ye see, we was all brought over from Africa, father an' mother an' I, an' a lot more of us; an' we was sold up an' down, an' hither an' yon; an' I can 'member, when I was a little thing, not bigger than this 'ere," pointing to her grandson, "how my ole mammy would sit out o' doors in the evenin', an' look up at the stars an' groan. She'd groan an' groan, an' says I to her,--

"'Mammy, what makes you groan so?'

"an' she'd say,--

"'Matter enough, chile! I'm groanin' to think o' my poor children: they don't know where I be, an' I don't know where they be; they looks up at the stars, an' I looks up at the stars, but I can't tell where they be.

"'Now,' she said, 'chile, when you're grown up, you may be sold away from your mother an' all your ole friends, an' have great troubles come on ye; an' when you has these troubles come on ye, ye jes' go to God, an' He'll help ye.'

"An' says I to her,--

"'Who is God, anyhow, mammy?'

"An' says she,--

"'Why, chile, you jes' look up DAR! It's Him that made all DEM!"

"Well, I didn't mind much 'bout God in them days. I grew up pretty lively an' strong, an' could row a boat, or ride a horse, or work round, an' do 'most anything.

"At last I got sold away to a real hard massa an' missis. Oh, I tell you, they WAS hard! 'Peared like I couldn't please 'em, nohow. An' then I thought o' what my old mammy told me about God; an' I thought I'd got into trouble, sure enough, an' I wanted to find God, an' I heerd some one tell a story about a man that met God on a threshin'-floor, an' I thought, 'Well an' good, I'll have a threshin'-floor, too.' So I went down in the lot, an' I threshed down a place real hard, an' I used to go down there every day, an' pray an' cry with all my might, a-prayin' to the Lord to make my massa an' missis better, but it didn't seem to do no good; an' so says I, one day,--

"'O God, I been a-askin' ye, an' askin' ye, an' askin' ye, for all this long time, to make my massa an' missis better, an' you don't do it, an' what CAN be the reason? Why, maybe you CAN'T. Well, I shouldn't wonder ef you couldn't. Well, now, I tell you, I'll make a bargain with you. Ef you'll help me to git away from my massa an' missis, I'll agree to be good; but ef you don't help me, I really don't think I can be. Now,' says I, 'I want to git away; but the trouble's jest here: ef I try to git away in the night, I can't see; an' ef I try to git away in the daytime, they'll see me, an' be after me.'

"Then the Lord said to me, 'Git up two or three hours afore daylight, an' start off.'

"An' says I, 'Thank 'ee, Lord! that's a good thought.'

"So up I got, about three o'clock in the mornin', an' I started an' travelled pretty fast, till, when the sun rose, I was clear away from our place an' our folks, an' out o' sight. An' then I begun to think I didn't know nothin' where to go. So I kneeled down, and says I,--

"'Well, Lord, you've started me out, an' now please to show me where to go.'

"Then the Lord made a house appear to me, an' He said to me that I was to walk on till I saw that house, an' then go in an' ask the people to take me. An' I travelled all day, an' didn't come to the house till late at night; but when I saw it, sure enough, I went in, an' I told the folks that the Lord sent me; an' they was Quakers, an' real kind they was to me. They jes' took me in, an' did for me as kind as ef I'd been one of 'em; an' after they'd giv me supper, they took me into a room where there was a great, tall, white bed; an' they told me to sleep there. Well, honey, I was kind o' skeered when they left me alone with that great white bed; 'cause I never had been in a bed in my life. It never came into my mind they could mean me to sleep in it. An' so I jes' camped down under it, on the floor, an' then I slep' pretty well. In the mornin', when they came in, they asked me ef I hadn't been asleep; an' I said, 'Yes, I never slep' better.' An' they said, 'Why, you haven't been in the bed!' An' says I, 'Laws, you didn't think o' such a thing as my sleepin' in dat 'ar' BED, did you? I never heerd o' such a thing in my life.'

"Well, ye see, honey, I stayed an' lived with 'em. An' now jes' look here: instead o' keepin' my promise an' bein' good, as I told the Lord I would, jest as soon as everything got a'goin' easy, I FORGOT ALL ABOUT GOD.

"Pretty well don't need no help; an' I gin up prayin.' I lived there two or three years, an' then the slaves in New York were all set free, an' ole massa came to our home to make a visit, an' he asked me ef I didn't want to go back an' see the folks on the ole place. An' I told him I did. So he said, ef I'd jes' git into the wagon with him, he'd carry me over. Well, jest as I was goin' out to git into the wagon, I MET GOD! an' says I, 'O God, I didn't know as you was so great!' An' I turned right round an' come into the house, an' set down in my room; for 't was God all around me. I could feel it burnin', burnin', burnin' all around me, an' goin' through me; an' I saw I was so wicked, it seemed as ef it would burn me up. An' I said, 'O somebody, somebody, stand between God an' me! for it burns me!' Then, honey, when I said so, I felt as it were somethin' like an amberill [umbrella] that came between me an' the light, an' I felt it was SOMEBODY,--somebody that stood between me an' God; an' it felt cool, like a shade; an' says I, 'Who's this that stands between me an' God? Is it old Cato?' He was a pious old preacher; but then I seemed to see Cato in the light, an' he was all polluted an' vile, like me; an' I said, 'Is it old Sally?' an' then I saw her, an' she seemed jes' so. An' then says I, 'WHO is this?' An' then, honey, for a while it was like the sun shinin' in a pail o' water, when it moves up an' down; for I begun to feel 't was somebody that loved me; an' I tried to know him. An' I said, 'I know you! I know you! I know you!'--an' then I said, 'I don't know you! I don't know you! I don't know you!' An' when I said, 'I know you, I know you,' the light came; an' when I said, 'I don't know you, I don't know you,' it went, jes' like the sun in a pail o' water. An' finally somethin' spoke out in me an' said, 'THIS IS JESUS!' An' I spoke out with all my might, an' says I, 'THIS IS JESUS! Glory be to God!' An' then the whole world grew bright, an' the trees they waved an' waved in glory, an' every little bit o' stone on the ground shone like glass; an' I shouted an' said, 'Praise, praise, praise to the Lord!' An' I begun to feel such a love in my soul as I never felt before,--love to all creatures. An' then, all of a sudden, it stopped, an' I said, 'Dar's de white folks, that have abused you an' beat you an' abused your people,--think o' them!' But then there came another rush of love through my soul, an' I cried out loud,--'Lord, Lord, I can love EVEN DE WHITE FOLKS!'

"Honey, I jes' walked round an' round in a dream. Jesus loved me! I knowed it,--I felt it. Jesus was my Jesus. Jesus would love me always. I didn't dare tell nobody; 't was a great secret. Everything had been got away from me that I ever had; an' I thought that ef I let white folks know about this, maybe they'd get HIM away,--so I said, 'I'll keep this close. I won't let any one know.'"

"But, Sojourner, had you never been told about Jesus Christ?"

"No, honey. I hadn't heerd no preachin',--been to no meetin'. Nobody hadn't told me. I'd kind o' heerd of Jesus, but thought he was like Gineral Lafayette, or some o' them. But one night there was a Methodist meetin' somewhere in our parts, an' I went; an' they got up an' begun for to tell der 'speriences; an' de fust one begun to speak. I started, 'cause he told about Jesus. 'Why,' says I to myself, 'dat man's found him, too!' An' another got up an' spoke, an I said, 'He's found him, too!' An' finally I said, 'Why, they all know him!' I was so happy! An' then they sung this hymn": (Here Sojourner sang, in a strange, cracked voice, but evidently with all her soul and might, mispronouncing the English, but seeming to derive as much elevation and comfort from bad English as from good):--

'There is a holy city, A world of light above, Above the stairs and regions,* Built by the God of Love.

"An Everlasting temple, And saints arrayed in white There serve their great Redeemer And dwell with him in light.

"The meanest child of glory Outshines the radiant sun; But who can speak the splendor Of Jesus on his throne?

"Is this the man of sorrows Who stood at Pilate's bar, Condemned by haughty Herod And by his men of war?

"He seems a mighty conqueror, Who spoiled the powers below, And ransomed many captives From everlasting woe.

"The hosts of saints around him Proclaim his work of grace, The patriarchs and prophets, And all the godly race,

"Who speak of fiery trials And tortures on their way; They came from tribulation To everlasting day.

"And what shall be my journey, How long I'll stay below, Or what shall be my trials, Are not for me to know.

"In every day of trouble I'll raise my thoughts on high, I'll think of that bright temple And crowns above the sky."

* Starry regions.

I put in this whole hymn, because Sojourner, carried away with her own feeling, sang it from beginning to end with a triumphant energy that held the whole circle around her intently listening. She sang with the strong barbaric accent of the native African, and with those indescribable upward turns and those deep gutturals which give such a wild, peculiar power to the negro singing,--but above all, with such an overwhelming energy of personal appropriation that the hymn seemed to be fused in the furnace of her feelings and come out recrystallized as a production of her own.

It is said that Rachel was wont to chant the "Marseillaise" in a manner that made her seem, for the time, the very spirit and impersonation of the gaunt, wild, hungry, avenging mob which rose against aristocratic oppression; and in like manner, Sojourner, singing this hymn, seemed to impersonate the fervor of Ethiopia, wild, savage, hunted of all nations, but burning after God in her tropic heart, and stretching her scarred hands towards the glory to be revealed.

"Well, den ye see, after a while, I thought I'd go back an' see de folks on de ole place. Well, you know, de law had passed dat de culled folks was all free; an' my old missis, she had a daughter married about dis time who went to live in Alabama,--an' what did she do but give her my son, a boy about de age of dis yer, for her to take down to Alabama? When I got back to de ole place, they told me about it, an' I went right up to see ole missis, an' says I,--

"'Missis, have you been an' sent my son away down to Alabama?'

"'Yes, I have,' says she; 'he's gone to live with your young missis.'

"'Oh, Missis,' says I, 'how could you do it?'

"'Poh!' says she, 'what a fuss you make about a little nigger! Got more of 'em now than you know what to do with.'

"I tell you, I stretched up. I felt as tall as the world!

"'Missis,' says I, 'I'LL HAVE MY SON BACK AGIN!'

"She laughed.

"'YOU will, you nigger? How you goin' to do it? You ha'n't got no money."

"'No, Missis,--but GOD has,--an' you'll see He'll help me!'--an' I turned round an' went out.

"Oh, but I WAS angry to have her speak to me so haughty an' so scornful, as ef my chile wasn't worth anything. I said to God, 'O Lord, render unto her double!' It was a dreadful prayer, an' I didn't know how true it would come.

"Well, I didn't rightly know which way to turn; but I went to the Lord, an' I said to Him, 'O Lord, ef I was as rich as you be, an' you was as poor as I be, I'd help you,--you KNOW I would; and, oh, do help me!' An' I felt sure then that He would.

"Well, I talked with people, an' they said I must git the case before a grand jury. So I went into the town when they was holdin' a court, to see ef I could find any grand jury. An' I stood round the court-house, an' when they was a-comin' out, I walked right up to the grandest-lookin' one I could see, an' says I to him,--

"'Sir, be you a grand jury?'

"An' then he wanted to know why I asked, an' I told him all about it; an' he asked me all sorts of questions, an' finally he says to me,--

"'I think, ef you pay me ten dollars, that I'd agree to git your son for you.' An' says he, pointin' to a house over the way, 'You go 'long an' tell your story to the folks in that house, an' I guess they'll give you the money.'

"Well, I went, an' I told them, an' they gave me twenty dollars; an' then I thought to myself, 'Ef ten dollars will git him, twenty dollars will git him SARTIN.' So I carried it to the man all out, an' said,--

"'Take it all,--only be sure an' git him.'

"Well, finally they got the boy brought back; an' then they tried to frighten him, an' to make him say that I wasn't his mammy, an' that he didn't know me; but they couldn't make it out. They gave him to me, an' I took him an' carried him home; an' when I came to take off his clothes, there was his poor little back all covered with scars an' hard lumps, where they'd flogged him.

"Well, you see, honey, I told you how I prayed the Lord to render unto her double. Well, it came true; for I was up at ole missis' house not long after, an' I heerd 'em readin' a letter to her how her daughter's husband had murdered her,--how he'd thrown her down an' stamped the life out of her, when he was in liquor; an' my ole missis, she giv a screech, an' fell flat on the floor. Then says I, 'O Lord, I didn't mean all that! You took me up too quick.'

"Well, I went in an' tended that poor critter all night. She was out of her mind,--a-cryin', an' callin' for her daughter; an' I held her poor ole head on my arm, an' watched for her as ef she'd been my babby. An' I watched by her, an' took care on her all through her sickness after that, an' she died in my arms, poor thing!"

"Well, Sojourner, did you always go by this name?"

"No, 'deed! My name was Isabella; but when I left the house of bondage, I left everything behind. I wa'n't goin' to keep nothin' of Egypt on me, an' so I went to the Lord an' asked Him to give me a new name. And the Lord gave me Sojourner, because I was to travel up an' down the land, showin' the people their sins, an' bein' a sign unto them. Afterwards I told the Lord I wanted another name, 'cause everybody else had two names; and the Lord gave me Truth, because I was to declare the truth to the people.

"Ye see some ladies have given me a white satin banner," she said, pulling out of her pocket and unfolding a white banner, printed with many texts, such as, "Proclaim liberty throughout all the land unto all the inhabitants thereof," and others of like nature. "Well," she said, "I journeys round to camp-meetins, an' wherever folks is, an' I sets up my banner, an' then I sings, an' then folks always comes up round me, an' then I preaches to 'em. I tells 'em about Jesus, an' I tells 'em about the sins of this people. A great many always comes to hear me; an' they're right good to me, too, an' say they want to hear me agin."

We all thought it likely; and as the company left her, they shook hands with her, and thanked her for her very original sermon; and one of the ministers was overheard to say to another, "There's more of the gospel in that story than in most sermons."

Sojourner stayed several days with us, a welcome guest. Her conversation was so strong, simple, shrewd, and with such a droll flavoring of humor, that the Professor was wont to say of an evening, "Come, I am dull, can't you get Sojourner up here to talk a little?" She would come up into the parlor, and sit among pictures and ornaments, in her simple stuff gown, with her heavy travelling-shoes, the central object of attention both to parents and children, always ready to talk or to sing, and putting into the common flow of conversation the keen edge of some shrewd remark.

"Sojourner, what do you think of Women's Rights?"

"Well, honey, I's ben to der meetins, an' harked a good deal. Dey wanted me for to speak. So I got up. Says I,--'Sisters, I a'n't clear what you'd be after. Ef women want any rights more 'n dey's got, why don't dey jes' TAKE 'EM, an' not be talkin' about it?' Some on 'em came round me, an' asked why I didn't wear Bloomers. An' I told 'em I had Bloomers enough when I was in bondage. You see," she said, "dey used to weave what dey called nigger-cloth, an' each one of us got jes' sech a strip, an' had to wear it width-wise. Them that was short got along pretty well, but as for me"--She gave an indescribably droll glance at her long limbs and then at us, and added,--"Tell YOU, I had enough of Bloomers in them days."

Sojourner then proceeded to give her views of the relative capacity of the sexes, in her own way.

"S'pose a man's mind holds a quart, an' a woman's don't hold but a pint; ef her pint is FULL, it's as good as his quart."

Sojourner was fond of singing an extraordinary lyric, commencing,--

"I'm on my way to Canada, That cold, but happy land; The dire effects of Slavery I can no longer stand. O righteous Father, Do look down on me, And help me on to Canada, Where colored folks are free!"

The lyric ran on to state, that, when the fugitive crosses the Canada line,

"The Queen comes down unto the shore, With arms extended wide, To welcome the poor fugitive Safe onto Freedom's side."

In the truth thus set forth she seemed to have the most simple faith.

But her chief delight was to talk of "glory," and to sing hymns whose burden was,--

"O glory, glory, glory, Won't you come along with me?"

and when left to herself, she would often hum these with great delight, nodding her head.

On one occasion, I remember her sitting at a window singing and fervently keeping time with her head, the little black Puck of a grandson meanwhile amusing himself with ornamenting her red-and-yellow turban with green dandelion-curls, which shook and trembled with her emotions, causing him perfect convulsions of delight.

"Sojourner," said the Professor to her, one day, when he heard her singing, "you seem to be very sure about heaven."

"Well, I be," she answered, triumphantly.

"What makes you so sure there is any heaven?"

"Well, 'cause I got such a hankerin' arter it in here," she said,--giving a thump on her breast with her usual energy.

There was at the time an invalid in the house, and Sojourner, on learning it, felt a mission to go and comfort her. It was curious to see the tall, gaunt, dusky figure stalk up to the bed with such an air of conscious authority, and take on herself the office of consoler with such a mixture of authority and tenderness. She talked as from above,--and at the same time, if a pillow needed changing or any office to be rendered, she did it with a strength and handiness that inspired trust. One felt as if the dark, strange woman were quite able to take up the invalid in her bosom, and bear her as a lamb, both physically and spiritually. There was both power and sweetness in that great warm soul and that vigorous frame.

At length, Sojourner, true to her name, departed. She had her mission elsewhere. Where now she is I know not; but she left deep memories behind her.

To these recollections of my own I will add one more anecdote, related by Wendell Phillips.

Speaking of the power of Rachel to move and bear down a whole audience by a few simple words, he said he never knew but one other human being that had that power, and that other was Sojourner Truth. He related a scene of which he was witness. It was at a crowded public meeting in Faneuil Hall, where Frederick Douglas was one of the chief speakers. Douglas had been describing the wrongs of the black race, and as he proceeded, he grew more and more excited, and finally ended by saying that they had no hope of justice from the whites, no possible hope except in their own right arms. It must come to blood; they must fight for themselves, and redeem themselves, or it would never be done.

Sojourner was sitting, tall and dark, on the very front seat, facing the platform; and in the hush of deep feeling, after Douglas sat down, she spoke out in her deep, peculiar voice, heard all over the house,--

"Frederick, IS GOD DEAD?"

The effect was perfectly electrical, and thrilled through the whole house, changing as by a flash the whole feeling of the audience. Not another word she said or needed to say; it was enough.

It is with a sad feeling that one contemplates noble minds and bodies, nobly and grandly formed human beings, that have come to us cramped, scarred, maimed, out of the prison-house of bondage. One longs to know what such beings might have become, if suffered to unfold and expand under the kindly developing influences of education.

It is the theory of some writers, that to the African is reserved, in the later and palmier days of the earth, the full and harmonious development of the religious element in man. The African seems to seize on the tropical fervor and luxuriance of Scripture imagery as something native; he appears to feel himself to be of the same blood with those old burning, simple souls, the patriarchs, prophets, and seers, whose impassioned words seem only grafted as foreign plants on the cooler stock of the Occidental mind.

I cannot but think that Sojourner with the same culture might have spoken words as eloquent and undying as those of the African Saint Augustine or Tertullian. How grand and queenly a woman she might have been, with her wonderful physical vigor, her great heaving sea of emotion, her power of spiritual conception, her quick penetration, and her boundless energy! We might conceive an African type of woman so largely made and moulded, so much fuller in all the elements of life, physical and spiritual, that the dark hue of the skin should seem only to add an appropriate charm,--as Milton says of his Penseroso, whom he imagines

"Black, but such as in esteem Prince Memnon's sister might beseem, Or that starred Ethiop queen that strove To set her beauty's praise above The sea-nymph's."

But though Sojourner Truth has passed away from among us as a wave of the sea, her memory still lives in one of the loftiest and most original works of modern art, the Libyan Sibyl, by Mr. Story, which attracted so much attention in the late World's Exhibition. Some years ago, when visiting Rome, I related Sojourner's history to Mr. Story at a breakfast at his house. Already had his mind begun to turn to Egypt in search of a type of art which should represent a larger and more vigorous development of nature than the cold elegance of Greek lines. His glorious Cleopatra was then in process of evolution, and his mind was working out the problem of her broadly developed nature, of all that slumbering weight and fulness of passion with which this statue seems charged, as a heavy thunder-cloud is charged with electricity.

The history of Sojourner Truth worked in his mind and led him into the deeper recesses of the African nature,--those unexplored depths of being and feeling, mighty and dark as the gigantic depths of tropical forests, mysterious as the hidden rivers and mines of that burning continent whose life-history is yet to be. A few days after, he told me that he had conceived the idea of a statue which he should call the Libyan Sibyl. Two years subsequently, I revisited Rome, and found the gorgeous Cleopatra finished, a thing to marvel at, as the creation of a new style of beauty, a new manner of art. Mr. Story requested me to come and repeat to him the history of Sojourner Truth, saying that the conception had never left him. I did so; and a day or two after, he showed me the clay model of the Libyan Sibyl. I have never seen the marble statue; but am told by those who have, that it was by far the most impressive work of art at the Exhibition.

A notice of the two statues from the London "Athenaeum" must supply a description which I cannot give.

"The Cleopatra and the Sibyl are seated, partly draped, with the characteristic Egyptian gown, that gathers about the torso and falls freely around the limbs; the first is covered to the bosom, the second bare to the hips. Queenly Cleopatra rests back against her chair in meditative ease, leaning her cheek against one hand, whose elbow the rail of the seat sustains; the other is outstretched upon her knee, nipping its forefinger upon the thumb thoughtfully, as though some firm, wilful purpose filled her brain, as it seems to

set those luxurious features to a smile as if the whole woman 'would.' Upon her head is the coif, bearing in front the mystic uraeus, or twining basilisk of sovereignty, while from its sides depend the wide Egyptian lappels, or wings, that fall upon her shoulders. The Sibilla Libica has crossed her knees,--an action universally held amongst the ancients as indicative of reticence or secrecy, and of power to bind. A secret-keeping looking dame she is, in the full-bloom proportions of ripe womanhood, wherein choosing to place his figure the sculptor has deftly gone between the disputed point whether these women were blooming and wise in youth, or deeply furrowed with age and burdened with the knowledge of centuries, as Virgil, Livy, and Gellius say. Good artistic example might be quoted on both sides. Her forward elbow is propped upon one knee; and to keep her secrets close, for this Libyan woman is the closest of all the Sibyls, she rests her shut mouth upon one closed palm, as if holding the African mystery deep in the brooding brain that looks out through mournful, warning eyes, seen under the wide shade of the strange horned (ammonite) crest, that bears the mystery of the Tetragrammaton upon its upturned front. Over her full bosom, mother of myriads as she was, hangs the same symbol. Her face has a Nubian cast, her hair wavy and plaited, as is meet."

We hope to see the day when copies both of the Cleopatra and the Libyan Sibyl shall adorn the Capitol at Washington.

RECONSTRUCTION by Frederick Douglass

The assembling of the Second Session of the Thirty-ninth Congress may very properly be made the occasion of a few earnest words on the already much-worn topic of reconstruction.

Seldom has any legislative body been the subject of a solicitude more intense, or of aspirations more sincere and ardent. There are the best of reasons for this profound interest. Questions of vast moment, left undecided by the last session of Congress, must be manfully grappled with by this. No political skirmishing will avail. The occasion demands statesmanship.

Whether the tremendous war so heroically fought and so victoriously ended shall pass into history a miserable failure, barren of permanent results,--a scandalous and shocking waste of blood and treasure,--a strife for empire, as Earl Russell characterized it, of no value to liberty or civilization,--an attempt to re-establish a Union by force, which must be the merest mockery of a Union,--an effort to bring under Federal authority States into which no loyal man from the North may safely enter, and to bring men into the national councils who deliberate with daggers and vote with revolvers, and who do not even conceal their deadly hate of the country that conquered them; or whether, on the other hand, we shall, as the rightful reward of victory over treason, have a solid nation, entirely delivered from all contradictions and social antagonisms, based upon loyalty, liberty, and equality, must be determined one way or the other by the present session of Congress. The last session really did nothing which can be considered final as to these questions. The Civil Rights Bill and the Freedmen's Bureau Bill and the proposed constitutional amendments, with the amendment already adopted and recognized as the law of the land, do not reach the difficulty, and cannot, unless the whole structure of the government is changed from a government by States to something like a despotic central government, with power to control even the municipal regulations of States, and to make them conform to its own despotic will. While there remains such an idea as the right of each State to control its own local affairs,--an idea, by the way, more deeply rooted in the minds of men of all sections of the country than perhaps any one other political idea,--no general assertion of human rights can be of any practical value. To change the character of the government at this point is neither possible nor desirable. All that is necessary to be done is to make the government consistent with itself, and render the rights of the States compatible with the sacred rights of human nature.

The arm of the Federal government is long, but it is far too short to protect the rights of individuals in the interior of distant States. They must have the power to protect themselves, or they will go unprotected, spite of all the laws the Federal government can put upon the national statute-book.

Slavery, like all other great systems of wrong, founded in the depths of human selfishness, and existing for ages, has not neglected its own conservation. It has steadily exerted an influence upon all around it favorable to its own continuance. And to-day it is so strong that it could exist, not only without law, but even against law. Custom, manners, morals, religion, are all on its side everywhere in the South; and when you add the ignorance and servility of the ex-slave to the intelligence and accustomed authority of the master, you have the conditions, not out of which slavery will again grow, but under which it is impossible for the Federal government to wholly destroy it, unless the Federal government be armed with despotic power, to blot out State authority, and to station a Federal officer at every cross-road. This, of course, cannot be done, and ought not even if it could. The true way and the easiest way is to make our government entirely consistent with itself, and give to every loyal citizen the elective franchise,--a right and power which will be ever present, and will form a wall of fire for his protection.

One of the invaluable compensations of the late Rebellion is the highly instructive disclosure it made of the true source of danger to republican government. Whatever may be tolerated in monarchical and despotic governments, no republic is safe that tolerates a privileged class, or denies to any of its citizens equal rights and equal means to maintain them. What was theory before the war has been made fact by the war.

There is cause to be thankful even for rebellion. It is an impressive teacher, though a stern and terrible one. In both characters it has come to us, and it was perhaps needed in both. It is an instructor never a day before its time, for it comes only when all other means of progress and enlightenment have failed. Whether the oppressed and despairing bondman, no longer able to repress his deep yearnings for manhood, or the tyrant, in his pride and impatience, takes the initiative, and strikes the blow for a firmer hold and a longer lease of oppression, the result is the same,--society is instructed, or may be.

Such are the limitations of the common mind, and so thoroughly engrossing are the cares of common life, that only the few among men can discern through the glitter and dazzle of present prosperity the dark outlines of approaching disasters, even though they may have come up to our very gates, and are already within striking distance. The yawning seam and corroded bolt conceal their defects from the mariner until the storm calls all hands to the pumps. Prophets, indeed, were abundant before the war; but who cares for prophets while their predictions remain unfulfilled, and the calamities of which they tell are masked behind a blinding blaze of national prosperity?

It is asked, said Henry Clay, on a memorable occasion, Will slavery never come to an end? That question, said he, was asked fifty years ago, and it has been answered by fifty years of unprecedented prosperity. Spite of the eloquence of the earnest Abolitionists,--poured out against slavery during thirty years,--even they must confess, that, in all the probabilities of the case, that system of barbarism would have continued its horrors far beyond the limits of the nineteenth century but for the Rebellion, and perhaps only have disappeared at last in a fiery conflict, even more fierce and bloody than that which has now been suppressed.

It is no disparagement to truth, that it can only prevail where reason prevails. War begins where reason ends. The thing worse than rebellion is the thing that causes rebellion. What that thing is, we have been taught to our cost. It remains now to be seen whether we have the needed courage to have that cause entirely removed from the Republic. At any rate, to this grand work of national regeneration and entire purification Congress must now address Itself, with full purpose that the work shall this time be thoroughly done. The deadly upas, root and branch, leaf and fibre, body and sap, must be utterly destroyed. The country is evidently not in a condition to listen patiently to pleas for postponement, however plausible, nor will it permit the responsibility to be shifted to other shoulders. Authority and power are here commensurate with the duty imposed. There are no cloud-flung shadows to obscure the way. Truth shines with brighter light and intenser heat at every moment, and a country torn and rent and bleeding implores relief from its distress and agony.

If time was at first needed, Congress has now had time. All the requisite materials from which to form an intelligent judgment are now before it. Whether its members look at the origin, the progress, the termination of the war, or at the mockery of a peace now existing, they will find only one unbroken chain of argument in favor of a radical policy of reconstruction. For the omissions of the last session, some excuses may be allowed. A treacherous President stood in the way; and it can be easily seen how reluctant good men might be to admit an apostasy which involved so much of baseness and ingratitude. It was natural that they should seek to save him by bending to him even when he leaned to the side of error. But all is changed now. Congress knows now that it must go on without his aid, and even against his machinations. The advantage of the present session over the last is immense. Where that investigated, this has the facts. Where that walked by faith, this may walk by sight. Where that halted, this must go forward, and where that failed, this must succeed, giving the country whole measures where that gave us half-measures, merely as a means of saving the elections in a few doubtful districts. That Congress saw what was right, but distrusted the enlightenment of the loyal masses; but what was forborne in distrust of the people must now be done with a full knowledge that the people expect and require it. The members go to Washington fresh from the inspiring presence of the people. In every considerable public meeting, and in almost every conceivable way, whether at court-house, school-house, or cross-roads, in doors and out, the subject has been discussed, and the people have emphatically pronounced in favor of a radical policy. Listening to the doctrines of expediency and compromise with pity, impatience, and disgust, they have everywhere broken into demonstrations of the wildest enthusiasm when a brave word has been spoken in favor of equal rights and impartial suffrage. Radicalism, so far from being odious, is not the popular passport to power. The men most bitterly charged with it go to Congress with the largest majorities, while the timid and doubtful are sent by lean majorities, or else left at home. The strange controversy between the President and the Congress, at one time so threatening, is disposed of by the people. The high reconstructive powers which he so confidently, ostentatiously, and haughtily

claimed, have been disallowed, denounced, and utterly repudiated; while those claimed by Congress have been confirmed.

Of the spirit and magnitude of the canvass nothing need be said. The appeal was to the people, and the verdict was worthy of the tribunal. Upon an occasion of his own selection, with the advice and approval of his astute Secretary, soon after the members of the Congress had returned to their constituents, the President quitted the executive mansion, sandwiched himself between two recognized heroes,--men whom the whole country delighted to honor,--and, with all the advantage which such company could give him, stumped the country from the Atlantic to the Mississippi, advocating everywhere his policy as against that of Congress. It was a strange sight, and perhaps the most disgraceful exhibition ever made by any President; but, as no evil is entirely unmixed, good has come of this, as from many others. Ambitious, unscrupulous, energetic, indefatigable, voluble, and plausible,--a political gladiator, ready for a "set-to" in any crowd,--he is beaten in his own chosen field, and stands to-day before the country as a convicted usurper, a political criminal, guilty of a bold and persistent attempt to possess himself of the legislative powers solemnly secured to Congress by the Constitution. No vindication could be more complete, no condemnation could be more absolute and humiliating. Unless reopened by the sword, as recklessly threatened in some circles, this question is now closed for all time.

Without attempting to settle here the metaphysical and somewhat theological question (about which so much has already been said and written), whether once in the Union means always in the Union,--agreeably to the formula, Once in grace always in grace,--it is obvious to common sense that the rebellious States stand to-day, in point of law, precisely where they stood when, exhausted, beaten, conquered, they fell powerless at the feet of Federal authority. Their State governments were overthrown, and the lives and property of the leaders of the Rebellion were forfeited. In reconstructing the institutions of these shattered and overthrown States, Congress should begin with a clean slate, and make clean work of it. Let there be no hesitation. It would be a cowardly deference to a defeated and treacherous President, if any account were made of the illegitimate, one-sided, sham governments hurried into existence for a malign purpose in the absence of Congress. These pretended governments, which were never submitted to the people, and from participation in which four millions of the loyal people were excluded by Presidential order, should now be treated according to their true character, as shams and impositions, and supplanted by true and legitimate governments, in the formation of which loyal men, black and white, shall participate.

It is not, however, within the scope of this paper to point out the precise steps to be taken, and the means to be employed. The people are less concerned about these than the grand end to be attained. They demand such a reconstruction as shall put an end to the present anarchical state of things in the late rebellious States,--where frightful murders and wholesale massacres are perpetrated in the very presence of Federal soldiers. This horrible business they require shall cease. They want a reconstruction such as will protect loyal men, black and white, in their persons and property; such a one as will cause Northern industry, Northern capital, and Northern civilization to flow into the South, and make a man from New England as much at home in Carolina as elsewhere in the Republic. No Chinese wall can now be tolerated. The South must be opened to the light of law and liberty, and this session of Congress is relied upon to accomplish this important work.

The plain, common-sense way of doing this work, as intimated at the beginning, is simply to establish in the South one law, one government, one administration of justice, one condition to the exercise of the elective franchise, for men of all races and colors alike. This great measure is sought as earnestly by loyal white men as by loyal blacks, and is needed alike by both. Let sound political prescience but take the place of an unreasoning prejudice, and this will be done.

Men denounce the negro for his prominence in this discussion; but it is no fault of his that in peace as in war, that in conquering Rebel armies as in reconstructing the rebellious States, the right of the negro is the true solution of our national troubles. The stern logic of events, which goes directly to the point, disdaining all concern for the color or features of men, has determined the interests of the country as identical with and inseparable from those of the negro.

The policy that emancipated and armed the negro--now seen to have been wise and proper by the dullest--was not certainly more sternly demanded than is now the policy of enfranchisement. If with the negro was success in war, and without him failure, so in peace it will be found that the nation must fall or flourish with the negro.

Fortunately, the Constitution of the United States knows no distinction between citizens on account of color. Neither does it know any difference between a citizen of a State and a citizen of the United States. Citizenship evidently includes all the rights of citizens, whether State or national. If the Constitution knows none, it is clearly no part of the duty of a Republican Congress now to institute one. The mistake of the last session was the attempt to do this very thing, by a renunciation of its power to secure political rights to any class of citizens, with the obvious purpose to allow the rebellious States to disfranchise, if they should see fit, their colored

citizens. This unfortunate blunder must now be retrieved, and the emasculated citizenship given to the negro supplanted by that contemplated in the Constitution of the United States, which declares that the citizens of each State shall enjoy all the rights and immunities of citizens of the several States,--so that a legal voter in any State shall be a legal voter in all the States.

AN APPEAL TO CONGRESS FOR IMPARTIAL SUFFRAGE by Frederick Douglas

A very limited statement of the argument for impartial suffrage, and for including the negro in the body politic, would require more space than can be reasonably asked here. It is supported by reasons as broad as the nature of man, and as numerous as the wants of society. Man is the only government-making animal in the world. His right to a participation in the production and operation of government is an inference from his nature, as direct and self-evident as is his right to acquire property or education. It is no less a crime against the manhood of a man, to declare that he shall not share in the making and directing of the government under which he lives, than to say that he shall not acquire property and education. The fundamental and unanswerable argument in favor of the enfranchisement of the negro is found in the undisputed fact of his manhood. He is a man, and by every fact and argument by which any man can sustain his right to vote, the negro can sustain his right equally. It is plain that, if the right belongs to any, it belongs to all. The doctrine that some men have no rights that others are bound to respect, is a doctrine which we must banish as we have banished slavery, from which it emanated. If black men have no rights in the eyes of white men, of course the whites can have none in the eyes of the blacks. The result is a war of races, and the annihilation of all proper human relations.

But suffrage for the negro, while easily sustained upon abstract principles, demands consideration upon what are recognized as the urgent necessities of the case. It is a measure of relief,--a shield to break the force of a blow already descending with violence, and render it harmless. The work of destruction has already been set in motion all over the South. Peace to the country has literally meant war to the loyal men of the South, white and black; and negro suffrage is the measure to arrest and put an end to that dreadful strife.

Something then, not by way of argument, (for that has been done by Charles Sumner, Thaddeus Stevens, Wendell Phillips, Gerrit Smith, and other able men,) but rather of statement and appeal.

For better or for worse, (as in some of the old marriage ceremonies,) the negroes are evidently a permanent part of the American population. They are too numerous and useful to be colonized, and too enduring and self-perpetuating to disappear by natural causes. Here they are, four millions of them, and, for weal or for woe, here they must remain. Their history is parallel to that of the country; but while the history of the latter has been cheerful and bright with blessings, theirs has been heavy and dark with agonies and curses. What O'Connell said of the history of Ireland may with greater truth be said of the negro's. It may be "traced like a wounded man through a crowd, by the blood." Yet the negroes have marvellously survived all the exterminating forces of slavery, and have emerged at the end of two hundred and fifty years of bondage, not morose, misanthropic, and revengeful, but cheerful, hopeful, and forgiving. They now stand before Congress and the country, not complaining of the past, but simply asking for a better future. The spectacle of these dusky millions thus imploring, not demanding, is touching; and if American statesmen could be moved by a simple appeal to the nobler elements of human nature, if they had not fallen, seemingly, into the incurable habit of weighing and measuring every proposition of reform by some standard of profit and loss, doing wrong from choice, and right only from necessity or some urgent demand of human selfishness, it would be enough to plead for the negroes on the score of past services and sufferings. But no such appeal shall be relied on here. Hardships, services, sufferings, and sacrifices are all waived. It is true that they came to the relief of the country at the hour of its extremest need. It is true that, in many of the rebellious States, they were almost the only reliable friends the nation had throughout the whole tremendous war. It is true that, notwithstanding their alleged ignorance, they were wiser than their masters, and knew enough to be loyal, while those masters only knew enough to be rebels and traitors. It is true that they fought side by side in the loyal cause with our gallant and patriotic white soldiers, and that, but for their help,--divided as the loyal States were,--the Rebels might have succeeded in breaking up the Union, thereby entailing border wars and troubles of unknown duration and incalculable calamity. All this and more is true of these loyal negroes. Many daring exploits will be told to their credit. Impartial history will paint them as men who deserved well of their country. It will tell how they forded and swam rivers, with what consummate address they evaded the sharp-eyed Rebel pickets, how they toiled in the darkness of night through the tangled marshes of briers and thorns, barefooted and weary, running the risk of losing their lives, to warn our generals of Rebel schemes to surprise and destroy our loyal army. It will tell how these poor people, whose rights we still despised, behaved to our wounded soldiers, when found cold, hungry, and bleeding on the deserted battle-field; how they assisted our escaping prisoners from Andersonville, Belle Isle, Castle Thunder, and elsewhere, sharing with them their wretched crusts, and otherwise affording them aid and comfort; how they promptly responded to the trumpet call for their services, fighting against a foe

that denied them the rights of civilized warfare, and for a government which was without the courage to assert those rights and avenge their violation in their behalf; with what gallantry they flung themselves upon Rebel fortifications, meeting death as fearlessly as any other troops in the service. But upon none of these things is reliance placed. These facts speak to the better dispositions of the human heart; but they seem of little weight with the opponents of impartial suffrage.

It is true that a strong plea for equal suffrage might be addressed to the national sense of honor. Something, too, might be said of national gratitude. A nation might well hesitate before the temptation to betray its allies. There is something immeasurably mean, to say nothing of the cruelty, in placing the loyal negroes of the South under the political power of their Rebel masters. To make peace with our enemies is all well enough; but to prefer our enemies and sacrifice our friends,--to exalt our enemies and cast down our friends,--to clothe our enemies, who sought the destruction of the government, with all political power, and leave our friends powerless in their hands,--is an act which need not be characterized here. We asked the negroes to espouse our cause, to be our friends, to fight for us, and against their masters; and now, after they have done all that we asked them to do,--helped us to conquer their masters, and thereby directed toward themselves the furious hate of the vanquished,--it is proposed in some quarters to turn them over to the political control of the common enemy of the government and of the negro. But of this let nothing be said in this place. Waiving humanity, national honor, the claims of gratitude, the precious satisfaction arising from deeds of charity and justice to the weak and defenceless,--the appeal for impartial suffrage addresses itself with great pertinency to the darkest, coldest, and flintiest side of the human heart, and would wring righteousness from the unfeeling calculations of human selfishness.

For in respect to this grand measure it is the good fortune of the negro that enlightened selfishness, not less than justice, fights on his side. National interest and national duty, if elsewhere separated, are firmly united here. The American people can, perhaps, afford to brave the censure of surrounding nations for the manifest injustice and meanness of excluding its faithful black soldiers from the ballot-box, but it cannot afford to allow the moral and mental energies of rapidly increasing millions to be consigned to hopeless degradation.

Strong as we are, we need the energy that slumbers in the black man's arm to make us stronger. We want no longer any heavy-footed, melancholy service from the negro. We want the cheerful activity of the quickened manhood of these sable millions. Nor can we afford to endure the moral blight which the existence of a degraded and hated class must necessarily inflict upon any people among whom such a class may exist. Exclude the negroes as a class from political rights,--teach them that the high and manly privilege of suffrage is to be enjoyed by white citizens only,--that they may bear the burdens of the state, but that they are to have no part in its direction or its honors,--and you at once deprive them of one of the main incentives to manly character and patriotic devotion to the interests of the government; in a word, you stamp them as a degraded caste,--you teach them to despise themselves, and all others to despise them. Men are so constituted that they largely derive their ideas of their abilities and their possibilities from the settled judgments of their fellow-men, and especially from such as they read in the institutions under which they live. If these bless them, they are blest indeed; but if these blast them, they are blasted indeed. Give the negro the elective franchise, and you give him at once a powerful motive for all noble exertion, and make him a man among men. A character is demanded of him, and here as elsewhere demand favors supply. It is nothing against this reasoning that all men who vote are not good men or good citizens. It is enough that the possession and exercise of the elective franchise is in itself an appeal to the nobler elements of manhood, and imposes education as essential to the safety of society.

To appreciate the full force of this argument, it must be observed, that disfranchisement in a republican government based upon the idea of human equality and universal suffrage, is a very different thing from disfranchisement in governments based upon the idea of the divine right of kings, or the entire subjugation of the masses. Masses of men can take care of themselves. Besides, the disabilities imposed upon all are necessarily without that bitter and stinging element of invidiousness which attaches to disfranchisement in a republic. What is common to all works no special sense of degradation to any. But in a country like ours, where men of all nations, kindred, and tongues are freely enfranchised, and allowed to vote, to say to the negro, You shall not vote, is to deal his manhood a staggering blow, and to burn into his soul a bitter and goading sense of wrong, or else work in him a stupid indifference to all the elements of a manly character. As a nation, we cannot afford to have amongst us either this indifference and stupidity, or that burning sense of wrong. These sable millions are too powerful to be allowed to remain either indifferent or discontented. Enfranchise them, and they become self-respecting and country-loving citizens. Disfranchise them, and the mark of Cain is set upon them less mercifully than upon the first murderer, for no man was to hurt him. But this mark of inferiority--all the more palpable because of a difference of color--not only dooms the negro to be a vagabond, but makes him the prey of insult and outrage everywhere. While nothing may be urged here as to the past services of the negro, it is quite within the line of this appeal to remind the nation of the possibility that a time may come when the services of the negro may be a second time required. History is

said to repeat itself, and, if so, having wanted the negro once, we may want him again. Can that statesmanship be wise which would leave the negro good ground to hesitate, when the exigencies of the country required his prompt assistance? Can that be sound statesmanship which leaves millions of men in gloomy discontent, and possibly in a state of alienation in the day of national trouble? Was not the nation stronger when two hundred thousand sable soldiers were hurled against the Rebel fortifications, than it would have been without them? Arming the negro was an urgent military necessity three years ago,--are we sure that another quite as pressing may not await us? Casting aside all thought of justice and magnanimity, is it wise to impose upon the negro all the burdens involved in sustaining government against foes within and foes without, to make him equal sharer in all sacrifices for the public good, to tax him in peace and conscript him in war, and then coldly exclude him from the ballot-box?

Look across the sea. Is Ireland, in her present condition, fretful, discontented, compelled to support an establishment in which she does not believe, and which the vast majority of her people abhor, a source of power or of weakness to Great Britain? Is not Austria wise in removing all ground of complaint against her on the part of Hungary? And does not the Emperor of Russia act wisely, as well as generously, when he not only breaks up the bondage of the serf, but extends him all the advantages of Russian citizenship? Is the present movement in England in favor of manhood suffrage--for the purpose of bringing four millions of British subjects into full sympathy and co-operation with the British government--a wise and humane movement, or otherwise? Is the existence of a rebellious element in our borders--which New Orleans, Memphis, and Texas show to be only disarmed, but at heart as malignant as ever, only waiting for an opportunity to reassert itself with fire and sword--a reason for leaving four millions of the nation's truest friends with just cause of complaint against the Federal government? If the doctrine that taxation should go hand in hand with representation can be appealed to in behalf of recent traitors and rebels, may it not properly be asserted in behalf of a people who have ever been loyal and faithful to the government? The answers to these questions are too obvious to require statement. Disguise it as we may, we are still a divided nation. The Rebel States have still an anti-national policy. Massachusetts and South Carolina may draw tears from the eyes of our tender-hearted President by walking arm in arm into his Philadelphia Convention, but a citizen of Massachusetts is still an alien in the Palmetto State. There is that, all over the South, which frightens Yankee industry, capital, and skill from its borders. We have crushed the Rebellion, but not its hopes or its malign purposes. The South fought for perfect and permanent control over the Southern laborer. It was a war of the rich against the poor. They who waged it had no objection to the government, while they could use it as a means of confirming their power over the laborer. They fought the government, not because they hated the government as such, but because they found it, as they thought, in the way between them and their one grand purpose of rendering permanent and indestructible their authority and power over the Southern laborer. Though the battle is for the present lost, the hope of gaining this object still exists, and pervades the whole South with a feverish excitement. We have thus far only gained a Union without unity, marriage without love, victory without peace. The hope of gaining by politics what they lost by the sword, is the secret of all this Southern unrest; and that hope must be extinguished before national ideas and objects can take full possession of the Southern mind. There is but one safe and constitutional way to banish that mischievous hope from the South, and that is by lifting the laborer beyond the unfriendly political designs of his former master. Give the negro the elective franchise, and you at once destroy the purely sectional policy, and wheel the Southern States into line with national interests and national objects. The last and shrewdest turn of Southern politics is a recognition of the necessity of getting into Congress immediately, and at any price. The South will comply with any conditions but suffrage for the negro. It will swallow all the unconstitutional test oaths, repeal all the ordinances of Secession, repudiate the Rebel debt, promise to pay the debt incurred in conquering its people, pass all the constitutional amendments, if only it can have the negro left under its political control. The proposition is as modest as that made on the mountain: "All these things will I give unto thee if thou wilt fall down and worship me."

But why are the Southerners so willing to make these sacrifices? The answer plainly is, they see in this policy the only hope of saving something of their old sectional peculiarities and power. Once firmly seated in Congress, their alliance with Northern Democrats re-established, their States restored to their former position inside the Union, they can easily find means of keeping the Federal government entirely too busy with other important matters to pay much attention to the local affairs of the Southern States. Under the potent shield of State Rights, the game would be in their own hands. Does any sane man doubt for a moment that the men who followed Jefferson Davis through the late terrible Rebellion, often marching barefooted and hungry, naked and penniless, and who now only profess an enforced loyalty, would plunge this country into a foreign war to-day, if they could thereby gain their coveted independence, and their still more coveted mastery over the negroes? Plainly enough, the peace not less than the prosperity of this country is involved in the great measure of impartial suffrage. King Cotton is deposed, but only deposed, and is ready to-day to reassert all his ancient pretensions upon the first favorable opportunity. Foreign countries abound with his agents. They are able, vigilant, devoted. The young men of the South burn with the desire to regain what they call the lost cause; the women are noisily malignant towards the Federal government. In fact, all the elements of treason and rebellion are there under the

thinnest disguise which necessity can impose.

What, then, is the work before Congress? It is to save the people of the South from themselves, and the nation from detriment on their account. Congress must supplant the evident sectional tendencies of the South by national dispositions and tendencies. It must cause national ideas and objects to take the lead and control the politics of those States. It must cease to recognize the old slave-masters as the only competent persons to rule the South. In a word, it must enfranchise the negro, and by means of the loyal negroes and the loyal white men of the South build up a national party there, and in time bridge the chasm between North and South, so that our country may have a common liberty and a common civilization. The new wine must be put into new bottles. The lamb may not be trusted with the wolf. Loyalty is hardly safe with traitors.

Statesmen of America! beware what you do. The ploughshare of rebellion has gone through the land beam-deep. The soil is in readiness, and the seed-time has come. Nations, not less than individuals, reap as they sow. The dreadful calamities of the past few years came not by accident, nor unbidden, from the ground. You shudder to-day at the harvest of blood sown in the spring-time of the Republic by your patriot fathers. The principle of slavery, which they tolerated under the erroneous impression that it would soon die out, became at last the dominant principle and power at the South. It early mastered the Constitution, became superior to the Union, and enthroned itself above the law.

Freedom of speech and of the press it slowly but successfully banished from the South, dictated its own code of honor and manners to the nation, brandished the bludgeon and the bowie-knife over Congressional debate, sapped the foundations of loyalty, dried up the springs of patriotism, blotted out the testimonies of the fathers against oppression, padlocked the pulpit, expelled liberty from its literature, invented nonsensical theories about master-races and slave-races of men, and in due season produced a Rebellion fierce, foul, and bloody.

This evil principle again seeks admission into our body politic. It comes now in shape of a denial of political rights to four million loyal colored people. The South does not now ask for slavery. It only asks for a large degraded caste, which shall have no political rights. This ends the case. Statesmen, beware what you do. The destiny of unborn and unnumbered generations is in your hands. Will you repeat the mistake of your fathers, who sinned ignorantly? or will you profit by the blood-bought wisdom all round you, and forever expel every vestige of the old abomination from our national borders? As you members of the Thirty-ninth Congress decide, will the country be peaceful, united, and happy, or troubled, divided, and miserable.

THE NEGRO EXODUS by James B. Runnion

A recent sojourn in the South for a few weeks, chiefly in Louisiana and Mississippi, gave the writer an opportunity to inquire into what has been so aptly called "the negro exodus." The emigration of blacks to Kansas began early in the spring of this year. For a time there was a stampede from two or three of the river parishes in Louisiana and as many counties opposite in Mississippi. Several thousand negroes (certainly not fewer than five thousand, and variously estimated as high as ten thousand) had left their cabins before the rush could be stayed or the excitement lulled. Early in May most of the negroes who had quit work for the purpose of emigrating, but had not succeeded in getting off, were persuaded to return to the plantations, and from that time on there have been only straggling families and groups that have watched for and seized the first opportunity for transportation to the North. There is no doubt, however, that there is still a consuming desire among the negroes of the cotton districts in these two States to seek new homes, and there are the best reasons for believing that the exodus will take a new start next spring, after the gathering and conversion of the growing crop. Hundreds of negroes who returned from the river-banks for lack of transportation, and thousands of others infected with the ruling discontent, are working harder in the fields this summer, and practicing more economy and self-denial than ever before, in order to have the means next winter and spring to pay their way to the "promised land."

"We've been working for fourteen long years," said an intelligent negro, in reply to a question as to the cause of the prevailing discontent, "and we ain't no better off than we was when we commenced." This is the negro version of the trouble, which is elaborated on occasion into a harrowing story of oppression and plunder.

"I tell you it's all owing to the radical politicians at the North," explained a representative of the type known as the Bourbons; "they've had their emissaries down here, and deluded the 'niggers' into a very fever of emigration, with the purpose of reducing our basis of representation in Congress and increasing that of the Northern States."

These are the two extremes of opinion at the South. The first is certainly the more reasonable and truthful, though it implies that all the blame rests upon the whites, which is not the case; the second, preposterous as it will appear to Northern readers, is religiously believed by large numbers of the "unreconciled." Between these two extremes there is an infinite variety of theories, all more or less governed by the political faction to which the various theorizers belong; there are at least a dozen of these factions, such as the Bourbons, the conservatives, the native white republicans, the carpet-bag republicans, the negro republicans, etc. There is a political tinge in almost everything in the extreme Southern States. The fact seems to be that the emigration movement among the blacks was spontaneous to the extent that they were ready and anxious to go. The immediate notion of going may have been inculcated by such circulars, issued by railroads and land companies, as are common enough at emigrant centres in the North and West, and the exaggeration characteristic of such literature may have stimulated the imagination of the negroes far beyond anything they are likely to realize in their new homes. Kansas was naturally the favorite goal of the negro emigre, for it was associated in his mind with the names of Jim Lane and John Brown, which are hallowed to him. The timid learned that they could escape what they have come to regard as a second bondage, and they flocked together to gain the moral support which comes from numbers.

Diligent inquiry among representative men, of all classes and from all parts of Louisiana, who were in attendance at the constitutional convention in New Orleans, and careful observation along the river among the land owners and field hands in both Louisiana and Mississippi, left a vivid impression of some material and political conditions which fully account for the negro exodus. I have dropped the social conditions out of the consideration, because I became convinced that the race troubles at the South can be solved to the satisfaction of both whites and blacks without cultivating any closer social relations than those which now prevail. The material conditions which I have in mind are less familiar than the political conditions; they are mainly the land-tenure and credit systems, and mere modifications (scarcely for the better) of the peculiar plantation system of slavery days.

The cotton lands at the South are owned now, as they were before the war, in large tracts. The land was about all that most of the Southern whites had left to them after the war, and they kept it when they could, at the first, in the hope that it would yield them a living through the labor of the blacks; of late years they have not been able to sell their plantations at any fair price, if they desired to do so. The white men with capital who went to the South from the North after the war seemed to acquire the true Southern ambition to be large land owners and planters; and when the ante-bellum owners lost their plantations the land usually went in bulk to the city factors who had made them advances from year to year, and had taken mortgages on their crops and broad acres. As a consequence, the land has never been distributed among the people who inhabit and cultivate it, and agricultural labor in the Southern States approaches the condition of the factory labor in England and the Eastern States more nearly than it does the farm labor of the North and West. Nearly every agricultural laborer north of Mason and Dixon's line, if not the actual possessor of the land he plows, looks forward to owning a farm some time; at the South such an ambition is rare, and small ownership still more an exception. The practice of paying day wages was first tried after the war; this practice is still in vogue in the sugar and rice districts, where laborers are paid from fifty to seventy cents per day, with quarters furnished and living guaranteed them at nine or ten cents a day. In sections where the wages system prevails, and where there have been no political disturbances, the negroes seem to be perfectly contented; at all events, the emigration fever has not spread among them. But it was found impracticable to maintain the wage system in the cotton districts. The negroes themselves fought against it, because it reminded them too much of the slave-gang, driven out at daybreak and home at sundown. In many cases the planters were forced to abandon it, because they had not the means to carry on such huge farming, and they could not secure the same liberal advances from capitalists as when they were able to mortgage a growing "crop of niggers." Then the system of working on shares was tried. This was reasonably fair, and the negro laborers were satisfied as long as it lasted. The owners of the land, under this system, would furnish the indispensable mule and the farming implements, and take one half the product. The planters themselves relinquished this system. Some of them contend that the laziness and indifference of the negro made the partnership undesirable; many others admit that they were not able to advance the negro tenant his supplies pending the growth of the year's crop, as it was necessary they should do under the sharing system. Now the renting system is almost universal. It yields the land owner a certainty, endangered only by the death, sickness, or desertion of the negro tenant; but it throws the latter upon his own responsibility, and frequently makes him the victim of his own ignorance and the rapacity of the white man. The rent of land, on a money basis, varies from six to ten dollars an acre per year, while the same land can be bought in large quantities all the way from fifteen to thirty dollars per acre, according to location, clearing, improvement, richness, etc. When paid in product, the rent varies from eighty to one hundred pounds of lint cotton per acre for land that produces from two hundred to four hundred pounds of cotton per acre; the tenant undertakes to pay from one quarter to one half--perhaps an average of one third--of his crop for the use of the land, without stock, tools, or assistance of any kind. The land owners usually claim that they make no money even at these exorbitant figures. If they do not, it is because

only a portion of their vast possessions is under cultivation, because they do no work themselves, and in some cases because the negroes do not cultivate and gather as large a crop as they could and ought to harvest. It is very certain that the negro tenants, as a class, make no money; if they are out of debt at the end of a season, they have reason to rejoice.

The credit system, which is as universal as the renting system, is even more illogical and oppressive. The utter viciousness of both systems in their mutual dependence is sufficiently illustrated by the single fact that, after fourteen years of freedom and labor on their own account, the great mass of the negroes depend for their living on an advance of supplies (as they need food, clothing, or tools during the year) upon the pledge of their growing crop. This is a generic imitation of the white man's improvidence during the slavery times; then the planters mortgaged their crops and negroes, and where one used the advances to extend his plantation, ten squandered the money. The negro's necessities have developed an offensive race, called merchants by courtesy, who keep supply stores at the cross-roads and steamboat landings, and live upon extortion. These people would be called sharks, harpies, and vampires in any Northwestern agricultural community, and they would not survive more than one season. The country merchant advances the negro tenant such supplies as the negro wants up to a certain amount, previously fixed by contract, and charges the negro at least double the value of every article sold to him. There is no concealment about the extortion; every store-keeper has his cash price and his credit price, and in nearly all cases the latter is one hundred per cent. higher than the former. The extortion is justified by those who practice it on the ground that their losses by bad debts, though their advances are always secured by mortgage on the growing crop, overbalance the profits; this assertion is scarcely borne out by the comparative opulence of the "merchant" and the pitiful poverty of the laborer. Some of the largest and wealthiest planters have sought to protect their tenants from the merciless clutches of the contrary merchant, who is more frequently than not an Israelite, by advancing supplies of necessary articles at reasonable prices. But the necessities of the planter, if not his greed, often betray him into plundering the negro. The planter himself is generally a victim to usury. He still draws on the city factor to the extent of ten dollars a bale upon his estimated crop. He pays this factor two and one half per cent. commission for the advance, eight per cent. interest for the money, two and one half per cent. more for disposing of the crop when consigned to him, and sometimes still another commission for the purchase of the supplies. The planter who furnishes his tenants with supplies on credit is usually paying an interest of fifteen to eighteen per cent. himself, and necessarily takes some risk in advancing upon an uncertain crop and to a laborer whom he believes to be neither scrupulous nor industrious; these conditions necessitate more than the ordinary profit, and in many cases suggest exorbitant and unreasonable charges. But whether the negro deals with the merchant or the land owner, his extravagance almost invariably exhausts his credit, even if it be large. The negro is a sensuous creature, and luxurious in his way. The male is an enormous consumer of tobacco and whisky; the female has an inordinate love for flummery; both are fond of sardines, potted meats, and canned goods generally, and they indulge themselves without any other restraint than the refusal of their merchant to sell to them. The man who advances supplies watches his negro customers constantly; if they are working well and their crop promises to be large, he will permit and even encourage them to draw upon him liberally; it is only a partial failure of the crop, or some intimation of the negro's intention to shirk his obligations, that induces his country factor to preach the virtue of self-restraint, or moralize upon the advantages of economy.

The land owner's rent and the merchant's advances are both secured by a chattel mortgage on the tenant's personal property, and by a pledge of the growing crop. The hired laborer (for it is common for negroes to work for wages for other negroes who rent lands) has also a lien upon the growing crops second only to the land owner's; but as the law requires that the liens shall be recorded, which the ignorant laborer usually neglects and the shrewd merchant never fails to do, the former is generally cheated of his security. Among those who usually work for hire are the women, who are expert cotton pickers, and the loss of wages which so many of them have suffered by reason of the prior lien gained by landlord and merchant has helped to make them earnest and effective advocates of emigration. The Western farmer considers it hard enough to struggle under one mortgage at a reasonable interest; the negro tenant begins his season with three mortgages, covering all he owns, his labor for the coming year, and all he expects to acquire during that period. He pays one third his product for the use of the land; he pays double the value of all he consumes; he pays an exorbitant fee for recording the contract by which he pledges his pound of flesh; he is charged two or three times as much as he ought to pay for ginning his cotton; and, finally, he turns over his crop to be eaten up in commissions, if anything still be left to him. It is easy to understand why the negro rarely gets ahead in the world. This mortgaging of future services, which is practically what a pledge of the growing crop amounts to, is in the nature of bondage. It has a tendency to make the negro extravagant, reckless, and unscrupulous; he has become convinced from previous experience that nothing will be coming to him on the day of settlement, and he is frequently actuated by the purpose of getting as much as possible and working as little as possible. Cases are numerous in which the negro abandons his own crop at picking time, because he knows that he has already eaten up its full value; and so he goes to picking for wages on some other plantation. In other cases, where negroes have

acquired mules and farming implements upon which a merchant has secured a mortgage in the manner described, they are practically bound to that merchant from year to year, in order to retain their property; if he removes from one section to another, they must follow him, and rent and cultivate lands in his neighborhood. It is only the ignorance, the improvidence, and the happy disposition of the negro, under the influence of the lazy, drowsy climate, to which he is so well adapted physically, that have enabled him to endure these hardships so long. And, though the negro is the loser, the white man is not often the gainer, from this false plantation and mercantile system. The incidental risk may not be so large as the planter and merchant pretend, but the condition of the people is an evidence that the extortion they practice yields no better profit in the long run than would be gained by competition in fair prices on a cash system; and in leading up to a general emigration of the laboring population the abuses described will eventually ruin and impoverish those who have heretofore been the only beneficiaries thereof. The decay of improvements inevitable under annual rentings, the lack of sufficient labor to cultivate all the good land, and the universal idleness of the rural whites have kept the land owners comparatively poor; the partial failure of crops and the unscrupulousness of the negro debtor, engendered by the infamous exactions of his creditor, have prevented the merchants, as a class, from prospering as much as might be supposed; and, finally, the uniform injustice to the laborers induces them to fly to ills they know not of, rather than bear those they have. It is a blessing to the negro that the laws do not yet provide for a detention of the person in the case of debt, or escape would be shut off entirely; as it is, various influences and circumstances appertaining to the system in vogue have been used to prevent the easy flight of those who desire to go, and have detained thousands of blacks for a time who are fretting to quit the country.

Political oppression has contributed largely to the discontent which is the prime cause of the exodus. "Bulldozing" is the term by which all forms of this oppression are known. The native whites are generally indisposed to confess that the negroes are quitting the country on account of political injustice and persecution; even those who freely admit and fitly characterize the abuses already described seek to deny, or at least belittle, the political abuses. The fact that a large number of negroes have emigrated from Madison Parish, Louisiana, where there has never been any bulldozing, and where the negroes are in full and undisputed political control, is cited as proof that political disturbances cut no figure in the case. But the town of Delta, in Madison Parish, is at once on the river and the terminus of a railroad that runs back through the interior of the State; thus Madison Parish would furnish the natural exit for the fugitives from the adjoining counties, where there have been political disturbances. It would be just as reasonable to contend that the plundering of the negroes has had no influence in driving them away, since many of those who have emigrated were among the most prosperous of the blacks, as to deny the agency of political persecution. Families that had been able to accumulate a certain amount of personal property, in spite of the extortionate practices, sold their mules, their implements, their cows, their pigs, their sheep, and their household goods for anything they would bring,--frequently as low as one sixth of their value,--in order that they might improve an immediate opportunity to go away; it is evident that there must have been some cause outside of extortion in their case. There are candid native whites who do not deny, but justify, the violent methods which have been employed to disfranchise the negroes, or compel them to vote under white dictation, in many parts of Louisiana and Mississippi, on the ground that the men who pay the taxes should vote them and control the disbursement of the public moneys. The gentlemen who advance this argument seem to ignore the fact that the very Northerner whom they are seeking to convert to "the Mississippi plan" may himself be a taxpayer in some Northern city, where public affairs are controlled by a class of voters in every way as ignorant and irresponsible as the blacks, but where bulldozing has never yet been suggested as a remedy. For the rest, the evidences of political oppression are abundant and convincing. The bulldozers as a class are more impecunious and irresponsible than the negroes, and, unlike the negroes, they will not work. There has been more of the "night-riding," the whippings, the mysterious disappearances, the hangings, and the terrorism comprehended in the term bulldozing than has been reported by those "abstracts and brief chronicles of the time," the Southern newspapers, which are now all of one party, and defer to the ruling sentiment among the whites. The exodus has wrung from two or three of the more candid and independent journals, however, a virtual confession of the fiendish practices of bulldozing in their insistance that these practices must be abandoned. The non-resident land owners and the resident planters, the city factors and the country merchants of means and respectability, have taken no personal part in the terrorizing of the negro, but they have tolerated it, and sometimes encouraged it, in order to gratify their preference for "white government." The negroes have suffered the more because they have not resisted and defended themselves; now they have begun to convince those who have persecuted them that, if they will not strike back, they can and will run away. No one who is at all familiar with the freedman can doubt that the abridgment of his political rights has been one of the main causes of the exodus. Voting is widely regarded at the North as a disagreeable duty, but the negro looks upon it as the highest privilege in life; to be frightened out of the exercise of this privilege, or compelled to exercise it in conflict with his convictions and preferences, is to suffer from a cruel injustice, which the negro will now try to escape, since he has learned that escape is possible. The women, though free from personal assaults, suffer from the terrorism that prevails in certain districts as much as the

men. "We might as well starve or freeze to death in Kansas," they say, "as to be shot-gunned here." If they talk to you in confidence, they declare that the ruling purpose is to escape from the "slaughter-pens" of the South. Political persecution, and not the extortion they suffer, is the refrain of all the speakers at negro meetings that are held in encouragement and aid of the emigration. It is idle to deny that the varied injustice which the negroes have suffered as voters is accountable for a large part of their universal yearning for new homes, and it will be folly for the responsible classes at the South to ignore this fact.

As it is the negroes who are fleeing from the South, it is natural to look among the dominant class for the injustice which is driving them away; but it would be unfair to conclude that the blame rests entirely upon the whites, and still more so to leave the impression that there is no extenuation for the mistakes and abuses for which the whites are responsible. Much of the intimidation of the blacks has been tolerated, if not suggested, by a fear of negro uprisings. The apprehension is a legacy from the days of slavery, and is more unreasonable now than it was then; but still it exists. This is not an excuse, but an explanation. The Pharaohs of the time of Moses were in constant dread lest the Hebrews under their rule should go over to their enemies, and their dread doubtless increased the cruelty of the Egyptians; but, while this dread was an extenuation in the eyes of the persecutors, it did not prevent the Hebrews from fleeing the persecution. So the blacks are going without regard to the justification which the whites may set up for their treatment; the only difference between the old and new exodus is that, as the writer heard one negro speaker express it, "every black man is his own Moses in this exodus." The negro may be lazy; it seems impossible to be otherwise in the Southern climate. He may not be willing to work on Saturdays, no matter how urgent the necessity; the indulgence in holidays is said to be one of the chief drawbacks to the advancement of the emancipated serfs of Russia. The blacks are certainly extravagant in their way, though the word seems to be almost misused in connection with a race who live largely on pork and molasses, and rarely wear more than half a dollar's worth of clothes at one time. They have not the instinct of home as it prevails among the whites, but incline to a crude and unsystematic communism; the negro quarters of the old plantations are all huddled together in the centre, and, except where the land owners have interfered to encourage a different life, there is still too much promiscuousness in the relation of the sexes. The negro, as a rule, has no ambition to become a land owner; he prefers to invest his surplus money, when he has any, in personal and movable property. In most cases where the blacks have been given the opportunity of buying land on long time, and paying yearly installments out of the proceeds of their annual crops, they have tired of the bargain after a year or two, and abandoned the contract. The negro politicians and preachers are not all that reformers and moralists would have them; the imitative faculty of the African has betrayed the black politician into many of the vicious ways of the white politician, and the colored preacher is frequently not above "the pomps and vanity of this wicked world." All this is the more unfortunate, as the blacks have a child-like confidence in their chosen leaders, founded partly on their primitive character, and partly on their distrust of the native whites. Both their politicians and their preachers have given abundant evidence of their insincerity during the excitement of emigration by blowing hot and blowing cold; by talking to the negroes one way, and to the whites another; and even to the extent, in some instances, of taking money to use their influence for discouraging and impeding emigration. These are some of the faults and misfortunes on the part of the blacks which enter into the race troubles. The chief blame which attaches to the whites is the failure to make a persistent effort, by education and kind treatment, to overcome the distrust and cure the faults of the negroes. The whites control, because they constitute the "property and intelligence" of the South, to use the words of a democratic statesman; this power should have been used to gain the confidence of the blacks. Had such a course been taken, there would not have been the fear of reenslavement, which actually prevails to a considerable extent among the negroes. So long as a portion of the whites entertain the conviction that the war of the sections will be renewed within a few years, as is the case, the negroes will suspect and dread the class who would treat them as enemies in case the war should come, and will seek to escape to a section of the country where they would not be so treated. Perhaps, too, there would have been a voluntary political division among the black voters, had the whites used more pacific means to bring it about, and had they themselves set the example. And last, but not least, in making up the sum of blame that the whites must bear, is their own unwillingness to labor, which gives the rural population too much time for mischief and too little sympathy with the working classes.

As we have traced the causes that have led to the exodus, and described the conditions which warrant the belief that there will be a renewal of the emigration on a more extended scale next spring, and endeavored to distribute the responsibility for the troubles equitably among whites and blacks, remedies have naturally suggested themselves to the reader; in fact, they are more easily to be thought out than accomplished. A few general reflections may be added, however, in order to indicate the probable solution of the race troubles that have brought about the exodus, if, indeed, the whites and blacks of the South are ever going to live together in peace.

(1.) It is certain that negro labor is the best the South can have, and equally certain that the climate and natural conditions of the South are better suited to the negro than any others on this continent. The alluvial lands, which many persons believe the negroes

alone can cultivate, on account of climatic conditions, are so rich that it might literally be said it is only necessary to tickle them with a hoe to make them laugh back a harvest. The common prosperity of the country--the agricultural interests of the South and the commercial interests of the North--will be best served, therefore, by the continued residence and labor of the blacks in the cotton States.

(2.) The fact stated in the foregoing paragraph is so well understood at the North that the Southern people should dismiss the idea that there is any scheming among the Northern people, political or otherwise, to draw the black labor away from its natural home. The same fact should also influence the people at the North not to be misled by any professional philanthropists who may have some self-interest in soliciting aid to facilitate negro emigration from the South. The duty of the North in this matter is simply to extend protection and assure safe-conduct to the negroes, if the Southern whites attempt to impede voluntary emigration by either law or violence. Any other course might be cruel to the negro in encouraging him to enter on a new life in a strange climate, as well as an injustice to the white land owners of the South.

(3.) There is danger that the Southern whites will, as a rule, misinterpret the meaning of the exodus. Many are inclined to underrate its importance, and those who appreciate its significance are apt to look for temporary and superficial remedies. The vague promises made at the Vicksburg convention, which was controlled by the whites, and called to consider the emigration movement, have had no influence with the negroes, because they have heard such promises before. Had the convention adopted some definite plan of action, such as ex-Governor Foote, of Mississippi, submitted, its session might not have been in vain. This plan was to establish a committee in every county, composed of men who have the confidence of both whites and blacks, that should be auxiliary to the public authorities, listen to complaints, and arbitrate, advise, conciliate, or prosecute, as each case should demand. It is short-sighted for the Southern people to make mere temporary concessions, such as have been made in some cases this year, for that course would establish an annual strike. It is folly for them to suppose they can stem the tide of emigration by influencing the regular lines of steamboats not to carry the refugees, for the people of the North will see that the blacks shall not be detained in the South against their will. It is unwise for them to devise schemes for importing Chinese, or encouraging the immigration of white labor as a substitute for negro labor, when they may much better bestir themselves to make the present effective labor content.

(4.) Education will be the most useful agent to employ in the permanent harmonizing of the two races, and the redemption of both from the faults and follies which constitute their troubles. It is not the education of the negro alone, whose ambition for learning is increasing notably with every new generation, but the education of the mass of the young whites, that is needed to inculcate more tolerance of color and opinion, to give them an aspiration beyond that of riding a horse and hanging a "nigger," and to enable them to set a better example to the imitative blacks in the way of work and frugality. The blacks need the education to protect them from designing white men; the whites need it to teach them that their own interests will be best served by abandoning bulldozing of all kinds.

(5.) Reform in the land tenure, by converting the plantation monopolies into small holdings; abolition of the credit system, by abandoning the laws which sustain it; a diversification of crops; and attention to new manufacturing, maritime, and commercial enterprises,--these are the material changes that are most needed. They can be secured only through the active and earnest efforts of the whites. The blacks will be found responsive.

(6.) The hope of the negro exodus at its present stage, or even if it shall continue another season, is that the actual loss of the valuable labor that has gone, and the prospective loss of more labor that is anxious to go, will induce the intelligent and responsible classes at the South to overcome their own prejudices, and to compel the extremists, irreconcilables, and politicians generally, of all parties, to abandon agitation, and give the South equal peace and equal chance for black and white.

MY ESCAPE FROM SLAVERY by Frederick Douglass

In the first narrative of my experience in slavery, written nearly forty years ago, and in various writings since, I have given the public what I considered very good reasons for withholding the manner of my escape. In substance these reasons were, first, that such publication at any time during the existence of slavery might be used by the master against the slave, and prevent the future escape of any who might adopt the same means that I did. The second reason was, if possible, still more binding to silence: the publication of details would certainly have put in peril the persons and property of those who assisted. Murder itself was not more sternly and certainly punished in the State of Maryland than that of aiding and abetting the escape of a slave. Many colored men, for no other crime than that of giving aid to a fugitive slave, have, like Charles T. Torrey, perished in prison. The abolition of slavery in my native State and throughout the country, and the lapse of time, render the caution hitherto observed no longer necessary. But

even since the abolition of slavery, I have sometimes thought it well enough to baffle curiosity by saying that while slavery existed there were good reasons for not telling the manner of my escape, and since slavery had ceased to exist, there was no reason for telling it. I shall now, however, cease to avail myself of this formula, and, as far as I can, endeavor to satisfy this very natural curiosity. I should, perhaps, have yielded to that feeling sooner, had there been anything very heroic or thrilling in the incidents connected with my escape, for I am sorry to say I have nothing of that sort to tell; and yet the courage that could risk betrayal and the bravery which was ready to encounter death, if need be, in pursuit of freedom, were essential features in the undertaking. My success was due to address rather than courage, to good luck rather than bravery. My means of escape were provided for me by the very men who were making laws to hold and bind me more securely in slavery.

It was the custom in the State of Maryland to require the free colored people to have what were called free papers. These instruments they were required to renew very often, and by charging a fee for this writing, considerable sums from time to time were collected by the State. In these papers the name, age, color, height, and form of the freeman were described, together with any scars or other marks upon his person which could assist in his identification. This device in some measure defeated itself--since more than one man could be found to answer the same general description. Hence many slaves could escape by personating the owner of one set of papers; and this was often done as follows: A slave, nearly or sufficiently answering the description set forth in the papers, would borrow or hire them till by means of them he could escape to a free State, and then, by mail or otherwise, would return them to the owner. The operation was a hazardous one for the lender as well as for the borrower. A failure on the part of the fugitive to send back the papers would imperil his benefactor, and the discovery of the papers in possession of the wrong man would imperil both the fugitive and his friend. It was, therefore, an act of supreme trust on the part of a freeman of color thus to put in jeopardy his own liberty that another might be free. It was, however, not unfrequently bravely done, and was seldom discovered. I was not so fortunate as to resemble any of my free acquaintances sufficiently to answer the description of their papers. But I had a friend--a sailor--who owned a sailor's protection, which answered somewhat the purpose of free papers--describing his person, and certifying to the fact that he was a free American sailor. The instrument had at its head the American eagle, which gave it the appearance at once of an authorized document. This protection, when in my hands, did not describe its bearer very accurately. Indeed, it called for a man much darker than myself, and close examination of it would have caused my arrest at the start.

In order to avoid this fatal scrutiny on the part of railroad officials, I arranged with Isaac Rolls, a Baltimore hackman, to bring my baggage to the Philadelphia train just on the moment of starting, and jumped upon the car myself when the train was in motion. Had I gone into the station and offered to purchase a ticket, I should have been instantly and carefully examined, and undoubtedly arrested. In choosing this plan I considered the jostle of the train, and the natural haste of the conductor, in a train crowded with passengers, and relied upon my skill and address in playing the sailor, as described in my protection, to do the rest. One element in my favor was the kind feeling which prevailed in Baltimore and other sea-ports at the time, toward "those who go down to the sea in ships." "Free trade and sailors' rights" just then expressed the sentiment of the country. In my clothing I was rigged out in sailor style. I had on a red shirt and a tarpaulin hat, and a black cravat tied in sailor fashion carelessly and loosely about my neck. My knowledge of ships and sailor's talk came much to my assistance, for I knew a ship from stem to stern, and from keelson to cross-trees, and could talk sailor like an "old salt." I was well on the way to Havre de Grace before the conductor came into the negro car to collect tickets and examine the papers of his black passengers. This was a critical moment in the drama. My whole future depended upon the decision of this conductor. Agitated though I was while this ceremony was proceeding, still, externally, at least, I was apparently calm and self-possessed. He went on with his duty--examining several colored passengers before reaching me. He was somewhat harsh in tome and peremptory in manner until he reached me, when, strange enough, and to my surprise and relief, his whole manner changed. Seeing that I did not readily produce my free papers, as the other colored persons in the car had done, he said to me, in friendly contrast with his bearing toward the others:

"I suppose you have your free papers?"

To which I answered:

"No sir; I never carry my free papers to sea with me."

"But you have something to show that you are a freeman, haven't you?"

"Yes, sir," I answered; "I have a paper with the American Eagle on it, and that will carry me around the world."

With this I drew from my deep sailor's pocket my seaman's protection, as before described. The merest glance at the paper satisfied him, and he took my fare and went on about his business. This moment of time was one of the most anxious I ever experienced. Had the conductor looked closely at the paper, he could not have failed to discover that it called for a very different-looking person from myself, and in that case it would have been his duty to arrest me on the instant, and send me back to Baltimore from the first station. When he left me with the assurance that I was all right, though much relieved, I realized that I was still in great danger: I was still in Maryland, and subject to arrest at any moment. I saw on the train several persons who would have known me in any other clothes, and I feared they might recognize me, even in my sailor "rig," and report me to the conductor, who would then subject me to a closer examination, which I knew well would be fatal to me.

Though I was not a murderer fleeing from justice, I felt perhaps quite as miserable as such a criminal. The train was moving at a very high rate of speed for that epoch of railroad travel, but to my anxious mind it was moving far too slowly. Minutes were hours, and hours were days during this part of my flight. After Maryland, I was to pass through Delaware--another slave State, where slave-catchers generally awaited their prey, for it was not in the interior of the State, but on its borders, that these human hounds were most vigilant and active. The border lines between slavery and freedom were the dangerous ones for the fugitives. The heart of no fox or deer, with hungry hounds on his trail in full chase, could have beaten more anxiously or noisily than did mine from the time I left Baltimore till I reached Philadelphia. The passage of the Susquehanna River at Havre de Grace was at that time made by ferry-boat, on board of which I met a young colored man by the name of Nichols, who came very near betraying me. He was a "hand" on the boat, but, instead of minding his business, he insisted upon knowing me, and asking me dangerous questions as to where I was going, when I was coming back, etc. I got away from my old and inconvenient acquaintance as soon as I could decently do so, and went to another part of the boat. Once across the river, I encountered a new danger. Only a few days before, I had been at work on a revenue cutter, in Mr. Price's ship-yard in Baltimore, under the care of Captain McGowan. On the meeting at this point of the two trains, the one going south stopped on the track just opposite to the one going north, and it so happened that this Captain McGowan sat at a window where he could see me very distinctly, and would certainly have recognized me had he looked at me but for a second. Fortunately, in the hurry of the moment, he did not see me; and the trains soon passed each other on their respective ways. But this was not my only hair-breadth escape. A German blacksmith whom I knew well was on the train with me, and looked at me very intently, as if he thought he had seen me somewhere before in his travels. I really believe he knew me, but had no heart to betray me. At any rate, he saw me escaping and held his peace.

The last point of imminent danger, and the one I dreaded most, was Wilmington. Here we left the train and took the steam-boat for Philadelphia. In making the change here I again apprehended arrest, but no one disturbed me, and I was soon on the broad and beautiful Delaware, speeding away to the Quaker City. On reaching Philadelphia in the afternoon, I inquired of a colored man how I could get on to New York. He directed me to the William-street depot, and thither I went, taking the train that night. I reached New York Tuesday morning, having completed the journey in less than twenty-four hours.

My free life began on the third of September, 1838. On the morning of the fourth of that month, after an anxious and most perilous but safe journey, I found myself in the big city of New York, a FREE MAN--one more added to the mighty throng which, like the confused waves of the troubled sea, surged to and fro between the lofty walls of Broadway. Though dazzled with the wonders which met me on every hand, my thoughts could not be much withdrawn from my strange situation. For the moment, the dreams of my youth and the hopes of my manhood were completely fulfilled. The bonds that had held me to "old master" were broken. No man now had a right to call me his slave or assert mastery over me. I was in the rough and tumble of an outdoor world, to take my chance with the rest of its busy number. I have often been asked how I felt when first I found myself on free soil. There is scarcely anything in my experience about which I could not give a more satisfactory answer. A new world had opened upon me. If life is more than breath and the "quick round of blood," I lived more in that one day than in a year of my slave life. It was a time of joyous excitement which words can but tamely describe. In a letter written to a friend soon after reaching New York, I said: "I felt as one might feel upon escape from a den of hungry lions." Anguish and grief, like darkness and rain, may be depicted; but gladness and joy, like the rainbow, defy the skill of pen or pencil. During ten or fifteen years I had been, as it were, dragging a heavy chain which no strength of mine could break; I was not only a slave, but a slave for life. I might become a husband, a father, an aged man, but through all, from birth to death, from the cradle to the grave, I had felt myself doomed. All efforts I had previously made to secure my freedom had not only failed, but had seemed only to rivet my fetters the more firmly, and to render my escape more difficult. Baffled, entangled, and discouraged, I had at times asked myself the question, May not my condition after all be God's work, and ordered for a wise purpose, and if so, Is not submission my duty? A contest had in fact been going on in my mind for a long time, between the clear consciousness of right and the plausible make-shifts of theology and superstition. The one held me an abject slave--a prisoner for life, punished for some transgression in which I had no lot nor part; and the other counseled me to manly

endeavor to secure my freedom. This contest was now ended; my chains were broken, and the victory brought me unspeakable joy.

But my gladness was short-lived, for I was not yet out of the reach and power of the slave-holders. I soon found that New York was not quite so free or so safe a refuge as I had supposed, and a sense of loneliness and insecurity again oppressed me most sadly. I chanced to meet on the street, a few hours after my landing, a fugitive slave whom I had once known well in slavery. The information received from him alarmed me. The fugitive in question was known in Baltimore as "Allender's Jake," but in New York he wore the more respectable name of "William Dixon." Jake, in law, was the property of Doctor Allender, and Tolly Allender, the son of the doctor, had once made an effort to recapture MR. DIXON, but had failed for want of evidence to support his claim. Jake told me the circumstances of this attempt, and how narrowly he escaped being sent back to slavery and torture. He told me that New York was then full of Southerners returning from the Northern watering-places; that the colored people of New York were not to be trusted; that there were hired men of my own color who would betray me for a few dollars; that there were hired men ever on the lookout for fugitives; that I must trust no man with my secret; that I must not think of going either upon the wharves or into any colored boarding-house, for all such places were closely watched; that he was himself unable to help me; and, in fact, he seemed while speaking to me to fear lest I myself might be a spy and a betrayer. Under this apprehension, as I suppose, he showed signs of wishing to be rid of me, and with whitewash brush in hand, in search of work, he soon disappeared.

This picture, given by poor "Jake," of New York, was a damper to my enthusiasm. My little store of money would soon be exhausted, and since it would be unsafe for me to go on the wharves for work, and I had no introductions elsewhere, the prospect for me was far from cheerful. I saw the wisdom of keeping away from the ship-yards, for, if pursued, as I felt certain I should be, Mr. Auld, my "master," would naturally seek me there among the calkers. Every door seemed closed against me. I was in the midst of an ocean of my fellow-men, and yet a perfect stranger to every one. I was without home, without acquaintance, without money, without credit, without work, and without any definite knowledge as to what course to take, or where to look for succor. In such an extremity, a man had something besides his new-born freedom to think of. While wandering about the streets of New York, and lodging at least one night among the barrels on one of the wharves, I was indeed free--from slavery, but free from food and shelter as well. I kept my secret to myself as long as I could, but I was compelled at last to seek some one who would befriend me without taking advantage of my destitution to betray me. Such a person I found in a sailor named Stuart, a warm-hearted and generous fellow, who, from his humble home on Centre street, saw me standing on the opposite sidewalk, near the Tombs prison. As he approached me, I ventured a remark to him which at once enlisted his interest in me. He took me to his home to spend the night, and in the morning went with me to Mr. David Ruggles, the secretary of the New York Vigilance Committee, a co-worker with Isaac T. Hopper, Lewis and Arthur Tappan, Theodore S. Wright, Samuel Cornish, Thomas Downing, Philip A. Bell, and other true men of their time. All these (save Mr. Bell, who still lives, and is editor and publisher of a paper called the "Elevator," in San Francisco) have finished their work on earth. Once in the hands of these brave and wise men, I felt comparatively safe. With Mr. Ruggles, on the corner of Lispenard and Church streets, I was hidden several days, during which time my intended wife came on from Baltimore at my call, to share the burdens of life with me. She was a free woman, and came at once on getting the good news of my safety. We were married by Rev. J. W. C. Pennington, then a well-known and respected Presbyterian minister. I had no money with which to pay the marriage fee, but he seemed well pleased with our thanks.

Mr. Ruggles was the first officer on the "Underground Railroad" whom I met after coming North, and was, indeed, the only one with whom I had anything to do till I became such an officer myself. Learning that my trade was that of a calker, he promptly decided that the best place for me was in New Bedford, Mass. He told me that many ships for whaling voyages were fitted out there, and that I might there find work at my trade and make a good living. So, on the day of the marriage ceremony, we took our little luggage to the steamer JOHN W. RICHMOND, which, at that time, was one of the line running between New York and Newport, R. I. Forty-three years ago colored travelers were not permitted in the cabin, nor allowed abaft the paddle-wheels of a steam vessel. They were compelled, whatever the weather might be,--whether cold or hot, wet or dry,--to spend the night on deck. Unjust as this regulation was, it did not trouble us much; we had fared much harder before. We arrived at Newport the next morning, and soon after an old fashioned stage-coach, with "New Bedford" in large yellow letters on its sides, came down to the wharf. I had not money enough to pay our fare, and stood hesitating what to do. Fortunately for us, there were two Quaker gentlemen who were about to take passage on the stage,--Friends William C. Taber and Joseph Ricketson,--who at once discerned our true situation, and, in a peculiarly quiet way, addressing me, Mr. Taber said: "Thee get in." I never obeyed an order with more alacrity, and we were soon on our way to our new home. When we reached "Stone Bridge" the passengers alighted for breakfast, and paid their fares to the driver. We took no breakfast, and, when asked for our fares, I told the driver I would make it right with him when we reached New Bedford. I expected some objection to this on his part, but he made none. When, however, we reached New Bedford,

he took our baggage, including three music-books,--two of them collections by Dyer, and one by Shaw,--and held them until I was able to redeem them by paying to him the amount due for our rides. This was soon done, for Mr. Nathan Johnson not only received me kindly and hospitably, but, on being informed about our baggage, at once loaned me the two dollars with which to square accounts with the stage-driver. Mr. and Mrs. Nathan Johnson reached a good old age, and now rest from their labors. I am under many grateful obligations to them. They not only "took me in when a stranger" and "fed me when hungry," but taught me how to make an honest living. Thus, in a fortnight after my flight from Maryland, I was safe in New Bedford, a citizen of the grand old commonwealth of Massachusetts.

Once initiated into my new life of freedom and assured by Mr. Johnson that I need not fear recapture in that city, a comparatively unimportant question arose as to the name by which I should be known thereafter in my new relation as a free man. The name given me by my dear mother was no less pretentious and long than Frederick Augustus Washington Bailey. I had, however, while living in Maryland, dispensed with the Augustus Washington, and retained only Frederick Bailey. Between Baltimore and New Bedford, the better to conceal myself from the slave-hunters, I had parted with Bailey and called myself Johnson; but in New Bedford I found that the Johnson family was already so numerous as to cause some confusion in distinguishing them, hence a change in this name seemed desirable. Nathan Johnson, mine host, placed great emphasis upon this necessity, and wished me to allow him to select a name for me. I consented, and he called me by my present name--the one by which I have been known for three and forty years--Frederick Douglass. Mr. Johnson had just been reading the "Lady of the Lake," and so pleased was he with its great character that he wished me to bear his name. Since reading that charming poem myself, I have often thought that, considering the noble hospitality and manly character of Nathan Johnson--black man though he was--he, far more than I, illustrated the virtues of the Douglas of Scotland. Sure am I that, if any slave-catcher had entered his domicile with a view to my recapture, Johnson would have shown himself like him of the "stalwart hand."

The reader may be surprised at the impressions I had in some way conceived of the social and material condition of the people at the North. I had no proper idea of the wealth, refinement, enterprise, and high civilization of this section of the country. My "Columbian Orator," almost my only book, had done nothing to enlighten me concerning Northern society. I had been taught that slavery was the bottom fact of all wealth. With this foundation idea, I came naturally to the conclusion that poverty must be the general condition of the people of the free States. In the country from which I came, a white man holding no slaves was usually an ignorant and poverty-stricken man, and men of this class were contemptuously called "poor white trash." Hence I supposed that, since the non-slave-holders at the South were ignorant, poor, and degraded as a class, the non-slave-holders at the North must be in a similar condition. I could have landed in no part of the United States where I should have found a more striking and gratifying contrast, not only to life generally in the South, but in the condition of the colored people there, than in New Bedford. I was amazed when Mr. Johnson told me that there was nothing in the laws or constitution of Massachusetts that would prevent a colored man from being governor of the State, if the people should see fit to elect him. There, too, the black man's children attended the public schools with the white man's children, and apparently without objection from any quarter. To impress me with my security from recapture and return to slavery, Mr. Johnson assured me that no slave-holder could take a slave out of New Bedford; that there were men there who would lay down their lives to save me from such a fate.

The fifth day after my arrival, I put on the clothes of a common laborer, and went upon the wharves in search of work. On my way down Union street I saw a large pile of coal in front of the house of Rev. Ephraim Peabody, the Unitarian minister. I went to the kitchen door and asked the privilege of bringing in and putting away this coal. "What will you charge?" said the lady. "I will leave that to you, madam." "You may put it away," she said. I was not long in accomplishing the job, when the dear lady put into my hand TWO SILVER HALF-DOLLARS. To understand the emotion which swelled my heart as I clasped this money, realizing that I had no master who could take it from me,--THAT IT WAS MINE--THAT MY HANDS WERE MY OWN, and could earn more of the precious coin,--one must have been in some sense himself a slave. My next job was stowing a sloop at Uncle Gid. Howland's wharf with a cargo of oil for New York. I was not only a freeman, but a free working-man, and no "master" stood ready at the end of the week to seize my hard earnings.

The season was growing late and work was plenty. Ships were being fitted out for whaling, and much wood was used in storing them. The sawing this wood was considered a good job. With the help of old Friend Johnson (blessings on his memory) I got a saw and "buck," and went at it. When I went into a store to buy a cord with which to brace up my saw in the frame, I asked for a "fip's" worth of cord. The man behind the counter looked rather sharply at me, and said with equal sharpness, "You don't belong about here." I was alarmed, and thought I had betrayed myself. A fip in Maryland was six and a quarter cents, called fourpence in Massachusetts. But no harm came from the "fi'penny-bit" blunder, and I confidently and cheerfully went to work with my saw and

buck. It was new business to me, but I never did better work, or more of it, in the same space of time on the plantation for Covey, the negro-breaker, than I did for myself in these earliest years of my freedom.

Notwithstanding the just and humane sentiment of New Bedford three and forty years ago, the place was not entirely free from race and color prejudice. The good influence of the Roaches, Rodmans, Arnolds, Grinnells, and Robesons did not pervade all classes of its people. The test of the real civilization of the community came when I applied for work at my trade, and then my repulse was emphatic and decisive. It so happened that Mr. Rodney French, a wealthy and enterprising citizen, distinguished as an anti-slavery man, was fitting out a vessel for a whaling voyage, upon which there was a heavy job of calking and coppering to be done. I had some skill in both branches, and applied to Mr. French for work. He, generous man that he was, told me he would employ me, and I might go at once to the vessel. I obeyed him, but upon reaching the float-stage, where others [sic] calkers were at work, I was told that every white man would leave the ship, in her unfinished condition, if I struck a blow at my trade upon her. This uncivil, inhuman, and selfish treatment was not so shocking and scandalous in my eyes at the time as it now appears to me. Slavery had inured me to hardships that made ordinary trouble sit lightly upon me. Could I have worked at my trade I could have earned two dollars a day, but as a common laborer I received but one dollar. The difference was of great importance to me, but if I could not get two dollars, I was glad to get one; and so I went to work for Mr. French as a common laborer. The consciousness that I was free--no longer a slave--kept me cheerful under this, and many similar proscriptions, which I was destined to meet in New Bedford and elsewhere on the free soil of Massachusetts. For instance, though colored children attended the schools, and were treated kindly by their teachers, the New Bedford Lyceum refused, till several years after my residence in that city, to allow any colored person to attend the lectures delivered in its hall. Not until such men as Charles Sumner, Theodore Parker, Ralph Waldo Emerson, and Horace Mann refused to lecture in their course while there was such a restriction, was it abandoned.

Becoming satisfied that I could not rely on my trade in New Bedford to give me a living, I prepared myself to do any kind of work that came to hand. I sawed wood, shoveled coal, dug cellars, moved rubbish from back yards, worked on the wharves, loaded and unloaded vessels, and scoured their cabins.

I afterward got steady work at the brass-foundry owned by Mr. Richmond. My duty here was to blow the bellows, swing the crane, and empty the flasks in which castings were made; and at times this was hot and heavy work. The articles produced here were mostly for ship work, and in the busy season the foundry was in operation night and day. I have often worked two nights and every working day of the week. My foreman, Mr. Cobb, was a good man, and more than once protected me from abuse that one or more of the hands was disposed to throw upon me. While in this situation I had little time for mental improvement. Hard work, night and day, over a furnace hot enough to keep the metal running like water, was more favorable to action than thought; yet here I often nailed a newspaper to the post near my bellows, and read while I was performing the up and down motion of the heavy beam by which the bellows was inflated and discharged. It was the pursuit of knowledge under difficulties, and I look back to it now, after so many years, with some complacency and a little wonder that I could have been so earnest and persevering in any pursuit other than for my daily bread. I certainly saw nothing in the conduct of those around to inspire me with such interest: they were all devoted exclusively to what their hands found to do. I am glad to be able to say that, during my engagement in this foundry, no complaint was ever made against me that I did not do my work, and do it well. The bellows which I worked by main strength was, after I left, moved by a steam-engine.

THE GOOPHERED GRAPEVINE by Charles W. Chesnutt

About ten years ago my wife was in poor health, and our family doctor, in whose skill and honesty I had implicit confidence, advised a change of climate. I was engaged in grape-culture in northern Ohio, and decided to look for a locality suitable for carrying on the same business in some Southern State. I wrote to a cousin who had gone into the turpentine business in central North Carolina, and he assured me that no better place could be found in the South than the State and neighborhood in which he lived: climate and soil were all that could be asked for, and land could be bought for a mere song. A cordial invitation to visit him while I looked into the matter was accepted. We found the weather delightful at that season, the end of the summer, and were most hospitably entertained. Our host placed a horse and buggy at our disposal, and himself acted as guide until I got somewhat familiar with the country.

I went several times to look at a place which I thought might suit me. It had been at one time a thriving plantation, but shiftless cultivation had well-night exhausted the soil. There had been a vineyard of some extent on the place, but it had not been attended to since the war, and had fallen into utter neglect. The vines--here partly supported by decayed and broken-down arbors, there

twining themselves among the branches of the slender saplings which had sprung up among them--grew in wild and unpruned luxuriance, and the few scanty grapes which they bore were the undisputed prey of the first comer. The site was admirably adapted to grape-raising; the soil, with a little attention, could not have been better; and with the native grape, the luscious scuppernong, mainly to rely upon, I felt sure that I could introduce and cultivate successfully a number of other varieties.

One day I went over with my wife, to show her the place. We drove between the decayed gate-posts--the gate itself had long since disappeared--and up the straight, sandy lane to the open space where a dwelling-house had once stood. But the house had fallen a victim to the fortunes of war, and nothing remained of it except the brick pillars upon which the sills had rested. We alighted, and walked about the place for a while; but on Annie's complaining of weariness I led the way back to the yard, where a pine log, lying under a spreading elm, formed a shady though somewhat hard seat. One end of the log was already occupied by a venerable-looking colored man. He held on his knees a hat full of grapes, over which he was smacking his lips with great gusto, and a pile of grape-skins near him indicated that the performance was no new thing. He respectfully rose as we approached, and was moving away, when I begged him to keep his seat.

"Don't let us disturb you," I said. "There's plenty of room for us all."

He resumed his seat with somewhat of embarrassment.

"Do you live around here?" I asked, anxious to put him at his ease.

"Yas, suh. I lives des ober yander, behine de nex' san'-hill, on de Lumberton plank-road."

"Do you know anything about the time when this vineyard was cultivated?"

"Lawd bless yer, suh, I knows all about it. Dey ain' na'er a man in dis settlement w'at won' tell yer ole Julius McAdoo 'uz bawn an' raise' on dis yer same plantation. Is you de Norv'n gemman w'at's gwine ter buy de ole vimya'd?"

"I am looking at it," I replied; "but I don't know that I shall care to buy unless I can be reasonably sure of making something out of it."

"Well, suh, you is a stranger ter me, en I is a stranger ter you, en we is bofe strangers ter one anudder, but 'f I 'uz in yo' place, I wouldn' buy dis vimya'd."

"Why not?" I asked.

"Well, I dunner whe'r you b'lieves in cunj'in er not,--some er de w'ite folks don't, er says dey don't,--but de truf er de matter is dat dis yer ole vimya'd is goophered."

"Is what?" I asked, not grasping the meaning of this unfamiliar word.

"Is goophered, cunju'd, bewitch'."

He imparted this information with such solemn earnestness, and with such an air of confidential mystery, that I felt somewhat interested, while Annie was evidently much impressed, and drew closer to me.

"How do you know it is bewitched?" I asked.

"I wouldn' spec' fer you ter b'lieve me 'less you know all 'bout de fac's. But ef you en young miss dere doan' min' lis'n'in' ter a ole nigger run on a minute er two w'ile you er restin', I kin 'splain to yer how it all happen'."

We assured him that we would be glad to hear how it all happened, and he began to tell us. At first the current of his memory--or imagination--seemed somewhat sluggish; but as his embarrassment wore off, his language flowed more freely, and the story acquired perspective and coherence. As he became more and more absorbed in the narrative, his eyes assumed a dreamy expression, and he seemed to lose sight of his auditors, and to be living over again in monologue his life on the old plantation.

"Ole Mars Dugal' McAdoo bought dis place long many years befo' de wah, en I 'member well w'en he sot out all dis yer part er de plantation in scuppernon's. De vimes growed monst'us fas', en Mars Dugal' made a thousan' gallon er scuppernon' wine eve'y year.

"Now, ef dey's an'thing a nigger lub, nex' ter 'possum, en chick'n, en watermillyums, it's scuppernon's. Dey ain' nuffin dat kin stan' up side'n de scuppernon' fer sweetness; sugar ain't a suckumstance ter scuppernon'. W'en de season is nigh 'bout ober, en de grapes begin ter swivel up des a little wid de wrinkles er ole age,--w'en de skin git sof' en brown,--den de scuppernon' make you

smack yo' lip en roll yo' eye en wush fer mo'; so I reckon it ain' very 'stonishin' dat niggers lub scuppernon'.

"Dey wuz a sight er niggers in de naberhood er de vimya'd. Dere wuz ole Mars Henry Brayboy's niggers, en ole Mars Dunkin McLean's niggers, en Mars Dugal's own niggers; den dey wuz a settlement er free niggers en po' buckrahs down by de Wim'l'ton Road, en Mars Dugal' had de only vimya'd in de naberhood. I reckon it ain' so much so nowadays, but befo' de wah, in slab'ry times, er nigger didn' mine goin' fi' er ten mile in a night, w'en dey wuz sump'n good ter eat at de yuther een.

"So atter a w'ile Mars Dugal' begin ter miss his scuppernon's. Co'se he 'cuse' de niggers er it, but dey all 'nied it ter de las'. Mars Dugal' sot spring guns en steel traps, en he en de oberseah sot up nights once't er twice't, tel one night Mars Dugal'--he 'uz a monst'us keerless man--got his leg shot full er cow-peas. But somehow er nudder dey couldn' nebber ketch none er de niggers. I dunner how it happen, but it happen des like I tell yer, en de grapes kep' on a-goin des de same.

"But bimeby ole Mars Dugal' fix' up a plan ter stop it. Dey 'uz a cunjuh 'ooman livin' down mongs' de free niggers on de Wim'l'ton Road, en all de darkies fum Rockfish ter Beaver Crick wuz feared uv her. She could wuk de mos' powerfulles' kind er goopher,--could make people hab fits er rheumatiz, er make 'em des dwinel away en die; en dey say she went out ridin' de niggers at night, for she wuz a witch 'sides bein' a cunjuh 'ooman. Mars Dugal' hearn 'bout Aun' Peggy's doin's, en begun ter 'flect whe'r er no he couldn' git her ter he'p him keep de niggers off'n de grapevimes. One day in de spring er de year, ole miss pack' up a basket er chick'n en poun'-cake, en a bottle er scuppernon' wine, en Mars Dugal' tuk it in his buggy en driv ober ter Aun' Peggy's cabin. He tuk de basket in, en had a long talk wid Aun' Peggy. De nex' day Aun' Peggy come up ter de vimya'd. De niggers seed her slippin' 'roun', en dey soon foun' out what she 'uz doin' dere. Mars Dugal' had hi'ed her ter goopher de grapevimes. She sa'ntered 'roun' mongs' de vimes, en tuk a leaf fum dis one, en a grape-hull fum dat one, en a grape-seed fum anudder one; en den a little twig fum here, en a little pinch er dirt fum dere,--en put it all in a big black bottle, wid a snake's toof en a speckle' hen's gall en some ha'rs fum a black cat's tail, en den fill' de bottle wid scuppernon' wine. W'en she got de goopher all ready en fix', she tuk 'n went out in de woods en buried it under de root uv a red oak tree, en den come back en tole one er de niggers she done goopher de grapevimes, en a'er a nigger w'at eat dem grapes 'ud be sho ter die inside'n twel' mont's.

"Atter dat de niggers let de scuppernon's 'lone, en Mars Dugal' didn' hab no 'casion ter fine no mo' fault; en de season wuz mos' gone, w'en a strange gemman stop at de plantation one night ter see Mars Dugal' on some business; en his coachman, seein' de scuppernon's growin' so nice en sweet, slip 'roun' behine de smoke-house, en et all de scuppernon's he could hole. Nobody didn' notice it at de time, but dat night, on de way home, de gemman's hoss runned away en kill' de coachman. W'en we hearn de noos, Aun' Lucy, de cook, she up 'n say she seed de strange nigger eat'n' er de scuppernon's behine de smoke-house; en den we knowed de goopher had b'en er wukkin. Den one er de nigger chilluns runned away fum de quarters one day, en got in de scuppernon's, en died de nex' week. W'ite folks say he die' er de fevuh, but de niggers knowed it wuz de goopher. So you k'n be sho de darkies didn' hab much ter do wid dem scuppernon' vimes.

"W'en de scuppernon' season 'uz ober fer dat year, Mars Dugal' foun' he had made fifteen hund'ed gallon er wine; en one er de niggers hearn him laffin' wid de oberseah fit ter kill, en sayin' dem fifteen hund'ed gallon er wine wuz monst'us good intrus' on de ten dollars he laid out on de vimya'd. So I 'low ez he paid Aun' Peggy ten dollars fer to goopher de grapevimes.

"De goopher didn' wuk no mo' tel de nex' summer, w'en 'long to'ds de middle er de season one er de fiel' han's died; en ez dat lef' Mars Dugal' sho't er han's, he went off ter town fer ter buy anudder. He fotch de noo nigger home wid 'im. He wuz er ole nigger, er de color er a gingy-cake, en ball ez a hoss-apple on de top er his head. He wuz a peart ole nigger, do', en could do a big day's wuk.

"Now it happen dat one er de niggers on de nex' plantation, one er ole Mars Henry Brayboy's niggers, had runned away de day befo', en tuk ter de swamp, en ole Mars Dugal' en some er de yuther nabor w'ite folks had gone out wid dere guns en dere dogs fer ter he'p 'em hunt fer de nigger; en de han's on our own plantation wuz all so flusterated dat we fuhgot ter tell de noo han' 'bout de goopher on de scuppernon' vimes. Co'se he smell de grapes en see de vimes, an atter dahk de fus' thing he done wuz ter slip off ter de grapevimes 'dout sayin' nuffin ter nobody. Nex' mawnin' he tole some er de niggers 'bout de fine bait er scuppernon' he et de night befo'.

"W'en dey tole 'im 'bout de goopher on de grapevimes, he 'uz dat tarrified dat he turn pale, en look des like he gwine ter die right in his tracks. De oberseah come up en axed w'at 'uz de matter; en w'en dey tole 'im Henry be'n eatin' er de scuppernon's, en got de goopher on 'im, he gin Henry a big drink er w'iskey, en 'low dat de nex' rainy day he take 'im ober ter Aun' Peggy's, en see ef she wouldn' take de goopher off'n him, seein' ez he didn' know nuffin erbout it tel he done et de grapes.

"Sho nuff, it rain de nex' day, en de oberseah went ober ter Aun' Peggy's wid Henry. En Aun' Peggy say dat bein' ez Henry didn' know 'bout de goopher, en et de grapes in ign'ance er de quinseconces, she reckon she mought be able fer ter take de goopher off'n him. So she fotch out er bottle wid some cunjuh medicine in it, en po'd some out in a go'd fer Henry ter drink. He manage ter git it down; he say it tas'e like whiskey wid sump'n bitter in it. She 'lowed dat 'ud keep de goopher off'n him tel de spring; but w'en de sap begin ter rise in de grapevimes he ha' ter come en see her agin, en she tell him w'at e's ter do.

"Nex' spring, w'en de sap commence' ter rise in de scuppernon' vime, Henry tuk a ham one night. Whar'd he git de ham? I doan know; dey wa'nt no hams on de plantation 'cep'n' w'at 'uz in de smoke-house, but I never see Henry 'bout de smoke-house. But ez I wuz a-sayin', he tuk de ham ober ter Aun' Peggy's; en Aun' Peggy tole 'im dat w'en Mars Dugal' begin ter prume de grapevimes, he mus' go en take 'n scrape off de sap whar it ooze out'n de cut een's er de vimes, en 'n'int his ball head wid it; en ef he do dat once't a year de goopher wouldn' wuk agin 'im long ez he done it. En bein' ez he fotch her de ham, she fix' it so he kin eat all de scuppernon' he want.

"So Henry 'n'int his head wid de sap out'n de big grapevime des ha'f way 'twix' de quarters en de big house, en de goopher nebber wuk agin him dat summer. But de beatenes' thing you eber see happen ter Henry. Up ter dat time he wuz ez ball ez a sweeten' 'tater, but des ez soon ez de young leaves begun ter come out on de grapevimes de ha'r begun ter grow out on Henry's head, en by de middle er de summer he had de bigges' head er ha'r on de plantation. Befo' dat, Henry had tol'able good ha'r 'roun de aidges, but soon ez de young grapes begun ter come Henry's ha'r begun ter quirl all up in little balls, des like dis yer reg'lar grapy ha'r, en by de time de grapes got ripe his head look des like a bunch er grapes. Combin' it didn' do no good; he wuk at it ha'f de night wid er Jim Crow [1], en think he git it straighten' out, but in de mawnin' de grapes 'ud be dere des de same. So he gin it up, en tried ter keep de grapes down by havin' his ha'r cut sho't."

[Footnote 1: A small card, resembling a curry-comb in construction, and used by negroes in the rural districts instead of a comb.]

"But dat wa'nt de quares' thing 'bout de goopher. When Henry come ter de plantation, he wuz gittin' a little ole an stiff in de j'ints. But dat summer he got des ez spry en libely ez any young nigger on de plantation; fac' he got so biggity dat Mars Jackson, de oberseah, ha' ter th'eaten ter whip 'im, ef he didn' stop cuttin' up his didos en behave hisse'f. But de mos' cur'ouses' thing happen' in de fall, when de sap begin ter go down in de grapevimes. Fus', when de grapes 'uz gethered, de knots begun ter straighten out'n Henry's h'ar; en w'en de leaves begin ter fall, Henry's ha'r begin ter drap out; en w'en de vimes 'uz b'ar, Henry's head wuz baller 'n it wuz in de spring, en he begin ter git ole en stiff in de j'ints ag'in, en paid no mo' tention ter de gals dyoin' er de whole winter. En nex' spring, w'en he rub de sap on ag'in, he got young ag'in, en so soopl en libely dat none er de young niggers on de plantation couldn' jump, ner dance, ner hoe ez much cotton ez Henry. But in de fall er de year his grapes begun ter straighten out, en his j'ints ter git stiff, en his ha'r drap off, en de rheumatiz begin ter wrastle wid 'im.

"Now, ef you'd a knowed ole Mars Dugal' McAdoo, you'd a knowed dat it ha' ter be a mighty rainy day when he couldn' fine sump'n fer his niggers ter do, en it ha' ter be a mighty little hole he couldn' crawl thoo, en ha' ter be a monst'us cloudy night w'en a dollar git by him in de dahkness; en w'en he see how Henry git young in de spring en ole in de fall, he 'lowed ter hisse'f ez how he could make mo' money outen Henry dan by wukkin' him in de cotton fiel'. 'Long de nex' spring, atter de sap commence' ter rise, en Henry 'n'int 'is head en commence fer ter git young en soopl, Mars Dugal' up 'n tuk Henry ter town, en sole 'im fer fifteen hunder' dollars. Co'se de man w'at bought Henry didn' know nuffin 'bout de goopher, en Mars Dugal' didn' see no 'casion fer ter tell 'im. Long to'ds de fall, w'en de sap went down, Henry begin ter git ole again same ez yuzhal, en his noo marster begin ter git skeered les'n he gwine ter lose his fifteen-hunder'-dollar nigger. He sent fer a mighty fine doctor, but de med'cine didn' 'pear ter do no good; de goopher had a good holt. Henry tole de doctor 'bout de goopher, but de doctor des laff at 'im.

"One day in de winter Mars Dugal' went ter town, en wuz santerin' 'long de Main Street, when who should he meet but Henry's noo marster. Dey said 'Hoddy,' en Mars Dugal' ax 'im ter hab a seegyar; en atter dey run on awhile 'bout de craps en de weather, Mars Dugal' ax 'im, sorter keerless, like ez ef he des thought of it,--

"'How you like de nigger I sole you las' spring?'

"Henry's marster shuck his head en knock de ashes off'n his seegyar.

"'Spec' I made a bad bahgin when I bought dat nigger. Henry done good wuk all de summer, but sence de fall set in he 'pears ter be sorter pinin' away. Dey ain' nuffin pertickler de matter wid 'im--leastways de doctor say so--'cep'n' a tech er de rheumatiz; but his ha'r is all fell out, en ef he don't pick up his strenk mighty soon, I spec' I'm gwine ter lose 'im."

"Dey smoked on awhile, en bimeby ole mars say, 'Well, a bahgin's a bahgin, but you en me is good fren's, en I doan wan' ter see you lose all de money you paid fer dat digger [sic]; en ef w'at you say is so, en I ain't 'sputin' it, he ain't wuf much now. I spec's you wukked him too ha'd dis summer, er e'se de swamps down here don't agree wid de san'-hill nigger. So you des lemme know, en ef he gits any wusser I'll be willin' ter gib yer five hund'ed dollars fer 'im, en take my chances on his livin'.'

"Sho nuff, when Henry begun ter draw up wid de rheumatiz en it look like he gwine ter die fer sho, his noo marster sen' fer Mars Dugal', en Mars Dugal' gin him what he promus, en brung Henry home ag'in. He tuk good keer uv 'im dyoin' er de winter,--give 'im w'iskey ter rub his rheumatiz, en terbacker ter smoke, en all he want ter eat,--'caze a nigger w'at he could make a thousan' dollars a year off'n didn' grow on eve'y huckleberry bush.

"Nex' spring, w'en de sap ris en Henry's ha'r commence' ter sprout, Mars Dugal' sole 'im ag'in, down in Robeson County dis time; en he kep' dat sellin' business up fer five year er mo'. Henry nebber say nuffin 'bout de goopher ter his noo marsters, 'caze he know he gwine ter be tuk good keer uv de nex' winter, w'en Mars Dugal' buy him back. En Mars Dugal' made 'nuff money off'n Henry ter buy anudder plantation ober on Beaver Crick.

"But long 'bout de een' er dat five year dey come a stranger ter stop at de plantation. De fus' day he 'uz dere he went out wid Mars Dugal' en spent all de mawnin' lookin' ober de vimya'd, en atter dinner dey spent all de evenin' playin' kya'ds. De niggers soon 'skiver' dat he wuz a Yankee, en dat he come down ter Norf C'lina fer ter learn de w'ite folks how to raise grapes en make wine. He promus Mars Dugal' he cud make de grapevimes b'ar twice't ez many grapes, en dat de noo wine-press he wuz a-sellin' would make mo' d'n twice't ez many gallons er wine. En ole Mars Dugal' des drunk it all in, des 'peared ter be bewitched wit dat Yankee. W'en de darkies see dat Yankee runnin' 'roun de vimya'd en diggin' under de grapevimes, dey shuk dere heads, en 'lowed dat dey feared Mars Dugal' losin' his min'. Mars Dugal' had all de dirt dug away fum under de roots er all de scuppernon' vimes, an' let 'em stan' dat away fer a week er mo'. Den dat Yankee made de niggers fix up a mixtry er lime en ashes en manyo, en po' it roun' de roots er de grapevimes. Den he 'vise' Mars Dugal' fer ter trim de vimes close't, en Mars Dugal' tuck 'n done eve'ything de Yankee tole him ter do. Dyoin' all er dis time, mind yer, 'e wuz libbin' off'n de fat er de lan', at de big house, en playin' kyards wid Mars Dugal' eve'y night; en dey say Mars Dugal' los' mo'n a thousan' dollars dyoin' er de week dat Yankee wuz a runnin' de grapevimes.

"W'en de sap ris nex' spring, ole Henry 'n'inted his head ez yuzhal, en his ha'r commence' ter grow des de same ez it done eve'y year. De scuppernon' vimes growed monst's fas', en de leaves wuz greener en thicker dan dey eber be'n dyowin my rememb'ance; en Henry's ha'r growed out thicker dan eber, en he 'peared ter git younger 'n younger, en soopler 'n soopler; en seein' ez he wuz sho't er han's dat spring, havin' tuk in consid'able noo groun', Mars Dugal' 'cluded he wouldn' sell Henry 'tel he git de crap in en de cotton chop'. So he kep' Henry on de plantation.

"But 'long 'bout time fer de grapes ter come on de scuppernon' vimes, dey 'peared ter come a change ober dem; de leaves wivered en swivel' up, en de young grapes turn' yaller, en bimeby eve'ybody on de plantation could see dat de whole vimya'd wuz dyin'. Mars Dugal' tuck 'n water de vimes en done all he could, but 't wan' no use: dat Yankee done bus' de watermillyum. One time de vimes picked up a bit, en Mars Dugal' thought dey wuz gwine ter come out ag'in; but dat Yankee done dug too close unde' de roots, en prune de branches too close ter de vime, en all dat lime en ashes done burn' de life outen de vimes, en dey des kep' a with'in' en a swivelin'.

"All dis time de goopher wuz a-wukkin'. W'en de vimes commence' ter wither, Henry commence' ter complain er his rheumatiz, en when de leaves begin ter dry up his ha'r commence' ter drap out. When de vimes fresh up a bit Henry 'ud git peart agin, en when de vimes wither agin Henry 'ud git ole agin, en des kep' gittin' mo' en mo' fitten fer nuffin; he des pined away, en fine'ly tuk ter his cabin; en when de big vime whar he got de sap ter 'n'int his head withered en turned yaller en died, Henry died too,--des went out sorter like a cannel. Dey didn't 'pear ter be nuffin de matter wid 'im, 'cep'n de rheumatiz, but his strenk des dwinel' away 'tel he didn' hab ernuff lef' ter draw his bref. De goopher had got de under holt, en th'owed Henry fer good en all dat time.

"Mars Dugal' tuk on might'ly 'bout losin' his vimes en his nigger in de same year; en he swo' dat ef he could git hold er dat Yankee he'd wear 'im ter a frazzle, en den chaw up de frazzle; en he'd done it, too, for Mars Dugal' 'uz a monst'us brash man w'en he once git started. He sot de vimya'd out ober agin, but it wuz th'ee er fo' year befo' de vimes got ter b'arin' any scuppernon's.

"W'en de wah broke out, Mars Dugal' raise' a comp'ny, en went off ter fight de Yankees. He saw he wuz mighty glad dat wah come, en he des want ter kill a Yankee fer eve'y dollar he los' 'long er dat grape-raisin' Yankee. En I 'spec' he would a done it, too, ef de Yankees hadn' s'picioned sump'n, en killed him fus'. Atter de s'render ole miss move' ter town, de niggers all scattered 'way fum de plantation, en de vimya'd ain' be'n cultervated sence."

"Is that story true?" asked Annie, doubtfully, but seriously, as the old man concluded his narrative.

"It's des ez true ez I'm a-settin' here, miss. Dey's a easy way ter prove it: I kin lead de way right ter Henry's grave ober yander in de plantation buryin'-groun'. En I tell yer w'at, marster, I wouldn' 'vise yer to buy dis yer ole vimya'd, 'caze de goopher's on it yit, en dey ain' no tellin' w'en it's gwine ter crap out."

"But I thought you said all the old vines died."

"Dey did 'pear ter die, but a few ov 'em come out ag'in, en is mixed in mongs' de yuthers. I ain' skeered ter eat de grapes, 'caze I knows de old vimes fum de noo ones; but wid strangers dey ain' no tellin' w'at might happen. I wouldn' 'vise yer ter buy dis vimya'd."

I bought the vineyard, nevertheless, and it has been for a long time in a thriving condition, and is referred to by the local press as a striking illustration of the opportunities open to Northern capital in the development of Southern industries. The luscious scuppernong holds first rank among our grapes, though we cultivate a great many other varieties, and our income from grapes packed and shipped to the Northern markets is quite considerable. I have not noticed any developments of the goopher in the vineyard, although I have a mild suspicion that our colored assistants do not suffer from want of grapes during the season.

I found, when I bought the vineyard, that Uncle Julius had occupied a cabin on the place for many years, and derived a respectable revenue from the neglected grapevines. This, doubtless, accounted for his advice to me not to buy the vineyard, though whether it inspired the goopher story I am unable to state. I believe, however, that the wages I pay him for his services are more than an equivalent for anything he lost by the sale of the vineyard.

PO' SANDY by Charles W. Chesnutt

On the northeast corner of my vineyard in central North Carolina, and fronting on the Lumberton plank-road, there stood a small frame house, of the simplest construction. It was built of pine lumber, and contained but one room, to which one window gave light and one door admission. Its weather-beaten sides revealed a virgin innocence of paint. Against one end of the house, and occupying half its width, there stood a huge brick chimney: the crumbling mortar had left large cracks between the bricks; the bricks themselves had begun to scale off in large flakes, leaving the chimney sprinkled with unsightly blotches. These evidences of decay were but partially concealed by a creeping vine, which extended its slender branches hither and thither in an ambitious but futile attempt to cover the whole chimney. The wooden shutter, which had once protected the unglazed window, had fallen from its hinges, and lay rotting in the rank grass and jimson-weeds beneath. This building, I learned when I bought the place, had been used as a school-house for several years prior to the breaking out of the war, since which time it had remained unoccupied, save when some stray cow or vagrant hog had sought shelter within its walls from the chill rains and nipping winds of winter.

One day my wife requested me to build her a new kitchen. The house erected by us, when we first came to live upon the vineyard, contained a very conveniently arranged kitchen; but for some occult reason my wife wanted a kitchen in the back yard, apart from the dwelling-house, after the usual Southern fashion. Of course I had to build it.

To save expense, I decided to tear down the old school-house, and use the lumber, which was in a good state of preservation, in the construction of the new kitchen. Before demolishing the old house, however, I made an estimate of the amount of material contained in it, and found that I would have to buy several hundred feet of new lumber in order to build the new kitchen according to my wife's plan.

One morning old Julius McAdoo, our colored coachman, harnessed the gray mare to the rockaway, and drove my wife and me over to the saw-mill from which I meant to order the new lumber. We drove down the long lane which led from our house to the plank-road; following the plank-road for about a mile, we turned into a road running through the forest and across the swamp to the sawmill beyond. Our carriage jolted over the half-rotted corduroy road which traversed the swamp, and then climbed the long hill leading to the saw-mill. When we reached the mill, the foreman had gone over to a neighboring farm-house, probably to smoke or gossip, and we were compelled to await his return before we could transact our business. We remained seated in the carriage, a few rods from the mill, and watched the leisurely movements of the mill-hands. We had not waited long before a huge pine log was placed in position, the machinery of the mill was set in motion, and the circular saw began to eat its way through the log, with a loud whirr which resounded throughout the vicinity of the mill. The sound rose and fell in a sort of rhythmic cadence, which, heard from where we sat, was not unpleasing, and not loud enough to prevent conversation. When the saw started on its second journey through the log, Julius observed, in a lugubrious tone, and with a perceptible shudder:--

"Ugh! but dat des do cuddle my blood!"

"What's the matter, Uncle Julius?" inquired my wife, who is of a very sympathetic turn of mind. "Does the noise affect your nerves?"

"No, Miss Annie," replied the old man, with emotion, "I ain' narvous; but dat saw, a-cuttin' en grindin' thoo dat stick er timber, en moanin', en groanin', en sweekin', kyars my 'memb'ance back ter ole times, en 'min's me er po' Sandy." The pathetic intonation with which he lengthened out the "po' Sandy" touched a responsive chord in our own hearts.

"And who was poor Sandy?" asked my wife, who takes a deep interest in the stories of plantation life which she hears from the lips of the older colored people. Some of these stories are quaintly humorous; others wildly extravagant, revealing the Oriental cast of the negro's imagination; while others, poured freely into the sympathetic ear of a Northern-bred woman, disclose many a tragic incident of the darker side of slavery.

"Sandy," said Julius, in reply to my wife's question, "was a nigger w'at useter b'long ter ole Mars Marrabo McSwayne. Mars Marrabo's place wuz on de yuther side'n de swamp, right nex' ter yo' place. Sandy wuz a monst'us good nigger, en could do so many things erbout a plantation, en alluz 'ten ter his wuk so well, dat w'en Mars Marrabo's chilluns growed up en married off, dey all un 'em wanted dey daddy fer ter gin 'em Sandy fer a weddin' present. But Mars Marrabo knowed de res' wouldn' be satisfied ef he gin Sandy ter a'er one un 'em; so w'en dey wuz all done married, he fix it by 'lowin' one er his chilluns ter take Sandy fer a mont' er so, en den ernudder for a mont' er so, en so on dat erway tel dey had all had 'im de same lenk er time; en den dey would all take him roun' ag'in, 'cep'n oncet in a w'ile w'en Mars Marrabo would len' 'im ter some er his yuther kinfolks 'roun' de country, w'en dey wuz short er han's; tel bimeby it go so Sandy didn' hardly knowed whar he wuz gwine ter stay fum one week's een ter de yuther.

"One time w'en Sandy wuz lent out ez yushal, a spekilater come erlong wid a lot er niggers, en Mars Marrabo swap' Sandy's wife off fer a noo 'oman. W'en Sandy come back, Mars Marrabo gin 'im a dollar, en 'lowed he wuz monst'us sorry fer ter break up de fambly, but de spekilater had gin 'im big boot, en times wuz hard en money skase, en so he wuz bleedst ter make de trade. Sandy tuk on some 'bout losin' his wife, but he soon seed dey want no use cryin' ober spilt merlasses; en bein' ez he lacked de looks er de noo 'ooman, he tuk up wid her atter she b'n on de plantation a mont' er so.

"Sandy en his noo wife got on mighty well tergedder, en de niggers all 'mence' ter talk about how lovin' dey wuz. W'en Tenie wuz tuk sick oncet, Sandy useter set up all night wid 'er, en den go ter wuk in de mawnin' des lack he had his reg'lar sleep; en Tenie would 'a done anythin' in de worl' for her Sandy.

"Sandy en Tenie hadn' b'en libbin' tergedder fer mo' d'n two mont's befo' Mars Marrabo's old uncle, w'at libbed down in Robeson County, sent up ter fine out ef Mars Marrabo couldn' len' 'im er hire 'im a good han' fer a mont' er so. Sandy's marster wuz one er dese yer easy-gwine folks w'at wanter please eve'ybody, en he says yas, he could len' 'im Sandy. En Mars Marrabo tole Sandy fer ter git ready ter go down ter Robeson nex' day, fer ter stay a mont' er so.

"Hit wuz monst'us hard on Sandy fer ter take 'im 'way fum Tenie. Hit wuz so fur down ter Robeson dat he didn' hab no chance er comin' back ter see her tel de time wuz up; he wouldn' a' mine comin' ten er fifteen mile at night ter see Tenie, but Mars Marrabo's uncle's plantation wuz mo' d'n forty mile off. Sandy wuz mighty sad en cas' down atter w'at Mars Marrabo tole 'im, en he says ter Tenie, sezee:--

"'I'm gittin monstus ti'ed er dish yer gwine roun' so much. Here I is lent ter Mars Jeems dis mont', en I got ter do so-en-so; en ter Mars Archie de nex' mont', en I got ter do so-en-so; den I got ter go ter Miss Jinnie's: en hit's Sandy dis en Sandy dat, en Sandy yer en Sandy dere, tel it 'pears ter me I ain' got no home, ner no marster, ner no mistiss, ner no nuffin'. I can't eben keep a wife: my yuther ole 'oman wuz sole away widout my gittin' a chance fer ter tell her good-by; en now I got ter go off en leab you, Tenie, en I dunno whe'r I'm eber gwine ter see yer ag'in er no. I wisht I wuz a tree, er a stump, er a rock, er sump'n w'at could stay on de plantation fer a w'ile.'

"Atter Sandy got thoo talkin', Tenie didn' say naer word, but des sot dere by de fier, studyin' en studyin'. Bimeby she up'n says:--

"'Sandy, is I eber tole you I wuz a cunjuh-'ooman?'

"Co'se Sandy hadn' nebber dremp' er nuffin lack dat, en he made a great miration w'en he hear w'at Tenie say. Bimeby Tenie went on:--

"'I ain' goophered nobody, ner done no cunjuh-wuk fer fifteen yer er mo; en w'en I got religion I made up my mine I wouldn' wuk no mo' goopher. But dey is some things I doan b'lieve it's no sin fer ter do; en ef you doan wanter be sent roun' fum pillar ter pos', en ef you doan wanter go down ter Robeson, I kin fix things so yer won't haf ter. Ef you'll des say de word, I kin turn yer ter w'ateber yer wanter be, en yer kin stay right whar yer wanter, ez long ez yer mineter.'

"Sandy say he doan keer; he's willin' fer ter do anythin' fer ter stay close ter Tenie. Den Tenie ax 'im ef he doan wanter be turnt inter a rabbit.

"Sandy say, 'No, de dogs mout git atter me.'

"'Shill I turn yer ter a wolf?' sez Tenie.

"'No, eve'ybody's skeered er a wolf, en I doan want nobody ter be skeered er me.'

"'Shill I turn yer ter a mawkin'-bird?'

"'No, a hawk mout ketch me. I wanter be turnt inter sump'n w'at'll stay in one place.'

"'I kin turn yer ter a tree,' sez Tenie. 'You won't hab no mouf ner years, but I kin turn yer back oncet in a w'ile, so yer kin git sump'n ter eat, en hear w'at's gwine on.'

"Well, Sandy say dat'll do. En so Tenie tuk 'im down by de aidge er de swamp, not fur fum de quarters, en turnt 'im inter a big pine-tree, en sot 'im out mongs' some yuther trees. En de nex' mawnin', ez some er de fiel' han's wuz gwine long dere, dey seed a tree w'at dey didn' 'member er habbin' seed befo; it wuz monst'us quare, en dey wuz bleedst ter 'low dat dey hadn' 'membered right, er e'se one er de saplin's had be'n growin' monst'us fas'.

"W'en Mars Marrabo 'skiver' dat Sandy wuz gone, he 'lowed Sandy had runned away. He got de dogs out, but de las' place dey could track Sandy ter wuz de foot er dat pine-tree. En dere de dogs stood en barked, en bayed, en pawed at de tree, en tried ter climb up on it; en w'en dey wuz tuk roun' thoo de swamp ter look fer de scent, dey broke loose en made fer dat tree ag'in. It wuz de beatenis' thing de w'ite folks eber hearn of, en Mars Marrabo 'lowed dat Sandy must a' clim' up on de tree en jump' off on a mule er sump'n, en rid fur 'nuff fer ter spile de scent. Mars Marrabo wanted ter 'cuse some er de yuther niggers er heppin Sandy off, but dey all 'nied it ter de las'; en eve'ybody knowed Tenie sot too much by Sandy fer ter he'p 'im run away whar she couldn' nebber see 'im no mo'.

"W'en Sandy had be'n gone long 'nuff fer folks ter think he done got clean away, Tenie useter go down ter de woods at night en turn 'im back, en den dey'd slip up ter de cabin en set by de fire en talk. But dey ha' ter be monst'us keerful, er e'se somebody would a seed 'em, en dat would a spile de whole thing; so Tenie alluz turnt Sandy back in de mawnin' early, befo' anybody wuz a'stirrin'.

"But Sandy didn' git erlong widout his trials en tribberlations. One day a woodpecker come erlong en 'mence' ter peck at de tree; en de nex' time Sandy wuz turnt back he had a little roun' hole in his arm, des lack a sharp stick be'n stuck in it. Atter dat Tenie sot a sparrer-hawk fer ter watch de tree; en w'en de woodpecker come erlong nex' mawnin' fer ter finish his nes', he got gobble' up mos' fo' he stuck his bill in de bark.

"Nudder time, Mars Marrabo sent a nigger out in de woods fer ter chop tuppentime boxes. De man chop a box in dish yer tree, en hack' de bark up two er th'ee feet, fer ter let de tuppentime run. De nex' time Sandy wuz turnt back he had a big skyar on his lef' leg, des lack it be'n skunt; en it tuk Tenie nigh 'bout all night fer ter fix a mixtry ter kyo it up. Atter dat, Tenie sot a hawnet fer ter watch de tree; en w'en de nigger come back ag'in fer ter cut ernudder box on de yuther side'n de tree, de hawnet stung 'im so hard dat de ax slip en cut his foot nigh 'bout off.

"W'en Tenie see so many things happenin' ter de tree, she 'cluded she'd ha' ter turn Sandy ter sump'n e'se; en atter studyin' de matter ober, en talkin' wid Sandy one ebenin', she made up her mine fer ter fix up a goopher mixtry w'at would turn herse'f en Sandy ter foxes, er sump'n, so dey could run away en go some'rs whar dey could be free en lib lack w'ite folks.

"But dey ain' no tellin' w'at's gwine ter happen in dis worl'. Tenie had got de night sot fer her en Sandy ter run away, w'en dat ve'y day one er Mars Marrabo's sons rid up ter de big house in his buggy, en say his wife wuz monst'us sick, en he want his mammy ter len' 'im a 'ooman fer ter nuss his wife. Tenie's mistiss say sen Tenie; she wuz a good nuss. Young mars wuz in a tarrible hurry fer ter git back home. Tenie wuz washin' at de big house dat day, en her mistiss say she should go right 'long wid her young marster. Tenie tried ter make some 'scuse fer ter git away en hide tel night, w'en she would have eve'ything fix' up fer her en Sandy; she say

she wanter go ter her cabin fer ter git her bonnet. Her mistiss say it doan matter 'bout de bonnet; her head-hankcher wuz good 'nuff. Den Tenie say she wanter git her bes' frock; her mistiss say no, she doan need no mo' frock, en w'en dat one got dirty she could git a clean one whar she wuz gwine. So Tenie had ter git in de buggy en go 'long wid young Mars Dunkin ter his plantation, w'ich wuz mo' d'n twenty mile away; en dey want no chance er her seein' Sandy no mo' tel she come back home. De po' gal felt monst'us bad erbout de way things wuz gwine on, en she knowed Sandy mus' be a wond'rin' why she didn' come en turn 'im back no mo'.

"W'iles Tenie wuz away nussin' young Mars Dunkin's wife, Mars Marrabo tuk a notion fer ter buil' 'im a noo kitchen; en bein' ez he had lots er timber on his place, he begun ter look 'roun' fer a tree ter hab de lumber sawed out'n. En I dunno how it come to be so, but he happen fer ter hit on de ve'y tree w'at Sandy wuz turnt inter. Tenie wuz gone, en dey wa'n't nobody ner nuffin' fer ter watch de tree.

"De two men w'at cut de tree down say dey nebber had sech a time wid a tree befo': dey axes would glansh off, en didn' 'pear ter make no progress thoo de wood; en of all de creakin', en shakin', en wobblin' you eber see, dat tree done it w'en it commence' ter fall. It wuz de beatenis' thing!

"W'en dey got de tree all trim' up, dey chain it up ter a timber waggin, en start fer de saw-mill. But dey had a hard time gittin' de log dere: fus' dey got stuck in de mud w'en dey wuz gwine crosst de swamp, en it wuz two er th'ee hours befo' dey could git out. W'en dey start' on ag'in, de chain kep' a-comin' loose, en dey had ter keep a-stoppin' en a-stoppin' fer ter hitch de log up ag'in. W'en dey commence' ter climb de hill ter de saw-mill, de log broke loose, en roll down de hill en in mongs' de trees, en hit tuk nigh 'bout half a day mo' ter git it haul' up ter de saw-mill.

"De nex' mawnin' atter de day de tree wuz haul' ter de saw-mill, Tenie come home. W'en she got back ter her cabin, de fus' thing she done wuz ter run down ter de woods en see how Sandy wuz gittin' on. W'en she seed de stump standin' dere, wid de sap runnin' out'n it, en de limbs layin' scattered roun', she nigh 'bout went out'n her mine. She run ter her cabin, en got her goopher mixtry, en den foller de track er de timber waggin ter de saw-mill. She knowed Sandy couldn' lib mo' d'n a minute er so ef she turn' him back, fer he wuz all chop' up so he'd a be'n bleedst ter die. But she wanted ter turn 'im back long ernuff fer ter 'splain ter 'im dat she hadn' went off a-purpose, en lef' 'im ter be chop' down en sawed up. She didn' want Sandy ter die wid no hard feelin's to'ds her.

"De han's at de saw-mill had des got de big log on de kerridge, en wuz startin' up de saw, w'en dey seed a 'oman runnin up de hill, all out er bref, cryin' en gwine on des lack she wuz plumb 'stracted. It wuz Tenie; she come right inter de mill, en th'owed herse'f on de log, right in front er de saw, a-hollerin' en cryin' ter her Sandy ter fergib her, en not ter think hard er her, fer it wa'n't no fault er hern. Den Tenie 'membered de tree didn' hab no years, en she wuz gittin' ready fer ter wuk her goopher mixtry so ez ter turn Sandy back, w'en de mill-hands kotch holt er her en tied her arms wid a rope, en fasten' her to one er de posts in de saw-mill; en den dey started de saw up ag'in, en cut de log up inter bo'ds en scantlin's right befo' her eyes. But it wuz mighty hard wuk; fer of all de sweekin', en moanin', en groanin', dat log done it w'iles de saw wuz a-cuttin' thoo it. De saw wuz one er dese yer ole-timey, up-en-down saws, en hit tuk longer dem days ter saw a log 'en it do now. Dey greased de saw, but dat didn' stop de fuss; hit kep' right on, tel finely dey got de log all sawed up.

"W'en de oberseah w'at run de saw-mill come fum brekfas', de han's up en tell him 'bout de crazy 'ooman--ez dey s'posed she wuz--w'at had come runnin' in de saw-mill, a-hollerin' en gwine on, en tried ter th'ow herse'f befo' de saw. En de oberseah sent two er th'ee er de han's fer ter take Tenie back ter her marster's plantation.

"Tenie 'peared ter be out'n her mine fer a long time, en her marster ha' ter lock her up in de smoke-'ouse tel she got ober her spells. Mars Marrabo wuz monst'us mad, en hit would a made yo' flesh crawl fer ter hear him cuss, caze he say de spekilater w'at he got Tenie fum had fooled 'im by wukkin' a crazy 'oman off on him. Wiles Tenie wuz lock up in de smoke-'ouse, Mars Marrabo tuk'n' haul de lumber fum de saw-mill, en put up his noo kitchen.

"W'en Tenie got quiet' down, so she could be 'lowed ter go 'roun' de plantation, she up'n tole her marster all erbout Sandy en de pine-tree; en w'en Mars Marrabo hearn it, he 'lowed she wuz de wuss 'stracted nigger he eber hearn of. He didn' know w'at ter do wid Tenie: fus' he thought he'd put her in de po'-house; but finely, seein' ez she didn' do no harm ter nobody ner nuffin', but des went roun' moanin', en groanin', en shakin' her head, he 'cluded ter let her stay on de plantation en nuss de little nigger chilluns w'en dey mammies wuz ter wuk in de cotton-fiel'.

"De noo kitchen Mars Marrabo buil' wuzn' much use, fer it hadn' be'n put up long befo' de niggers 'mence' ter notice quare things erbout it. Dey could hear sump'n moanin' en groanin' 'bout de kitchen in de night-time, en w'en de win' would blow dey could hear

sump'n a-hollerin' en sweekin' lack hit wuz in great pain en sufferin'. En hit got so atter a w'ile dat hit wuz all Mars Marrabo's wife could do ter git a 'ooman ter stay in de kitchen in de daytime long ernuff ter do de cookin'; en dey wa'n't naer nigger on de plantation w'at wouldn' rudder take forty dan ter go 'bout dat kitchen atter dark,--dat is, 'cep'n Tenie; she didn' pear ter mine de ha'nts. She useter slip 'roun' at night, en set on de kitchen steps, en lean up agin de do'-jamb, en run on ter herse'f wid some kine er foolishness w'at nobody couldn' make out; fer Mars Marrabo had th'eaten' ter sen' her off'n de plantation ef she say anything ter any er de yuther niggers 'bout de pine-tree. But somehow er nudder de niggers foun' out all 'bout it, en dey knowed de kitchen wuz ha'anted by Sandy's sperrit. En bimeby hit got so Mars Marrabo's wife herse'f wuz skeered ter go out in de yard atter dark.

"W'en it come ter dat, Mars Marrabo tuk 'n' to' de kitchen down, en use' de lumber fer ter buil' dat ole school-'ouse w'at youer talkin' 'bout pullin' down. De school-'ouse wuzn' use' 'cep'n' in de daytime, en on dark nights folks gwine 'long de road would hear quare soun's en see quare things. Po' ole Tenie useter go down dere at night, en wander 'roun' de school-'ouse; en de niggers all 'lowed she went fer ter talk wid Sandy's sperrit. En one winter mawnin', w'en one er de boys went ter school early fer ter start de fire, w'at should he fine but po' ole Tenie, layin' on de flo', stiff, en cole, en dead. Dere didn' 'pear ter be nuffin' pertickler de matter wid her,--she had des grieve' herse'f ter def fer her Sandy. Mars Marrabo didn' shed no tears. He thought Tenie wuz crazy, en dey wa'n't no tellin' w'at she mout do nex'; en dey ain' much room in dis worl' fer crazy w'ite folks, let 'lone a crazy nigger.

"Hit wa'n't long atter dat befo' Mars Marrabo sole a piece er his track er lan' ter Mars Dugal' McAdoo,--MY ole marster,--en dat's how de ole school-house happen to be on yo' place. W'en de wah broke out, de school stop', en de ole school-'ouse be'n stannin' empty ever sence,--dat is, 'cep'n' fer de ha'nts. En folks sez dat de ole school-'ouse, er any yuther house w'at got any er dat lumber in it w'at wuz sawed out'n de tree w'at Sandy wuz turnt inter, is gwine ter be ha'nted tel de las' piece er plank is rotted en crumble' inter dus'."

Annie had listened to this gruesome narrative with strained attention.

"What a system it was," she exclaimed, when Julius had finished, "under which such things were possible!"

"What things?" I asked, in amazement. "Are you seriously considering the possibility of a man's being turned into a tree?"

"Oh, no," she replied quickly, "not that;" and then she added absently, and with a dim look in her fine eyes, "Poor Tenie!"

We ordered the lumber, and returned home. That night, after we had gone to bed, and my wife had to all appearances been sound asleep for half an hour, she startled me out of an incipient doze by exclaiming suddenly,--

"John, I don't believe I want my new kitchen built out of the lumber in that old school-house."

"You wouldn't for a moment allow yourself," I replied, with some asperity, "to be influenced by that absurdly impossible yarn which Julius was spinning to-day?"

"I know the story is absurd," she replied dreamily, "and I am not so silly as to believe it. But I don't think I should ever be able to take any pleasure in that kitchen if it were built out of that lumber. Besides, I think the kitchen would look better and last longer if the lumber were all new."

Of course she had her way. I bought the new lumber, though not without grumbling. A week or two later I was called away from home on business. On my return, after an absence of several days, my wife remarked to me,--

"John, there has been a split in the Sandy Run Colored Baptist Church, on the temperance question. About half the members have come out from the main body, and set up for themselves. Uncle Julius is one of the seceders, and he came to me yesterday and asked if they might not hold their meetings in the old school-house for the present."

"I hope you didn't let the old rascal have it," I returned, with some warmth. I had just received a bill for the new lumber I had bought.

"Well," she replied, "I could not refuse him the use of the house for so good a purpose."

"And I'll venture to say," I continued, "that you subscribed something toward the support of the new church?"

She did not attempt to deny it.

"What are they going to do about the ghost?" I asked, somewhat curious to know how Julius would get around this obstacle.

"Oh," replied Annie, "Uncle Julius says that ghosts never disturb religious worship, but that if Sandy's spirit SHOULD happen to stray into meeting by mistake, no doubt the preaching would do it good."

DAVE'S NECKLISS by Charles W. Chesnutt

"Have some dinner, Uncle Julius?" said my wife.

It was a Sunday afternoon in early autumn. Our two women-servants had gone to a camp-meeting some miles away, and would not return until evening. My wife had served the dinner, and we were just rising from the table, when Julius came up the lane, and, taking off his hat, seated himself on the piazza.

The old man glanced through the open door at the dinner-table, and his eyes rested lovingly upon a large sugar-cured ham, from which several slices had been cut, exposing a rich pink expanse that would have appealed strongly to the appetite of any hungry Christian.

"Thanky, Miss Annie," he said, after a momentary hesitation, "I dunno ez I keers ef I does tas'e a piece er dat ham, ef yer'll cut me off a slice un it."

"No," said Annie, "I won't. Just sit down to the table and help yourself; eat all you want, and don't be bashful."

Julius drew a chair up to the table, while my wife and I went out on the piazza. Julius was in my employment; he took his meals with his own family, but when he happened to be about our house at meal-times, my wife never let him go away hungry.

I threw myself into a hammock, from which I could see Julius through an open window. He ate with evident relish, devoting his attention chiefly to the ham, slice after slice of which disappeared in the spacious cavity of his mouth. At first the old man ate rapidly, but after the edge of his appetite had been taken off he proceeded in a more leisurely manner. When he had cut the sixth slice of ham (I kept count of them from a lazy curiosity to see how much he COULD eat) I saw him lay it on his plate; as he adjusted the knife and fork to cut it into smaller pieces, he paused, as if struck by a sudden thought, and a tear rolled down his rugged cheek and fell upon the slice of ham before him. But the emotion, whatever the thought that caused it, was transitory, and in a moment he continued his dinner. When he was through eating, he came out on the porch, and resumed his seat with the satisfied expression of countenance that usually follows a good dinner.

"Julius," I said, "you seemed to be affected by something, a moment ago. Was the mustard so strong that it moved you to tears?"

"No, suh, it wa'n't de mustard; I wuz studyin' 'bout Dave."

"Who was Dave, and what about him?" I asked.

The conditions were all favorable to story-telling. There was an autumnal languor in the air, and a dreamy haze softened the dark green of the distant pines and the deep blue of the Southern sky. The generous meal he had made had put the old man in a very good humor. He was not always so, for his curiously undeveloped nature was subject to moods which were almost childish in their variableness. It was only now and then that we were able to study, through the medium of his recollection, the simple but intensely human inner life of slavery. His way of looking at the past seemed very strange to us; his view of certain sides of life was essentially different from ours. He never indulged in any regrets for the Arcadian joyousness and irresponsibility which was a somewhat popular conception of slavery; his had not been the lot of the petted house-servant, but that of the toiling field-hand. While he mentioned with a warm appreciation the acts of kindness which those in authority had shown to him and his people, he would speak of a cruel deed, not with the indignation of one accustomed to quick feeling and spontaneous expression, but with a furtive disapproval which suggested to us a doubt in his own mind as to whether he had a right to think or to feel, and presented to us the curious psychological spectacle of a mind enslaved long after the shackles had been struck off from the limbs of its possessor. Whether the sacred name of liberty ever set his soul aglow with a generous fire; whether he had more than the most elementary ideas of love, friendship, patriotism, religion,--things which are half, and the better half, of life to us; whether he even realized, except in a vague, uncertain way, his own degradation, I do not know. I fear not; and if not, then centuries of repression had borne their legitimate fruit. But in the simple human feeling, and still more in the undertone of sadness, which pervaded his stories, I thought I could see a spark which, fanned by favoring breezes and fed by the memories of the past, might become in his children's children a glowing flame of sensibility, alive to every thrill of human happiness or human woe.

"Dave use' ter b'long ter my ole marster," said Julius; "he wuz raise' on dis yer plantation, en I kin 'member all erbout 'im, fer I wuz ole 'nuff ter chop cotton w'en it all happen'. Dave wuz a tall man, en monst'us strong: he could do mo' wuk in a day dan any yuther two niggers on de plantation. He wuz one er dese yer solemn kine er men, en nebber run on wid much foolishness, like de yuther darkies. He use' ter go out in de woods en pray; en w'en he hear de han's on de plantation cussin' en gwine on wid dere dancin' en foolishness, he use' ter tell 'em 'bout religion en jedgmen'-day, w'en dey would haf ter gin account fer eve'y idle word en all dey yuther sinful kyarin's-on.

"Dave had l'arn' how ter read de Bible. Dey wuz a free nigger boy in de settlement w'at wuz monst'us smart, en could write en cipher, en wuz alluz readin' books er papers. En Dave had hi'ed dis free boy fer ter l'arn 'im how ter read. Hit wuz 'g'in de law, but co'se none er de niggers didn' say nuffin ter de w'ite folks 'bout it. Howsomedever, one day Mars Walker--he wuz de oberseah--foun' out Dave could read. Mars Walker wa'n't nuffin but a po' bockrah, en folks said he couldn' read ner write hisse'f, en co'se he didn' lack ter see a nigger w'at knowed mo' d'n he did; so he went en tole Mars Dugal'. Mars Dugal' sont fer Dave, en ax' 'im 'bout it.

"Dave didn't hardly knowed w'at ter do; but he couldn' tell no lie, so he 'fessed he could read de Bible a little by spellin' out de words. Mars Dugal' look' mighty solemn.

"'Dis yer is a se'ious matter,' sezee; 'it's 'g'in de law ter l'arn niggers how ter read, er 'low 'em ter hab books. But w'at yer l'arn out'n dat Bible, Dave?'

"Dave wa'n't no fool, ef he wuz a nigger, en sezee:--

"'Marster, I l'arns dat it's a sin fer ter steal, er ter lie, er fer ter want w'at doan b'long ter yer; en I l'arns fer ter love de Lawd en ter 'bey my marster.'

"Mars Dugal' sorter smile' en laf' ter hisse'f, like he 'uz might'ly tickle' 'bout sump'n, en sezee:--

"'Doan 'pear ter me lack readin' de Bible done yer much harm, Dave. Dat's w'at I wants all my niggers fer ter know. Yer keep right on readin', en tell de yuther han's w'at yer be'n tellin' me. How would yer lack fer ter preach ter de niggers on Sunday?'

"Dave say he'd be glad fer ter do w'at he could. So Mars Dugal' tole de oberseah fer ter let Dave preach ter de niggers, en tell 'em w'at wuz in de Bible, en it would he'p ter keep 'em fum stealin' er runnin' erway.

"So Dave 'mence' ter preach, en done de han's on de plantation a heap er good, en most un 'em lef' off dey wicked ways, en 'mence' ter love ter hear 'bout God, en religion, en de Bible; en dey done dey wuk better, en didn' gib de oberseah but mighty little trouble fer ter manage 'em.

"Dave wuz one er dese yer men w'at didn' keer much fer de gals,--leastways he didn' tel Dilsey come ter de plantation. Dilsey wuz a monst'us peart, good-lookin', gingybread-colored gal,--one er dese yer high-steppin' gals w'at hol's dey heads up, en won' stan' no foolishness fum no man. She had b'long' ter a gemman over on Rockfish, w'at died, en whose 'state ha' ter be sol' fer ter pay his debts. En Mars Dugal' had b'en ter de oction, en w'en he seed dis gal a-cryin' en gwine on 'bout bein' sol' erway fum her ole mammy, Aun' Mahaly, Mars Dugal' bid 'em bofe in, en fotch 'em ober ter our plantation.

"De young nigger men on de plantation wuz des wil' atter Dilsey, but it didn' do no good, en none un 'em couldn' git Dilsey fer dey junesey,[2] 'tel Dave 'mence' fer ter go roun' Aun' Mahaly's cabin. Dey wuz a fine-lookin' couple, Dave en Dilsey wuz, bofe tall, en well-shape', en soopl'. En dey sot a heap by one ernudder. Mars Dugal' seed 'em tergedder one Sunday, en de nex' time he seed Dave atter dat, sezee:--

"Dave, w'en yer en Dilsey gits ready fer ter git married, I ain' got no rejections. Dey's a poun' er so er chawin'-terbacker up at de house, en I reckon yo' mist'iss kin fine a frock en a ribbin er two fer Dilsey. Youer bofe good niggers, en yer neenter be feared er bein' sol' 'way fum one ernudder long ez I owns dis plantation; en I 'spec's ter own it fer a long time yit.'"

[Footnote 2: Sweetheart.]

"But dere wuz one man on de plantation w'at didn' lack ter see Dave en Dilsey tergedder ez much ez ole marster did. W'en Mars Dugal' went ter de sale whar he got Dilsey en Mahaly, he bought ernudder han', by de name er Wiley. Wiley wuz one er dese yer shiny-eyed, double-headed little niggers, sha'p ez a steel trap, en sly ez de fox w'at keep out'n it. Dis yer Wiley had be'n pesterin' Dilsey 'fo' she come ter our plantation, en had nigh 'bout worried de life out'n her. She didn' keer nuffin fer 'im, but he pestered her

so she ha' ter th'eaten ter tell her marster fer ter make Wiley let her 'lone. W'en he come ober to our place it wuz des ez bad, 'tel bimeby Wiley seed dat Dilsey had got ter thinkin' a heap 'bout Dave, en den he sorter hilt off aw'ile, en purten' lack he gin Dilsey up. But he wuz one er dese yer 'ceitful niggers, en w'ile he wuz laffin' en jokin' wid de yuther han's 'bout Dave en Dilsey, he wuz settin' a trap fer ter ketch Dave en git Dilsey back fer hisse'f.

"Dave en Dilsey made up dere min's fer ter git married long 'bout Christmas time, w'en dey'd hab mo' time fer a weddin'. But 'long 'bout two weeks befo' dat time ole mars 'mence' ter lose a heap er bacon. Eve'y night er so somebody 'ud steal a side er bacon, er a ham, er a shoulder, er sump'n, fum one er de smoke-'ouses. De smoke-'ouses wuz lock', but somebody had a key, en manage' ter git in some way er 'nudder. Dey's mo' ways 'n one ter skin a cat, en dey's mo' d'n one way ter git in a smoke-'ouse,--leastways dat's w'at I hearn say. Folks w'at had bacon fer ter sell didn' hab no trouble 'bout gittin' rid un it. Hit wuz 'g'in' de law fer ter buy things fum slabes; but Lawd! dat law didn' 'mount ter a hill er peas. Eve'y week er so one er dese yer big covered waggins would come 'long de road, peddlin' terbacker en w'iskey. Dey wuz a sight er room in one er dem big waggins, en it wuz monst'us easy fer ter swop off bacon fer sump'n ter chaw er ter wa'm yer up in de winter-time. I s'pose de peddlers didn' knowed dey wuz breakin' de law, caze de niggers alluz went at night, en stayed on de dark side er de waggin; en it wuz mighty hard fer ter tell W'AT kine er folks dey wuz.

"Atter two er th'ee hund'ed er meat had be'n stole', Mars Walker call all de niggers up one ebenin', en tol' 'em dat de fus' nigger he cot stealin' bacon on dat plantation would git sump'n fer ter 'member it by long ez he lib'. En he say he'd gin fi' dollars ter de nigger w'at 'skiver' de rogue. Mars Walker say he s'picion' one er two er de niggers, but he couldn' tell fer sho, en co'se dey all 'nied it w'en he 'cuse em un it.

"Dey wa'n't no bacon stole' fer a week er so, 'tel one dark night w'en somebody tuk a ham fum one er de smoke-'ouses. Mars Walker des cusst awful w'en he foun' out de ham wuz gone, en say he gwine ter sarch all de niggers' cabins; w'en dis yer Wiley I wuz tellin' yer 'bout up'n say he s'picion' who tuk de ham, fer he seed Dave comin' 'cross de plantation fum to'ds de smoke-'ouse de night befo'. W'en Mars Walker hearn dis fum Wiley, he went en sarch' Dave's cabin, en foun' de ham hid under de flo'.

"Eve'ybody wuz 'stonish'; but dere wuz de ham. Co'se Dave 'nied it ter de las', but dere wuz de ham. Mars Walker say it wuz des ez he 'spected: he didn' b'lieve in dese yer readin' en prayin' niggers; it wuz all 'pocrisy, en sarve' Mars Dugal' right fer 'lowin' Dave ter be readin' books w'en it wuz 'g'in de law.

"W'en Mars Dugal' hearn 'bout de ham, he say he wuz might'ly 'ceived en disapp'inted in Dave. He say he wouldn' nebber hab no mo' conferdence in no nigger, en Mars Walker could do des ez he wuz a mineter wid Dave er any er de res' er de niggers. So Mars Walker tuk'n tied Dave up en gin 'im forty; en den he got some er dis yer wire clof w'at dey uses fer ter make sifters out'n, en tuk'n wrap' it roun' de ham en fasten it tergedder at de little een'. Den he tuk Dave down ter de blacksmif-shop, en had Unker Silas, de plantation black-smif, fasten a chain ter de ham, en den fasten de yuther een' er de chain roun' Dave's neck. En den he says ter Dave, sezee:--

"'Now, suh, yer'll wear dat neckliss fer de nex' six mont's; en I 'spec's yer ner none er de yuther niggers on dis plantation won' steal no mo' bacon dyoin' er dat time.'

"Well, it des 'peared ez if fum dat time Dave didn' hab nuffin but trouble. De niggers all turnt ag'in' 'im, caze he be'n de 'casion er Mars Dugal' turnin' 'em all ober ter Mars Walker. Mars Dugal' wa'n't a bad marster hisse'f, but Mars Walker wuz hard ez a rock. Dave kep' on sayin' he didn' take de ham, but none un 'em didn' b'lieve 'im.

"Dilsey wa'n't on de plantation w'en Dave wuz 'cused er stealin' de bacon. Ole mist'iss had sont her ter town fer a week er so fer ter wait on one er her darters w'at had a young baby, en she didn' fine out nuffin 'bout Dave's trouble 'tel she got back ter de plantation. Dave had patien'ly endyoed de finger er scawn, en all de hard words w'at de niggers pile' on 'im, caze he wuz sho' Dilsey would stan' by 'im, en wouldn' b'lieve he wuz a rogue, ner none er de yuther tales de darkies wuz tellin' 'bout 'im.

"W'en Dilsey come back fum town, en got down fum behine de buggy whar she be'n ridin' wid ole mars, de fus' nigger 'ooman she met says ter her,--

"'Is yer seed Dave, Dilsey?'

"No, I ain' seed Dave,' says Dilsey.

"'Yer des oughter look at dat nigger; reckon yer wouldn' want 'im fer yo' junesey no mo'. Mars Walker cotch 'im stealin' bacon, en gone en fasten' a ham roun' his neck, so he can't git it off'n hisse'f. He sut'nly do look quare.' En den de 'ooman bus' out laffin' fit ter kill herse'f. W'en she got thoo laffin' she up'n tole Dilsey all 'bout de ham, en all de yuther lies w'at de niggers be'n tellin' on Dave.

"W'en Dilsey started down ter de quarters, who should she meet but Dave, comin' in fum de cotton-fiel'. She turnt her head ter one side, en purten' lack she didn' seed Dave.

"'Dilsey!' sezee.

"Dilsey walk' right on, en didn' notice 'im.

"'OH, Dilsey!'

"Dilsey didn' paid no 'tention ter 'im, en den Dave knowed some er de niggers be'n tellin' her 'bout de ham. He felt monst'us bad, but he 'lowed ef he could des git Dilsey fer ter listen ter 'im fer a minute er so, he could make her b'lieve he didn' stole de bacon. It wuz a week er two befo' he could git a chance ter speak ter her ag'in; but fine'ly he cotch her down by de spring one day, en sezee:--

"'Dilsey, w'at fer yer won' speak ter me, en purten' lack yer doan see me? Dilsey, yer knows me too well fer ter b'lieve I'd steal, er do dis yuther wick'ness de niggers is all layin' ter me,--yer KNOWS I wouldn' do dat, Dilsey. Yer ain' gwine back on yo' Dave, is yer?'

"But w'at Dave say didn' hab no 'fec' on Dilsey. Dem lies folks b'en tellin' her had p'isen' her min' 'g'in' Dave.

"'I doan wanter talk ter no nigger,' says she, 'w'at be'n whip' fer stealin', en w'at gwine roun' wid sich a lookin' thing ez dat hung roun' his neck. I's a 'spectable gal, I is. W'at yer call dat, Dave? Is dat a cha'm fer ter keep off witches, er is it a noo kine er neckliss yer got?'

"Po' Dave didn' knowed w'at ter do. De las' one he had 'pended on fer ter stan' by 'im had gone back on 'im, en dey didn' 'pear ter be nuffin mo' wuf libbin' fer. He couldn' hol' no mo' pra'r-meetin's, fer Mars Walker wouldn' 'low 'im ter preach, en de darkies wouldn' 'a' listen' ter 'im ef he had preach'. He didn' eben hab his Bible fer ter comfort hisse'f wid, fer Mars Walker had tuk it erway fum 'im en burnt it up, en say ef he ketch any mo' niggers wid Bibles on de plantation he'd do 'em wuss'n he done Dave.

"En ter make it still harder fer Dave, Dilsey tuk up wid Wiley. Dave could see him gwine up ter Aun' Mahaly's cabin, en settin' out on de bench in de moonlight wid Dilsey, en singin' sinful songs en playin' de banjer. Dave use' ter scrouch down behine de bushes, en wonder w'at de Lawd sen' 'im all dem tribberlations fer.

"But all er Dave's yuther troubles wa'n't nuffin side er dat ham. He had wrap' de chain roun' wid a rag, so it didn' hurt his neck; but w'eneber he went ter wuk, dat ham would be in his way; he had ter do his task, howsomedever, des de same ez ef he didn' hab de ham. W'eneber he went ter lay down, dat ham would be in de way. Ef he turn ober in his sleep, dat ham would be tuggin' at his neck. It wuz de las' thing he seed at night, en de fus' thing he seed in de mawnin'. W'eneber he met a stranger, de ham would be de fus' thing de stranger would see. Most un 'em would 'mence' ter laf, en whareber Dave went he could see folks p'intin' at him, en year 'em sayin:--

"'W'at kine er collar dat nigger got roun' his neck?' er, ef dey knowed 'im, 'Is yer stole any mo' hams lately?' er 'W'at yer take fer yo' neckliss, Dave?' er some joke er 'nuther 'bout dat ham.

"Fus' Dave didn' mine it so much, caze he knowed he hadn' done nuffin. But bimeby he got so he couldn' stan' it no longer, en he'd hide hisse'f in de bushes w'eneber he seed anybody comin', en alluz kep' hisse'f shet up in his cabin atter he come in fum wuk.

"It wuz monst'us hard on Dave, en bimeby, w'at wid dat ham eberlastin' en etarnally draggin' roun' his neck, he 'mence' fer ter do en say quare things, en make de niggers wonder ef he wa'n't gittin' out'n his mine. He got ter gwine roun' talkin' ter hisse'f, en singin' corn-shuckin' songs, en laffin' fit ter kill 'bout nuffin. En one day he tole one er de niggers he had 'skivered a noo way fer ter raise hams,--gwine ter pick 'em off'n trees, en save de expense er smoke-'ouses by kyoin' 'em in de sun. En one day he up'n tole Mars Walker he got sump'n pertickler fer ter say ter 'im; en he tuk Mars Walker off ter one side, en tole 'im he wuz gwine ter show 'im a place in de swamp whar dey wuz a whole trac' er lan' covered wid ham-trees.

"W'en Mars Walker hearn Dave talkin' dis kine er fool-talk, en w'en he seed how Dave wuz 'mencin' ter git behine in his wuk, en w'en he ax' de niggers en dey tole 'im how Dave be'n gwine on, he 'lowed he reckon' he'd punish' Dave ernuff, en it mou't do mo' harm dan good fer ter keep de ham on his neck any longer. So he sont Dave down ter de blacksmif-shop en had de ham tak off.

Dey wa'n't much er de ham lef' by dat time, fer de sun had melt all de fat, en de lean had all swivel' up, so dey wa'n't but th'ee er fo' poun's lef'.

"W'en de ham had be'n tuk off'n Dave, folks kinder stopped talkin' 'bout 'im so much. But de ham had be'n on his neck so long dat Dave had sorter got use' ter it. He look des lack he'd los' sump'n fer a day er so atter de ham wuz tuk off, en didn' 'pear ter know w'at ter do wid hisse'f; en fine'ly he up'n tuk'n tied a lightered-knot ter a string, en hid it under de flo' er his cabin, en w'en nobody wuzn' lookin' he'd take it out en hang it roun' his neck, en go off in de woods en holler en sing; en he allus tied it roun' his neck w'en he went ter sleep. Fac', it 'peared lack Dave done gone clean out'n his mine. En atter a w'ile he got one er de quarest notions you eber hearn tell un. It wuz 'bout dat time dat I come back ter de plantation fer ter wuk,--I had be'n out ter Mars Dugal's yuther place on Beaver Crick for a mont' er so. I had hearn 'bout Dave en de bacon, en 'bout w'at wuz gwine on on de plantation; but I didn' b'lieve w'at dey all say 'bout Dave, fer I knowed Dave wa'n't dat kine er man. One day atter I come back, me'n Dave wuz choppin' cotton tergedder, w'en Dave lean' on his hoe, en motion' fer me ter come ober close ter 'im; en den he retch' ober en w'ispered ter me.

"'Julius', [sic] sezee, 'did yer knowed yer wuz wukkin' long yer wid a ham?'

"I couldn 'magine w'at he meant. 'G'way fum yer, Dave,' says I. 'Yer ain' wearin' no ham no mo'; try en fergit 'bout dat; 't ain' gwine ter do yer no good fer ter 'member it.'

"Look a-yer, Julius,' sezee, 'kin yer keep a secret?'

"'Co'se I kin, Dave,' says I. 'I doan go roun' tellin' people w'at yuther folks says ter me.'

"'Kin I trus' yer, Julius? Will yer cross yo' heart?'

"I cross' my heart. 'Wush I may die ef I tells a soul,' says I.

"Dave look' at me des lack he wuz lookin' thoo me en 'way on de yuther side er me, en sezee:--

"'Did yer knowed I wuz turnin' ter a ham, Julius?'

"I tried ter 'suade Dave dat dat wuz all foolishness, en dat he oughtn't ter be talkin' dat-a-way,--hit wa'n't right. En I tole 'im ef he'd des be patien', de time would sho'ly come w'en eve'ything would be straighten' out, en folks would fine out who de rale rogue wuz w'at stole de bacon. Dave 'peared ter listen ter w'at I say, en promise' ter do better, en stop gwine on dat-a-way; en it seem lack he pick' up a bit w'en he seed dey wuz one pusson didn' b'lieve dem tales 'bout 'im.

"Hit wa'n't long atter dat befo' Mars Archie McIntyre, ober on de Wimbleton road, 'mence' ter complain 'bout somebody stealin' chickens fum his hen-'ouse. De chickens kip' on gwine, en at las' Mars Archie tole de han's on his plantation dat he gwine ter shoot de fus' man he ketch in his hen-'ouse. In less'n a week atter he gin dis warnin', he cotch a nigger in de hen-'ouse, en fill' 'im full er squir'l-shot. W'en he got a light, he 'skivered it wuz a strange nigger; en w'en he call' one er his own sarven's, de nigger tole 'im it wuz our Wiley. W'en Mars Archie foun' dat out, he sont ober ter our plantation fer ter tell Mars Dugal' he had shot one er his niggers, en dat he could sen' ober dere en git w'at wuz lef' un 'im.

"Mars Dugal' wuz mad at fus'; but w'en he got ober dere en hearn how it all happen', he didn' hab much ter say. Wiley wuz shot so bad he wuz sho' he wuz gwine ter die, so he up'n says ter ole marster:--

"'Mars Dugal',' sezee, 'I knows I's be'n a monst'us bad nigger, but befo' I go I wanter git sump'n off'n my mine. Dave didn' steal dat bacon w'at wuz tuk out'n de smoke-'ouse. I stole it all, en I hid de ham under Dave's cabin fer ter th'ow de blame on him--en may de good Lawd fergib me fer it.'

"Mars Dugal' had Wiley tuk back ter de plantation, en sont fer a doctor fer ter pick de shot out'n 'im. En de ve'y nex' mawnin' Mars Dugal' sont fer Dave ter come up ter de big house; he felt kinder sorry fer de way Dave had be'n treated. Co'se it wa'n't no fault er Mars Dugal's, but he wuz gwine ter do w'at he could fer ter make up fer it. So he sont word down ter de quarters fer Dave en all de yuther han's ter 'semble up in de yard befo' de big house at sun-up nex' mawnin'.

"Yearly in de mawnin' de niggers all swarm' up in de yard. Mars Dugal' wuz feelin' so kine dat he had brung up a bairl er cider, en tole de niggers all fer ter he'p deyselves.

"All dey han's on de plantation come but Dave; en bimeby, w'en it seem lack he wa'n't comin', Mars Dugal' sont a nigger down ter de quarters ter look fer 'im. De sun wuz gittin' up, en dey wuz a heap er wuk ter be done, en Mars Dugal' sorter got ti'ed waitin'; so he up'n says:--

"'Well, boys en gals, I sont fer yer all up yer fer ter tell yer dat all dat 'bout Dave's stealin' er de bacon wuz a mistake, ez I s'pose yer all done hearn befo' now, en I's mighty sorry it happen'. I wants ter treat all my niggers right, en I wants yer all ter know dat I sets a heap by all er my han's w'at is hones' en smart. En I want yer all ter treat Dave des lack yer did befo' dis thing happen', en mine w'at he preach ter yer; fer Dave is a good nigger, en has had a hard row ter hoe. En de fus' one I ketch sayin' anythin' 'g'in Dave, I'll tell Mister Walker ter gin 'im forty. Now take ernudder drink er cider all roun', en den git at dat cotton, fer I wanter git dat Persimmon Hill trac' all pick' ober ter-day.'

"W'en de niggers wuz gwine 'way, Mars Dugal' tole me fer ter go en hunt up Dave, en bring 'im up ter de house. I went down ter Dave's cabin, but couldn' fine 'im dere. Den I look' roun' de plantation, en in de aidge er de woods, en 'long de road; but I couldn' fine no sign er Dave. I wuz 'bout ter gin up de sarch, w'en I happen' fer ter run 'cross a foot-track w'at look' lack Dave's. I had wukked 'long wid Dave so much dat I knowed his tracks: he had a monst'us long foot, wid a holler instep, w'ich wuz sump'n skase 'mongs' black folks. So I follered dat track 'cross de fiel' fum de quarters 'tel I got ter de smoke-'ouse. De fus' thing I notice' wuz smoke comin' out'n de cracks: it wuz cu'ous, caze dey hadn' be'n no hogs kill' on de plantation fer six mont' er so, en all de bacon in de smoke-'ouse wuz done kyoed. I couldn' 'magine fer ter sabe my life w'at Dave wuz doin' in dat smoke-'ouse. I went up ter de do' en hollered:--

"'Dave!'

"Dey didn' nobody answer. I didn' wanter open de do', fer w'ite folks is monst'us pertickler 'bout dey smoke-'ouses; en ef de oberseah had a-come up en cotch me in dere, he mou't not wanter b'lieve I wuz des lookin' fer Dave. So I sorter knock at de do' en call' out ag'in:--

"'O Dave, hit's me--Julius! Doan be skeered. Mars Dugal' wants yer ter come up ter de big house,--he done 'skivered who stole de ham.'

"But Dave didn' answer. En w'en I look' roun' ag'in en didn' seed none er his tracks gwine way fum de smoke-'ouse, I knowed he wuz in dere yit, en I wuz 'termine' fer ter fetch 'im out; so I push de do' open en look in.

"Dey wuz a pile er bark burnin' in de middle er de flo', en right ober de fier, hangin' fum one er de rafters, wuz Dave; dey wuz a rope roun' his neck, en I didn' haf ter look at his face mo' d'n once fer ter see he wuz dead.

"Den I knowed how it all happen'. Dave had kep' on gittin' wusser en wusser in his mine, 'tel he des got ter b'lievin' he wuz all done turnt ter a ham; en den he had gone en built a fier, en tied a rope roun' his neck, des lack de hams wuz tied, en had hung hisse'f up in de smoke-'ouse fer ter kyo.

"Dave wuz buried down by de swamp, in de plantation buryin'-groun'. Wiley didn' died fum de woun' he got in Mars McIntyre's hen-'ouse; he got well atter a w'ile, but Dilsey wouldn' hab nuffin mo' ter do wid 'im, en 't wa'n't long 'fo' Mars Dugal' sol' 'im ter a spekilater on his way souf,--he say he didn' want no sich a nigger on de plantation, ner in de county, ef he could he'p it. En w'en de een' er de year come, Mars Dugal' turnt Mars Walker off, en run de plantation hisse'f atter dat.

"Eber sence den," said Julius in conclusion, "w'eneber I eats ham, it min's me er Dave. I lacks ham, but I nebber kin eat mo' d'n two er th'ee poun's befo' I gits ter studyin' 'bout Dave, en den I has ter stop en leab de res' fer ernudder time."

There was a short silence after the old man had finished his story, and then my wife began to talk to him about the weather, on which subject he was an authority. I went into the house. When I came out, half an hour later, I saw Julius disappearing down the lane, with a basket on his arm.

At breakfast, next morning, it occurred to me that I should like a slice of ham. I said as much to my wife.

"Oh, no, John," she responded, "you shouldn't eat anything so heavy for breakfast."

I insisted.

"The fact is," she said, pensively, "I couldn't have eaten any more of that ham, and so I gave it to Julius."

THE AWAKENING OF THE NEGRO by Booker T. Washington

When a mere boy, I saw a young colored man, who had spent several years in school, sitting in a common cabin in the South, studying a French grammar. I noted the poverty, the untidiness, the want of system and thrift, that existed about the cabin, notwithstanding his knowledge of French and other academic subjects. Another time, when riding on the outer edges of a town in the South, I heard the sound of a piano coming from a cabin of the same kind. Contriving some excuse, I entered, and began a conversation with the young colored woman who was playing, and who had recently returned from a boarding-school, where she had been studying instrumental music among other things. Despite the fact that her parents were living in a rented cabin, eating poorly cooked food, surrounded with poverty, and having almost none of the conveniences of life, she had persuaded them to rent a piano for four or five dollars per month. Many such instances as these, in connection with my own struggles, impressed upon me the importance of making a study of our needs as a race, and applying the remedy accordingly.

Some one may be tempted to ask, Has not the negro boy or girl as good a right to study a French grammar and instrumental music as the white youth? I answer, Yes, but in the present condition of the negro race in this country there is need of something more. Perhaps I may be forgiven for the seeming egotism if I mention the expansion of my own life partly as an example of what I mean. My earliest recollection is of a small one-room log hut on a large slave plantation in Virginia. After the close of the war, while working in the coal-mines of West Virginia for the support of my mother, I heart in some accidental way of the Hampton Institute. When I learned that it was an institution where a black boy could study, could have a chance to work for his board, and at the same time be taught how to work and to realize the dignity of labor, I resolved to go there. Bidding my mother good-by, I started out one morning to find my way to Hampton, though I was almost penniless and had no definite idea where Hampton was. By walking, begging rides, and paying for a portion of the journey on the steam-cars, I finally succeeded in reaching the city of Richmond, Virginia. I was without money or friends. I slept under a sidewalk, and by working on a vessel next day I earned money to continue my way to the institute, where I arrived with a surplus of fifty cents. At Hampton I found the opportunity--in the way of buildings, teachers, and industries provided by the generous--to get training in the class-room and by practical touch with industrial life, to learn thrift, economy, and push. I was surrounded by an atmosphere of business, Christian influence, and a spirit of self-help that seemed to have awakened every faculty in me, and caused me for the first time to realize what it meant to be a man instead of a piece of property.

While there I resolved that when I had finished the course of training I would go into the far South, into the Black Belt of the South, and give my life to providing the same kind of opportunity for self-reliance and self-awakening that I had found provided for me at Hampton. My work began at Tuskegee, Alabama, in 1881, in a small shanty and church, with one teacher and thirty students, without a dollar's worth of property. The spirit of work and of industrial thrift, with aid from the State and generosity from the North, has enabled us to develop an institution of eight hundred students gathered from nineteen States, with seventy-nine instructors, fourteen hundred acres of land, and thirty buildings, including large and small; in all, property valued at $280,000. Twenty-five industries have been organized, and the whole work is carried on at an annual cost of about $80,000 in cash; two fifths of the annual expense so far has gone into permanent plant.

What is the object of all this outlay? First, it must be borne in mind that we have in the South a peculiar and unprecedented state of things. It is of the utmost importance that our energy be given to meeting conditions that exist right about us rather than conditions that existed centuries ago or that exist in countries a thousand miles away. What are the cardinal needs among the seven millions of colored people in the South, most of whom are to be found on the plantations? Roughly, these needs may be stated as food, clothing, shelter, education, proper habits, and a settlement of race relations. The seven millions of colored people of the South cannot be reached directly by any missionary agency, but they can be reached by sending out among them strong selected young men and women, with the proper training of head, hand, and heart, who will live among these masses and show them how to lift themselves up.

The problem that the Tuskegee Institute keeps before itself constantly is how to prepare these leaders. From the outset, in connection with religious and academic training, it has emphasized industrial or hand training as a means of finding the way out of present conditions. First, we have found the industrial teaching useful in giving the student a chance to work out a portion of his expenses while in school. Second, the school furnishes labor that has an economic value, and at the same time gives the student a chance to acquire knowledge and skill while performing the labor. Most of all, we find the industrial system valuable in teaching economy, thrift, and the dignity of labor, and in giving moral backbone to students. The fact that a student goes out into the world conscious of his power to build a house or a wagon, or to make a harness, gives him a certain confidence and moral independence

that he would not possess without such training.

A more detailed example of our methods at Tuskegee may be of interest. For example, we cultivate by student labor six hundred and fifty acres of land. The object is not only to cultivate the land in a way to make it pay our boarding department, but at the same time to teach the students, in addition to the practical work, something of the chemistry of the soil, the best methods of drainage, dairying, the cultivation of fruit, the care of livestock and tools, and scores of other lessons needed by a people whose main dependence is on agriculture. Notwithstanding that eighty-five per cent of the colored people in the South live by agriculture in some form, aside from what has been done by Hampton, Tuskegee, and one or two other institutions practically nothing has been attempted in the direction of teaching them about the very industry from which the masses of our people must get their subsistence. Friends have recently provided means for the erection of a large new chapel at Tuskegee. Our students have made the bricks for this chapel. A large part of the timber is sawed by students at our own sawmill, the plans are drawn by our teacher of architecture and mechanical drawing, and students do the brick-masonry, plastering, painting, carpentry work, tinning, slating, and make most of the furniture. Practically, the whole chapel will be built and furnished by student labor; in the end the school will have the building for permanent use, and the students will have a knowledge of the trades employed in its construction. In this way all but three of the thirty buildings on the grounds have been erected. While the young men do the kinds of work I have mentioned, the young women to a large extent make, mend, and launder the clothing of the young men, and thus are taught important industries.

One of the objections sometimes urged against industrial education for the negro is that it aims merely to teach him to work on the same plan that he was made to follow when in slavery. This is far from being the object at Tuskegee. At the head of each of the twenty-five industrial departments we have an intelligent and competent instructor, just as we have in our history classes, so that the student is taught not only practical brick-masonry, for example, but also the underlying principles of that industry, the mathematics and the mechanical and architectural drawing. Or he is taught how to become master of the forces of nature so that, instead of cultivating corn in the old way, he can use a corn cultivator, that lays off the furrows, drops the corn into them, and covers it, and in this way he can do more work than three men by the old process of corn-planting; at the same time much of the toil is eliminated and labor is dignified. In a word, the constant aim is to show the student how to put brains into every process of labor; how to bring his knowledge of mathematics and the sciences into farming, carpentry, forging, foundry work; how to dispense as soon as possible with the old form of ante-bellum labor. In the erection of the chapel just referred to, instead of letting the money which was given us go into outside hands, we make it accomplish three objects: first, it provides the chapel; second, it gives the students a chance to get a practical knowledge of the trades connected with building; and third, it enables them to earn something toward the payment of board while receiving academic and industrial training.

Having been fortified at Tuskegee by education of mind, skill of hand, Christian character, ideas of thrift, economy, and push, and a spirit of independence, the student is sent out to become a centre of influence and light in showing the masses of our people in the Black Belt of the South how to lift themselves up. How can this be done? I give but one or two examples. Ten years ago a young colored man came to the institute from one of the large plantation districts; he studied in the class-room a portion of the time, and received practical and theoretical training on the farm the remainder of the time. Having finished his course at Tuskegee, he returned to his plantation home, which was in a county where the colored people outnumber the whites six to one, as is true of many of the counties in the Black Belt of the South. He found the negroes in debt. Ever since the war they had been mortgaging their crops for the food on which to live while the crops were growing. The majority of them were living from hand to mouth on rented land, in small, one-room log cabins, and attempting to pay a rate of interest on their advances that ranged from fifteen to forty per cent per annum. The school had been taught in a wreck of a log cabin, with no apparatus, and had never been in session longer than three months out of twelve. With as many as eight or ten persons of all ages and conditions and of both sexes huddled together in one cabin year after year, and with a minister whose only aim was to work upon the emotions of the people, one can imagine something of the moral and religious state of the community.

But the remedy. In spite of the evil, the negro got the habit of work from slavery. The rank and file of the race, especially those on the Southern plantations, work hard, but the trouble is, what they earn gets away from them in high rents, crop mortgages, whiskey, snuff, cheap jewelry, and the like. The young man just referred to had been trained at Tuskegee, as most of our graduates are, to meet just this condition of things. He took the three months' public school as a nucleus for his work. Then he organized the older people into a club, or conference, that held meetings every week. In these meetings he taught the people in a plain, simple manner how to save their money, how to farm in a better way, how to sacrifice,--to live on bread and potatoes, if need be, till they could get out of debt, and begin the buying of lands.

Soon a large proportion of the people were in condition to make contracts for the buying of homes (land is very cheap in the South), and to live without mortgaging their crops. Not only this: under the guidance and leadership of this teacher, the first year that he was among them they learned how, by contributions in money and labor, to build a neat, comfortable schoolhouse that replaced the wreck of a log cabin formerly used. The following year the weekly meetings were continued, and two months were added to the original three months of school. The next year two more months were added. The improvement has gone on, until now these people have every year an eight months' school.

I wish my readers could have the chance that I have had of going into this community. I wish they could look into the faces of the people and see them beaming with hope and delight. I wish they could see the two or three room cottages that have taken the place of the usual one-room cabin, the well-cultivated farms, and the religious life of the people that now means something more than the name. The teacher has a good cottage and a well-kept farm that serve as models. In a word, a complete revolution has been wrought in the industrial, educational, and religious life of this whole community by reason of the fact that they have had this leader, this guide and object-lesson, to show them how to take the money and effort that had hitherto been scattered to the wind in mortgages and high rents, in whiskey and gewgaws, and concentrate them in the direction of their own uplifting. One community on its feet presents an object-lesson for the adjoining communities, and soon improvements show themselves in other places.

Another student who received academic and industrial training at Tuskegee established himself, three years ago, as a blacksmith and wheelwright in a community, and, in addition to the influence of his successful business enterprise, he is fast making the same kind of changes in the life of the people about him that I have just recounted. It would be easy for me to fill many pages describing the influence of the Tuskegee graduates in every part of the South. We keep it constantly in the minds of our students and graduates that the industrial or material condition of the masses of our people must be improved, as well as the intellectual, before there can be any permanent change in their moral and religious life. We find it a pretty hard thing to make a good Christian of a hungry man. No matter how much our people "get happy" and "shout" in church, if they go home at night from church hungry, they are tempted to find something before morning. This is a principle of human nature, and is not confined to the negro.

The negro has within him immense power for self-uplifting, but for years it will be necessary to guide and stimulate him. The recognition of this power led us to organize, five years ago, what is now known as the Tuskegee Negro Conference,--a gathering that meets every February, and is composed of about eight hundred representative colored men and women from all sections of the Black Belt. They come in ox-carts, mule-carts, buggies, on muleback and horseback, on foot, by railroad: some traveling all night in order to be present. The matters considered at the conferences are those that the colored people have it within their own power to control: such as the evils of the mortgage system, the one-room cabin, buying on credit, the importance of owning a home and of putting money in the bank, how to build schoolhouses and prolong the school term, and how to improve their moral and religious condition.

As a single example of the results, one delegate reported that since the conferences were started five years ago eleven people in his neighborhood had bought homes, fourteen had got out of debt, and a number had stopped mortgaging their crops. Moreover, a schoolhouse had been built by the people themselves, and the school term had been extended from three to six months; and with a look of triumph he exclaimed, "We is done stopped libin' in de ashes!"

Besides this Negro Conference for the masses of the people, we now have a gathering at the same time known as the Workers' Conference, composed of the officers and instructors in the leading colored schools of the South. After listening to the story of the conditions and needs from the people themselves, the Workers' Conference finds much food for thought and discussion.

Nothing else so soon brings about right relations between the two races in the South as the industrial progress of the negro. Friction between the races will pass away in proportion as the black man, by reason of his skill, intelligence, and character, can produce something that the white man wants or respects in the commercial world. This is another reason why at Tuskegee we push the industrial training. We find that as every year we put into a Southern community colored men who can start a brick-yard, a sawmill, a tin-shop, or a printing-office,--men who produce something that makes the white man partly dependent upon the negro, instead of all the dependence being on the other side,--a change takes place in the relations of the races.

Let us go on for a few more years knitting our business and industrial relations into those of the white man, till a black man gets a mortgage on a white man's house that he can foreclose at will. The white man on whose house the mortgage rests will not try to prevent that negro from voting when he goes to the polls. It is through the dairy farm, the truck garden, the trades, and commercial life, largely, that the negro is to find his way to the enjoyment of all his rights. Whether he will or not, a white man respects a negro

who owns a two-story brick house.

What is the permanent value of the Tuskegee system of training to the South in a broader sense? In connection with this, it is well to bear in mind that slavery taught the white man that labor with the hands was something fit for the negro only, and something for the white man to come into contact with just as little as possible. It is true that there was a large class of poor white people who labored with the hands, but they did it because they were not able to secure negroes to work for them; and these poor whites were constantly trying to imitate the slave-holding class in escaping labor, and they too regarded it as anything but elevating. The negro in turn looked down upon the poor whites with a certain contempt because they had to work. The negro, it is to be borne in mind, worked under constant protest, because he felt that his labor was being unjustly required, and he spent almost as much effort in planning how to escape work as in learning how to work. Labor with him was a badge of degradation. The white man was held up before him as the highest type of civilization, but the negro noted that this highest type of civilization himself did no labor; hence he argued that the less work he did, the more nearly he would be like a white man. Then, in addition to these influences, the slave system discouraged labor-saving machinery. To use labor-saving machinery intelligence was required, and intelligence and slavery were not on friendly terms; hence the negro always associated labor with toil, drudgery, something to be escaped. When the negro first became free, his idea of education was that it was something that would soon put him in the same position as regards work that his recent master had occupied. Out of these conditions grew the Southern habit of putting off till to-morrow and the day after the duty that should be done promptly to-day. The leaky house was not repaired while the sun shone, for then the rain did not come through. While the rain was falling, no one cared to expose himself to stop the leak. The plough, on the same principle, was left where the last furrow was run, to rot and rust in the field during the winter. There was no need to repair the wooden chimney that was exposed to the fire, because water could be thrown on it when it was on fire. There was no need to trouble about the payment of a debt to-day, for it could just as well be paid next week or next year. Besides these conditions, the whole South, at the close of the war, was without proper food, clothing, and shelter,--was in need of habits of thrift and economy and of something laid up for a rainy day.

To me it seemed perfectly plain that here was a condition of things that could not be met by the ordinary process of education. At Tuskegee we became convinced that the thing to do was to make a careful systematic study of the condition and needs of the South, especially the Black Belt, and to bend our efforts in the direction of meeting these needs, whether we were following a well-beaten track, or were hewing out a new path to meet conditions probably without a parallel in the world. After fourteen years of experience and observation, what is the result? Gradually but surely, we find that all through the South the disposition to look upon labor as a disgrace is on the wane, and the parents who themselves sought to escape work are so anxious to give their children training in intelligent labor that every institution which gives training in the handicrafts is crowded, and many (among them Tuskegee) have to refuse admission to hundreds of applicants. The influence of the Tuskegee system is shown again by the fact that almost every little school at the remotest cross-roads is anxious to be known as an industrial school, or, as some of the colored people call it, an "industrus" school.

The social lines that were once sharply drawn between those who labored with the hand and those who did not are disappearing. Those who formerly sought to escape labor, now when they see that brains and skill rob labor of the toil and drudgery once associated with it, instead of trying to avoid it are willing to pay to be taught how to engage in it. The South is beginning to see labor raised up, dignified and beautified, and in this sees its salvation. In proportion as the love of labor grows, the large idle class which has long been one of the curses of the South disappears. As its members become absorbed in occupations, they have less time to attend to everybody else's business, and more time for their own.

The South is still an undeveloped and unsettled country, and for the next half century and more the greater part of the energy of the masses will be needed to develop its material opportunities. Any force that brings the rank and file of the people to a greater love of industry is therefore especially valuable. This result industrial education is surely bringing about. It stimulates production and increases trade,--trade between the races,--and in this new and engrossing relation both forget the past. The white man respects the vote of the colored man who does $10,000 worth of business, and the more business the colored man has, the more careful he is how he votes.

Immediately after the war, there was a large class of Southern people who feared that the opening of the free schools to the freedmen and the poor whites--the education of the head alone--would result merely in increasing the class who sought to escape labor, and that the South would soon be overrun by the idle and vicious. But as the results of industrial combined with academic training begin to show themselves in hundreds of communities that have been lifted up through the medium of the Tuskegee system, these former prejudices against education are being removed. Many of those who a few years ago opposed general

education are now among its warmest advocates.

This industrial training, emphasizing as it does the idea of economic production, is gradually bringing the South to the point where it is feeding itself. Before the war, and long after it, the South made what little profit was received from the cotton crop, and sent its earnings out of the South to purchase food supplies,--meat, bread, canned vegetables, and the like; but the improved methods of agriculture are fast changing this habit. With the newer methods of labor, which teach promptness and system, and emphasize the worth of the beautiful,--the moral value of the well-painted house, and the fence with every paling and nail in its place,--we are bringing to bear upon the South an influence that is making it a new country in industry, education, and religion.

THE STORY OF UNCLE TOM'S CABIN by Charles Dudley Warner

On the 29th of June, 1852, Henry Clay died. In that month the two great political parties, in their national conventions, had accepted as a finality all the compromise measures of 1850, and the last hours of the Kentucky statesman were brightened by the thought that his efforts had secured the perpetuity of the Union.

But on the 20th of March, 1852, there had been an event, the significance of which was not taken into account by the political conventions or by Clay, which was to test the conscience of the nation. This was the publication of Uncle Tom's Cabin. Was this only an "event," the advent of a new force in politics; was the book merely an abolition pamphlet, or was it a novel, one of the few great masterpieces of fiction that the world has produced? After the lapse of forty-four years and the disappearance of African slavery on this continent, it is perhaps possible to consider this question dispassionately.

The compromise of 1850 satisfied neither the North nor the South. The admission of California as a free State was regarded by Calhoun as fatal to the balance between the free and the slave States, and thereafter a fierce agitation sprang up for the recovery of this loss of balance, and ultimately for Southern preponderance, which resulted in the repeal of the Missouri Compromise, the Kansas-Nebraska war, and the civil war. The fugitive slave law was hateful to the North not only because it was cruel and degrading, but because it was seen to be a move formed for nationalizing slavery. It was unsatisfactory to the South because it was deemed inadequate in its provisions, and because the South did not believe the North would execute it in good faith. So unstable did the compromise seem that in less than a year after the passage of all its measures, Henry Clay and forty-four Senators and Representatives united in a manifesto declaring that they would support no man for office who was not known to be opposed to any disturbance of the settlements of the compromise. When, in February, 1851, the recaptured fugitive slave, Burns, was rescued from the United States officers in Boston, Clay urged the investment of the President with extraordinary power to enforce the law.

Henry Clay was a patriot, a typical American. The republic and its preservation were the passions of his life. Like Lincoln, who was born in the State of his adoption, he was willing to make almost any sacrifice for the maintenance of the Union. He had no sympathy with the system of slavery. There is no doubt that he would have been happy in the belief that it was in the way of gradual and peaceful extinction. With him, it was always the Union before state rights and before slavery. Unlike Lincoln, he had not the clear vision to see that the republic could not endure half slave and half free. He believed that the South, appealing to the compromises of the Constitution, would sacrifice the Union before it would give up slavery, and in fear of this menace he begged the North to conquer its prejudices. We are not liable to overrate his influence as a compromising pacificator from 1832 to 1852. History will no doubt say that it was largely due to him that the war on the Union was postponed to a date when its success was impossible.

It was the fugitive slave law that brought the North face to face with slavery nationalized, and it was the fugitive slave law that produced Uncle Tom's Cabin. The effect of this story was immediate and electric. It went straight to the hearts of tens of thousands of people who had never before considered slavery except as a political institution for which they had no personal responsibility. What was this book, and how did it happen to produce such an effect? It is true that it struck into a time of great irritation and agitation, but in one sense there was nothing new in it. The facts had all been published. For twenty years abolition tracts, pamphlets, newspapers, and books had left little to be revealed, to those who cared to read, as to the nature of slavery or its economic aspects. The evidence was practically all in,--supplied largely by the advertisements of Southern newspapers and by the legislation of the slaveholding States,--but it did not carry conviction; that is, the sort of conviction that results in action. The subject had to be carried home to the conscience. Pamphleteering, convention-holding, sermons, had failed to do this. Even the degrading requirements of the fugitive slave law, which brought shame and humiliation, had not sufficed to fuse the public conscience, emphasize the necessity of obedience to the moral law, and compel recognition of the responsibility of the North for slavery. Evidence had not done this, passionate appeals had not done it, vituperation had not done it. What sort of presentation of the case

would gain the public ear and go to the heart? If Mrs. Stowe, in all her fervor, had put forth first the facts in The Key to Uncle Tom's Cabin, which so buttressed her romance, the book would have had no more effect than had followed the like compilations and arraignments. What was needed? If we can discover this, we shall have the secret of this epoch-making novel.

The story of this book has often been told. It is in the nature of a dramatic incident of which the reader never tires any more than the son of Massachusetts does of the minutest details of that famous scene in the Senate Chamber when Webster replied to Hayne.

At the age of twenty-four the author was married and went to live in Cincinnati, where her husband held a chair in the Lane Theological Seminary. There for the first time she was brought into relations with the African race and saw the effects of slavery. She visited slaveholders in Kentucky and had friends among them. In some homes she saw the "patriarchal" institution at its best. The Beecher family were anti-slavery, but they had not been identified with the abolitionists, except perhaps Edward, who was associated with the murdered Lovejoy. It was long a reproach brought by the abolitionists against Henry Ward Beecher that he held entirely aloof from their movement. At Cincinnati, however, the personal aspects of the case were brought home to Mrs. Stowe. She learned the capacities and peculiarities of the negro race. They were her servants; she taught some of them; hunted fugitives applied to her; she ransomed some by her own efforts; every day there came to her knowledge stories of the hunger for freedom, of the ruthless separation of man and wife and mother and child, and of the heroic sufferings of those who ran away from the fearful doom of those "sold down South." These things crowded upon her mind and awoke her deepest compassion. But what could she do against all the laws, the political and commercial interests, the great public apathy? Relieve a case here and there, yes. But to dwell upon the gigantic evil, with no means of making head against it, was to invite insanity.

As late as 1850, when Professor Stowe was called to Bowdoin College, and the family removed to Brunswick, Maine, Mrs. Stowe had not felt impelled to the duty she afterwards undertook. "In fact, it was a sort of general impression upon her mind, as upon that of many humane people in those days, that the subject was so dark and painful a one, so involved in difficulty and obscurity, so utterly beyond human hope or help, that it was of no use to read, or think, or distress one's self about it." But when she reached New England the excitement over the fugitive slave law was at its height. There was a panic in Boston among the colored people settled there, who were daily fleeing to Canada. Every mail brought her pitiful letters from Boston, from Illinois, and elsewhere, of the terror and despair caused by the law. Still more was the impressed by the apathy of the Christian world at the North, and surely, she said, the people did not understand what the "system" was. Appeals were made to her, who had some personal knowledge of the subject, to take up her pen. The task seemed beyond her in every way. She was not strong, she was in the midst of heavy domestic cares, with a young infant, with pupils to whom she was giving daily lessons, and the limited income of the family required the strictest economy. The dependence was upon the small salary of Professor Stowe, and the few dollars she could earn by an occasional newspaper or magazine article. But the theme burned in her mind, and finally took this shape: at least she would write some sketches and show the Christian world what slavery really was, and what the system was that they were defending. She wanted to do this with entire fairness, showing all the mitigations of the "patriarchal" system, and all that individuals concerned in it could do to alleviate its misery. While pondering this she came by chance, in a volume of an anti-slavery magazine, upon the authenticated account of the escape of a woman with her child on the ice across the Ohio River from Kentucky. She began to meditate. The faithful slave husband in Kentucky, who had refused to escape from a master who trusted him, when he was about to be sold "down river," came to her as a pattern of Uncle Tom, and the scenes of the story began to form themselves in her mind. "The first part of the book ever committed to writing [this is the statement of Mrs. Stowe] was the death of Uncle Tom. This scene presented itself almost as a tangible vision to her mind while sitting at the communion-table in the little church in Brunswick. She was perfectly overcome by it, and could scarcely restrain the convulsion of tears and sobbings that shook her frame. She hastened home and wrote it, and her husband being away, read it to her two sons of ten and twelve years of age. The little fellows broke out into convulsions of weeping, one of them saying through his sobs, 'Oh, mamma, slavery is the most cursed thing in the world!' From that time the story can less be said to have been composed by her than imposed upon her. Scenes, incidents, conversations rushed upon her with a vividness and importunity that would not be denied. The book insisted upon getting itself into being, and would take no denial."

When two or three chapters were written she wrote to her friend, Dr. Bailey, of Washington, the editor of The National Era, to which she had contributed, that she was planning a story that might run through several numbers of the Era. The story was at once applied for, and thereafter weekly installments were sent on regularly, in spite of all cares and distractions. The installments were mostly written during the morning, on a little desk in a corner of the dining-room of the cottage in Brunswick, subject to all the interruptions of house-keeping, her children bursting into the room continually with the importunity of childhood. But they did not break the spell or destroy her abstraction. With a smile and a word and a motion of the hand she would wave them off, and keep on

in her magician's work. Long afterwards they recalled this, dimly understood at the time, and wondered at her power of concentration. Usually at night the chapters were read to the family, who followed the story with intense feeling. The narrative ran on for nine months, exciting great interest among the limited readers of the Era, and gaining sympathetic words from the anti-slavery people, but without making any wide impression on the public.

We may pause here in the narrative to note two things: the story was not the work of a novice, and it was written out of abundant experience and from an immense mass of accumulated thought and material. Mrs. Stowe was in her fortieth year. She had been using her pen since she was twelve years old, in extensive correspondence, in occasional essays, in short stories and sketches, some of which appeared in a volume called The Mayflower, published in 1843, and for many years her writing for newspapers and periodicals had added appreciably to the small family income. She was in the maturity of her intellectual powers, she was trained in the art of writing, and she had, as Walter Scott had when he began the Waverley Novels at the age of forty-three, abundant store of materials on which to draw. To be sure, she was on fire with a moral purpose, but she had the dramatic instinct, and she felt that her object would not be reached by writing an abolition tract.

"In shaping her material the author had but one purpose, to show the institution of slavery truly, just as it existed. She had visited in Kentucky; had formed the acquaintance of people who were just, upright, and generous, and yet slave-holders. She had heard their views, and appreciated their situation; she felt that justice required that their difficulties should be recognized and their virtues acknowledged. It was her object to show that the evils of slavery were the inherent evils of a bad system, and not always the fault of those who had become involved in it and were its actual administrators. Then she was convinced that the presentation of slavery alone, in its most dreadful forms, would be a picture of such unrelieved horror and darkness as nobody could be induced to look at. Of set purpose, she sought to light up the darkness by humorous and grotesque episodes, and the presentation of the milder and more amusing phases of slavery, for which her recollection of the never-failing wit and drollery of her former colored friends in Ohio gave her abundant material."

This is her own account of the process, years after. But it is evident that, whether consciously or unconsciously, she did but follow the inevitable law of all great dramatic creators and true story-tellers since literature began.

For this story Mrs. Stowe received from the Era the sum of three hundred dollars. Before it was finished it attracted the attention of Mr. J. P. Jewett, of Boston, a young and then unknown publisher, who offered to issue it in book form. His offer was accepted, but as the tale ran on he became alarmed at its length, and wrote to the author that she was making the story too long for a one-volume novel; that the subject was unpopular; that people would not willingly hear much about it; that one short volume might possibly sell, but that if it grew to two that might prove a fatal obstacle to its success. Mrs. Stowe replied that she did not make the story, that the story made itself, and that she could not stop it till it was done. The publisher hesitated. It is said that a competent literary critic to whom he submitted it sat up all night with the novel, and then reported, "The story has life in it; it will sell." Mr. Jewett proposed to Professor Stowe to publish it on half profits if he would share the expenses. This offer was declined, for the Stowes had no money to advance, and the common royalty of ten per cent on the sales was accepted.

Mrs. Stowe was not interested in this business transaction. She was thinking only of having the book circulated for the effect she had at heart. The intense absorption in the story held her until the virtual end in the death of Uncle Tom, and then it seemed as if the whole vital force had left her. She sank into a profound discouragement. Would this appeal, which she had written with her heart's blood, go for nothing, as all the prayers and tears and strivings had already gone? When the last proof sheets left her hands, "it seemed to her that there was no hope; that nobody would read, nobody would pity; that this frightful system, which had already pursued its victims into the free States, might at last even threaten them in Canada." Resolved to leave nothing undone to attract attention to her cause, she wrote letters and ordered copies of her novel sent to men of prominence who had been known for their anti-slavery sympathies,--to Prince Albert, Macaulay, Charles Dickens, Charles Kingsley, and Lord Carlisle. Then she waited for the result.

She had not long to wait. The success of the book was immediate. Three thousand copies were sold the first day, within a few days ten thousand copies had gone, on the 1st of April a second edition went to press, and thereafter eight presses running day and night were barely able to keep pace with the demand for it. Within a year three hundred thousand copies were sold. No work of fiction ever spread more quickly throughout the reading community or awakened a greater amount of public feeling. It was read by everybody, learned and unlearned, high and low, for it was an appeal to universal human sympathy, and the kindling of this spread the book like wildfire. At first it seemed to go by acclamation. But this was not altogether owing to sympathy with the theme. I believe that it was its power as a novel that carried it largely. The community was generally apathetic when it was not hostile to any

real effort to be rid of slavery. This presently appeared. At first there were few dissenting voices from the chorus of praise. But when the effect of the book began to be evident it met with an opposition fiercer and more personal than the great wave of affectionate thankfulness which greeted it at first. The South and the defenders and apologists of slavery everywhere were up in arms. It was denounced in pulpit and in press, and some of the severest things were said of it at the North. The leading religious newspaper of the country, published in New York, declared that it was "anti-Christian."

Mrs. Stowe was twice astonished: first by its extraordinary sale, and second by the quarter from which the assault on it came. She herself says that her expectations were strikingly different from the facts. "She had painted slaveholders as amiable, generous, and just. She had shown examples among them of the noblest and most beautiful traits of character; had admitted fully their temptations, their perplexities, and their difficulties, so that a friend of hers who had many relatives in the South wrote to her: 'Your book is going to be the great pacificator; it will unite both North and South.' Her expectation was that the professed abolitionists would denounce it as altogether too mild in its dealings with slaveholders. To her astonishment, it was the extreme abolitionists who received, and the entire South who rose up against it."

There is something almost amusing in Mrs. Stowe's honest expectation that the deadliest blow the system ever suffered should have been received thankfully by those whose traditions, education, and interests were all bound up in it. And yet from her point of view it was not altogether unreasonable. Her blackest villain and most loathsome agent of the system, Legree, was a native of Vermont. All her wrath falls upon the slave-traders, the auctioneers, the public whippers, and the overseers, and all these persons and classes were detested by the Southerners to the point of loathing, and were social outcasts. The slave-traders and the overseers were tolerated as perhaps necessary in the system, but they were never admitted into respectable society. This feeling Mrs. Stowe regarded as a condemnation of the system.

Pecuniary reward was the last thing that Mrs. Stowe expected for her disinterested labor, but it suits the world's notion of the fitness of things that this was not altogether wanting. For the millions of copies of Uncle Tom scattered over the world the author could expect nothing, but in her own country her copyright yielded her a moderate return that lifted her out of poverty and enabled her to pursue her philanthropic and literary career. Four months after the publication of the book Professor Stowe was in the publisher's office, and Mr. Jewett asked him how much he expected to receive. "I hope," said Professor Stowe, with a whimsical smile, "that it will be enough to buy my wife a silk dress." The publisher handed him a check for ten thousand dollars.

Before Mrs. Stowe had a response to the letters accompanying the books privately sent to England, the novel was getting known there. Its career in Great Britain paralleled its success in America. In April a copy reached London in the hands of a gentleman who had taken it on the steamer to read. He gave it to Mr. Henry Vizetelly, who submitted it to Mr. David Bogue, a man known for his shrewdness and enterprise. He took a night to consider it, and then declined it, although it was offered to him for five pounds. A Mr. Gilpin also declined it. It was then submitted to Mr. Salisbury, a printer. This taster for the public sat up with the book till four o'clock in the morning, alternately weeping and laughing. Fearing, however, that this result was due to his own weakness, he woke up his wife, whom he describes as a rather strong-minded woman, and finding that the story kept her awake and made her also laugh and cry, he thought it might safely be printed. It seems, therefore, that Mr. Vizetelly ventured to risk five pounds, and the volume was brought out through the nominal agency of Clarke & Company. In the first week an edition of seven thousand was worked off. It made no great stir until the middle of June, but during July it sold at the rate of one thousand a week. By the 20th of August the demand for it was overwhelming. The printing firm was then employing four hundred people in getting it out, and seventeen printing-machines, besides hand-presses. Already one hundred and fifty thousand copies were sold. Mr. Vizetelly disposed of his interest, and a new printing firm began to issue monster editions. About this time the publishers awoke to the fact that any one was at liberty to reprint the book, and the era of cheap literature was initiated, founded on American reprints which cost the publisher no royalty. A shilling edition followed the one-and-sixpence, and then one complete for sixpence. As to the total sale, Mr. Sampson Low reports: "From April to December, 1852, twelve different editions (not reissues) were published, and within the twelve months of its first appearance eighteen different London publishing houses were engaged in supplying the great demand that had set in, the total number of editions being forty, varying from fine illustrated editions at 15s., 10s., and 7s. 6d. to the cheap popular editions of 1s. 9d. and 6d. After carefully analyzing these editions and weighing probabilities with ascertained facts, I am able pretty confidently to say that the aggregate number of copies circulated in Great Britain and the colonies exceeds one and a half millions." Later, abridgments were published.

Almost simultaneously with this furor in England the book made its way on the Continent. Several translations appeared in Germany and France, and for the authorized French edition Mrs. Stowe wrote a new preface, which served thereafter for most of the European editions. I find no record of the order of the translations of the book into foreign languages, but those into some of the

Oriental tongues did not appear till several years after the great excitement. The ascertained translations are into twenty-three tongues, namely: Arabic, Armenian, Chinese, Danish, Dutch, Finnish, Flemish, French, German, Hungarian, Illyrian, Italian, Japanese, Polish, Portuguese, modern Greek, Russian, Servian, Siamese, Spanish, Swedish, Wallachian, and Welsh. Into some of these languages several translations were made. In 1878 the British Museum contained thirty-five editions of the original text, and eight editions of abridgments or adaptations.

The story was dramatized in the United States in August, 1852, without the consent or knowledge of the author, and was played most successfully in the leading cities, and subsequently was acted in every capital in Europe. Mrs. Stowe had neglected to secure the dramatic rights, and she derived no benefit from the great popularity of a drama which still holds the stage. From the phenomenal sale of a book which was literally read by the whole world, the author received only the ten per cent on the American editions, and by the laws of her own country her copyright expired before her death.

The narrative of the rise and fortunes of this book would be incomplete without some reference to the response that the author received from England and the Continent, and of her triumphant progress through the British Isles. Her letters accompanying the special copies were almost immediately replied to, generally in terms of enthusiastic and fervent thankfulness for the book, and before midsummer her mail contained letters from all classes of English society. In some of them appeared a curious evidence of the English sensitiveness to criticism. Lord Carlisle and Sir Arthur Helps supplemented their admiration by a protest against the remark in the mouth of one of the characters that "slaves are better off than a large class of the population of England." This occurred in the defense of the institution by St. Clare, but it was treated by the British correspondents as the opinion of Mrs. Stowe. The charge was disposed of in Mrs. Stowe's reply: "The remark on that subject occurs in the dramatic part of the book, in the mouth of an intelligent Southerner. As a fair-minded person, bound to state for both sides all that could be said, in the person of St. Clare, the best that could be said on that point, and what I know IS in fact constantly reiterated, namely, that the laboring class of the South are in many respects, as to physical comfort, in a better condition than the poor in England. This is the slaveholder's stereo-typed apology; a defense it cannot be, unless two wrongs make one right."

In April, 1853, Mr. and Mrs. Stowe and the latter's brother, Charles Beecher, sailed for Europe. Her reception there was like a royal progress. She was met everywhere by deputations and addresses, and the enthusiasm her presence called forth was thoroughly democratic, extending from the highest in rank to the lowest. At Edinburgh there was presented to her a national penny offering, consisting of a thousand golden sovereigns on a magnificent silver salver, an unsolicited contribution in small sums by the people.

At a reception in Stafford House, London, the Duchess of Sutherland presented her with a massive gold bracelet, which has an interesting history. It is made of ten oval links in imitation of slave fetters. On two of the links were the inscriptions "March 25, 1807," the date of the abolition of the slave-trade, and "August 1, 1838," the date of the abolition of slavery in all British territory. The third inscription is "562,848--March 19, 1853," the date of the address of the women of England to the women of America on slavery, and the number of the women who signed. It was Mrs. Stowe's privilege to add to these inscriptions the following: "Emancipation D. C. Apl. 16, '62;" "President's Proclamation Jan. 1, '63;" "Maryland free Oct. 13, '64;" "Missouri free Jan. 11, '65;" and on the clasp link, "Constitution amended by Congress Jan. 31, '65. Constitutional Amendment ratified." Two of the links are vacant. What will the progress of civilization in America offer for the links nine and ten?

One of the most remarkable documents which resulted from Uncle Tom was an address from the women of England to the women of America, acknowledging the complicity in slavery of England, but praying aid in removing from the world "our common crimes and common dishonor," which was presented to Mrs. Stowe in 1853. It was the result of a meeting at Stafford House, and the address, composed by Lord Shaftesbury, was put into the hands of canvassers in England and on the Continent, and as far as Jerusalem. The signatures of 562,848 women were obtained, with their occupations and residences, from the nobility on the steps of the throne down to maids in the kitchen. The address is handsomely engrossed on vellum. The names are contained in twenty-six massive volumes, each fourteen inches high by nine in breadth and three inches thick, inclosed in an oak case. It is believed that this is the most numerously signed address in existence. The value of the address, with so many names collected in haphazard fashion, was much questioned, but its use was apparent in the height of the civil war, when Mrs. Stowe replied to it in one of the most vigorous and noble appeals that ever came from her pen. This powerful reply made a profound impression in England.

This is in brief the story of the book. It is still read, and read the world over, with tears and with laughter; it is still played to excited audiences. Is it a great novel, or was it only an event of an era of agitation and passion? Has it the real dramatic quality--the poet's visualizing of human life--that makes works of fiction, of imagination, live? Till recently, I had not read the book since 1852. I feared

to renew acquaintance with it lest I should find only the shell of an exploded cartridge. I took it up at the beginning of a three-hours' railway journey. To my surprise the journey did not seem to last half an hour, and half the time I could not keep back the tears from my eyes. A London critic, full of sympathy with Mrs. Stowe and her work, recently said, "Yet she was not an artist, she was not a great woman." What is greatness? What is art? In 1862 probably no one who knew General Grant would have called him a great man. But he took Vicksburg. This woman did something with her pen,--on the whole, the most remarkable and effective book in her generation. How did she do it? Without art? George Sand said, "In matters of art there is but one rule, to paint and to move. And where shall we find conditions more complete, types more vivid, situations more touching, more original, than in Uncle Tom?" If there is not room in our art for such a book, I think we shall have to stretch our art a little. "Women, too, are here judged and painted with a master hand." This subtle critic, in her overpoweringly tender and enthusiastic review, had already inquired about the capacity of this writer. "Mrs. Stowe is all instinct; it is the very reason that she appears to some not to have talent. Has she not talent? What is talent? Nothing, doubtless, compared to genius; but has she genius? I cannot say that she has talent as one understands it in the world of letters, but she has genius as humanity feels the need of genius,--the genius of goodness, not that of the man of letters, but of the saint." It is admitted that Mrs. Stowe was not a woman of letters in the common acceptation of that term, and it is plain that in the French tribunal, where form is of the substance of the achievement, and which reluctantly overlooked the crudeness of Walter Scott, in France where the best English novel seems a violation of established canons, Uncle Tom would seem to belong where some modern critics place it, with works of the heart, and not of the head. The reviewer is, however, candid: "For a long time we have striven in France against the prolix explanations of Walter Scott. We have cried out against those of Balzac, but on consideration have perceived that the painter of manners and character has never done too much, that every stroke of the pencil was needed for the general effect. Let us learn then to appreciate all kinds of treatment, where the effect is good, and where they bear the seal of a master hand."

It must be admitted to the art critic that the book is defective according to the rules of the modern French romance; that Mrs. Stowe was possessed by her subject, and let her fervid interest in it be felt; that she had a definite purpose. That purpose was to quicken the sense of responsibility of the North by showing the real character of slavery, and to touch the South by showing that the inevitable wrong of it lay in the system rather than in those involved in it. Abundant material was in her hands, and the author burned to make it serviceable. What should she do? She might have done what she did afterwards in The Key, presented to the public a mass of statistics, of legal documents. The evidence would have been unanswerable, but the jury might not have been moved by it; they would have balanced it by considerations of political and commercial expediency. I presume that Mrs. Stowe made no calculation of this kind. She felt her course, and went on in it. What would an artist have done, animated by her purpose and with her material? He would have done what Cervantes did, what Tourgenieff did, what Mrs. Stowe did. He would have dramatized his facts in living personalities, in effective scenes, in vivid pictures of life. Mrs. Stowe exhibited the system of slavery by a succession of dramatized pictures, not always artistically welded together, but always effective as an exhibition of the system. Cervantes also showed a fading feudal romantic condition by a series of amusing and pathetic adventures, grouped rather loosely about a singularly fascinating figure.

Tourgenieff, a more consummate artist, in his hunting scenes exhibited the effect of serfdom upon society, in a series of scenes with no necessary central figure, without comment, and with absolute concealment of any motive. I believe the three writers followed their instincts, without an analytic argument as to the method, as the great painter follows his when he puts an idea upon canvas. He may invent a theory about it afterwards; if he does not, some one else will invent it for him. There are degrees of art. One painter will put in unnecessary accessories, another will exhibit his sympathy too openly, the technique or the composition of another can be criticised. But the question is, is the picture great and effective?

Mrs. Stowe had not Tourgenieff's artistic calmness. Her mind was fused into a white heat with her message. Yet, how did she begin her story? Like an artist, by a highly dramatized scene, in which the actors, by a few strokes of the pen, appear as distinct and unmistakable personalities, marked by individual peculiarities of manner, speech, motive, character, living persons in natural attitudes. The reader becomes interested in a shrewd study of human nature, of a section of life, with its various refinement, coarseness, fastidiousness and vulgarity, its humor and pathos. As he goes on he discovers that every character has been perfectly visualized, accurately limned from the first; that a type has been created which remains consistent, which is never deflected from its integrity by any exigencies of plot. This clear conception of character (not of earmarks and peculiarities adopted as labels), and faithful adhesion to it in all vicissitudes, is one of the rarest and highest attributes of genius. All the chief characters in the book follow this line of absolutely consistent development, from Uncle Tom and Legree down to the most aggravating and contemptible of all, Marie St. Clare. The selfish and hysterical woman has never been so faithfully depicted by any other author.

Distinguished as the novel is by its character-drawing and its pathos, I doubt if it would have captivated the world without its humor. This is of the old-fashioned kind, the large humor of Scott, and again of Cervantes, not verbal pleasantry, not the felicities of Lamb, but the humor of character in action, of situations elaborated with great freedom, and with what may be called a hilarious conception. This quality is never wanting in the book, either for the reader's entertainment by the way, or to heighten the pathos of the narrative by contrast. The introduction of Topsy into the New Orleans household saves us in the dangerous approach to melodrama in the religious passages between Tom and St. Clare. Considering the opportunities of the subject, the book has very little melodrama; one is apt to hear low music on the entrance of little Eva, but we are convinced of the wholesome sanity of the sweet child. And it is to be remarked that some of the most exciting episodes, such as that of Eliza crossing the Ohio River on the floating ice (of which Mr. Ruskin did not approve), are based upon authentic occurrences. The want of unity in construction of which the critics complain is partially explained by the necessity of exhibiting the effect of slavery in its entirety. The parallel plots, one running to Louisiana and the other to Canada, are tied together by this consideration, and not by any real necessity to each other.

There is no doubt that Mrs. Stowe was wholly possessed by her theme, rapt away like a prophet in a vision, and that, in her feeling at the time, it was written through her quite as much as by her. This idea grew upon her mind in the retrospective light of the tremendous stir the story made in the world, so that in her later years she came to regard herself as a providential instrument, and frankly to declare that she did not write the book; "God wrote it." In her own account, when she reached the death of Uncle Tom, "the whole vital force left her." The inspiration there left her, and the end of the story, the weaving together of all the loose ends of the plot, in the joining together almost by miracle the long separated, and the discovery of the relationships, is the conscious invention of the novelist.

It would be perhaps going beyond the province of the critic to remark upon what the author considered the central power of the story, and its power to move the world, the faith of Uncle Tom in the Bible. This appeal to the emotion of millions of readers cannot, however, be overlooked. Many regard the book as effective in regions remote from our perplexities by reason of this grace. When the work was translated into Siamese, the perusal of it by one of the ladies of the court induced her to liberate all her slaves, men, women, and children, one hundred and thirty in all. "Hidden Perfume," for that was the English equivalent of her name, said she was wishful to be good like Harriet Beecher Stowe. And as to the standpoint of Uncle Tom and the Bible, nothing more significant can be cited than this passage from one of the latest writings of Heinrich Heine:--

"The reawakening of my religious feelings I owe to that holy book the Bible. Astonishing that after I have whirled about all my life over all the dance-floors of philosophy, and yielded myself to all the orgies of the intellect, and paid my addresses to all possible systems, without satisfaction like Messalina after a licentious night, I now find myself on the same standpoint where poor Uncle Tom stands,--on that of the Bible! I kneel down by my black brother in the same prayer! What a humiliation! With all my science I have come no further than the poor ignorant negro who has scarce learned to spell. Poor Tom, indeed, seems to have seen deeper things in the holy book than I.... Tom, perhaps, understands them better than I, because more flogging occurs in them; that is to say, those ceaseless blows of the whip which have aesthetically disgusted me in reading the Gospels and the Acts. But a poor negro slave reads with his back, and understands better than we do. But I, who used to make citations from Homer, now begin to quote the Bible as Uncle Tom does."

The one indispensable requisite of a great work of imaginative fiction is its universality, its conception and construction so that it will appeal to universal human nature in all races and situations and climates. Uncle Tom's Cabin does that. Considering certain artistic deficiencies, which the French writers perceived, we might say that it was the timeliness of its theme that gave it currency in England and America. But that argument falls before the world-wide interest in it as a mere story, in so many languages, by races unaffected by our own relation to slavery.

It was the opinion of James Russell Lowell that the anti-slavery element in Uncle Tom and Dred stood in the way of a full appreciation, at least in her own country, of the remarkable genius of Mrs. Stowe. Writing in 1859, he said, "From my habits and the tendency of my studies I cannot help looking at things purely from an aesthetic point of view, and what I valued in Uncle Tom was the genius, and not the moral." This had been his impression when he read the book in Paris, long after the whirl of excitement produced by its publication had subsided, and far removed by distance from local influences. Subsequently, in a review, he wrote, "We felt then, and we believe now, that the secret of Mrs. Stowe's power lay in that same genius by which the great successes in creative literature have always been achieved,--the genius that instinctively goes to the organic elements of human nature, whether under a white skin or a black, and which disregards as trivial the conventions and fictitious notions which make so large a part both of our thinking and feeling.... The creative faculty of Mrs. Stowe, like that of Cervantes in Don Quixote and of Fielding in Joseph Andrews, overpowered the narrow specialty of her design, and expanded a local and temporary theme with the cosmopolitanism of

genius."

A half-century is not much in the life of a people; it is in time an inadequate test of the staying power of a book. Nothing is more futile than prophecy on contemporary literary work. It is safe, however, to say that Uncle Tom's Cabin has the fundamental qualities, the sure insight into human nature, and the fidelity to the facts of its own time which have from age to age preserved works of genius.

STRIVINGS OF THE NEGRO PEOPLE by W. E. Burghardt Du Bois

Berween me and the other world there is ever an unasked question: unasked by some through feelings of delicacy; by others through the difficulty of rightly framing it. All, nevertheless, flutter round it. They approach me in a half-hesitant sort of way, eye me curiously or compassionately, and then, instead of saying directly, How does it feel to be a problem? they say, I know an excellent colored man in my town; or, I fought at Mechanicsville; or, Do not these Southern outrages make your blood boil? At these I smile, or am interested, or reduce the boiling to a simmer, as the occasion may require. To the real question, How does it feel to be a problem? I answer seldom a word.

And yet, being a problem is a strange experience,--peculiar even for one who has never been anything else, save perhaps in babyhood and in Europe. It is in the early days of rollicking boyhood that the revelation first bursts upon one, all in a day, as it were. I remember well when the shadow swept across me. I was a little thing, away up in the hills of New England, where the dark Housatonic winds between Hoosac and Taghanic to the sea. In a wee wooden schoolhouse, something put it into the boys' and girls' heads to buy gorgeous visiting-cards--ten cents a package--and exchange. The exchange was merry, till one girl, a tall newcomer, refused my card,--refused it peremptorily, with a glance. Then it dawned upon me with a certain suddenness that I was different from the others; or like, mayhap, in heart and life and longing, but shut out from their world by a vast veil. I had thereafter no desire to tear down that veil, to creep through; I held all beyond it in common contempt, and lived above it in a region of blue sky and great wandering shadows. That sky was bluest when I could beat my mates at examination-time, or beat them at a foot-race, or even beat their stringy heads. Alas, with the years all this fine contempt began to fade; for the world I longed for, and all its dazzling opportunities, were theirs, not mine. But they should not keep these prizes, I said; some, all, I would wrest from them. Just how I would do it I could never decide: by reading law, by healing the sick, by telling the wonderful tales that swam in my head,--some way. With other black boys the strife was not so fiercely sunny: their youth shrunk into tasteless sycophancy, or into silent hatred of the pale world about them and mocking distrust of everything white; or wasted itself in a bitter cry. Why did God make me an outcast and a stranger in mine own house? The "shades of the prison-house" closed round about us all: walls strait and stubborn to the whitest, but relentlessly narrow, tall, and unscalable to sons of night who must plod darkly on in resignation, or beat unavailing palms against the stone, or steadily, half hopelessly watch the streak of blue above.

After the Egyptian and Indian, the Greek and Roman, the Teuton and Mongolian, the Negro is a sort of seventh son, born with a veil, and gifted with second-sight in this American world,--a world which yields him no self-consciousness, but only lets him see himself through the revelation of the other world. It is a peculiar sensation, this double-consciousness, this sense of always looking at one's self through the eyes of others, of measuring one's soul by the tape of a world that looks on in amused contempt and pity. One ever feels his two-ness,--an American, a Negro; two souls, two thoughts, two unreconciled strivings; two warring ideals in one dark body, whose dogged strength alone keeps it from being torn asunder. The history of the American Negro is the history of this strife,--this longing to attain self-conscious manhood, to merge his double self into a better and truer self. In this merging he wishes neither of the older selves to be lost. He does not wish to Africanize America, for America has too much to teach the world and Africa; he does not wish to bleach his Negro blood in a flood of white Americanism, for he believes--foolishly, perhaps, but fervently--that Negro blood has yet a message for the world. He simply wishes to make it possible for a man to be both a Negro and an American without being cursed and spit upon by his fellows, without losing the opportunity of self-development.

This is the end of his striving: to be a co-worker in the kingdom of culture, to escape both death and isolation, and to husband and use his best powers. These powers, of body and of mind, have in the past been so wasted and dispersed as to lose all effectiveness, and to seem like absence of all power, like weakness. The double-aimed struggle of the black artisan, on the one hand to escape white contempt for a nation of mere hewers of wood and drawers of water, and on the other hand to plough and nail and dig for a poverty-stricken horde, could only result in making him a poor craftsman, for he had but half a heart in either cause. By the poverty and ignorance of his people the Negro lawyer or doctor was pushed toward quackery and demagogism, and by the criticism of the other world toward an elaborate preparation that overfitted him for his lowly tasks. The would-be black savant was

confronted by the paradox that the knowledge his people needed was a twice-told tale to his white neighbors, while the knowledge which would teach the white world was Greek to his own flesh and blood. The innate love of harmony and beauty that set the ruder souls of his people a-dancing, a-singing, and a-laughing raised but confusion and doubt in the soul of the black artist; for the beauty revealed to him was the soul-beauty of a race which his larger audience despised, and he could not articulate the message of another people.

This waste of double aims, this seeking to satisfy two unreconciled ideals, has wrought sad havoc with the courage and faith and deeds of eight thousand thousand people, has sent them often wooing false gods and invoking false means of salvation, and has even at times seemed destined to make them ashamed of themselves. In the days of bondage they thought to see in one divine event the end of all doubt and disappointment; eighteenth-century Rousseauism never worshiped freedom with half the unquestioning faith that the American Negro did for two centuries. To him slavery was, indeed, the sum of all villainies, the cause of all sorrow, the root of all prejudice; emancipation was the key to a promised land of sweeter beauty than ever stretched before the eyes of wearied Israelites. In his songs and exhortations swelled one refrain, liberty; in his tears and curses the god he implored had freedom in his right hand. At last it came,--suddenly, fearfully, like a dream. With one wild carnival of blood and passion came the message in his own plaintive cadences:--

"Shout, O children! Shout, you're free! The Lord has bought your liberty!"

Years have passed away, ten, twenty, thirty. Thirty years of national life, thirty years of renewal and development, and yet the swarthy ghost of Banquo sits in its old place at the national feast. In vain does the nation cry to its vastest problem,--

"Take any shape but that, and my firm nerves Shall never tremble!"

The freedman has not yet found in freedom his promised land. Whatever of lesser good may have come in these years of change, the shadow of a deep disappointment rests upon the Negro people,--a disappointment all the more bitter because the unattained ideal was unbounded save by the simple ignorance of a lowly folk.

The first decade was merely a prolongation of the vain search for freedom, the boom that seemed ever barely to elude their grasp,--like a tantalizing will-o'-the-wisp, maddening and misleading the headless host. The holocaust of war, the terrors of the Kuklux Klan, the lies of carpet-baggers, the disorganization of industry, and the contradictory advice of friends and foes left the bewildered serf with no new watchword beyond the old cry for freedom. As the decade closed, however, he began to grasp a new idea. The ideal of liberty demanded for its attainment powerful means, and these the Fifteenth Amendment gave him. The ballot, which before he had looked upon as a visible sign of freedom, he now regarded as the chief means of gaining and perfecting the liberty with which war had partially endowed him. And why not? Had not votes made war and emancipated millions? Had not votes enfranchised the freedmen? Was anything impossible to a power that had done all this? A million black men started with renewed zeal to vote themselves into the kingdom. The decade fled away,--a decade containing, to the freedman's mind, nothing but suppressed votes, stuffed ballot-boxes, and election outrages that nullified his vaunted right of suffrage. And yet that decade from 1875 to 1885 held another powerful movement, the rise of another ideal to guide the unguided, another pillar of fire by night after a clouded day. It was the ideal of "book-learning;" the curiosity, born of compulsory ignorance, to know and test the power of the cabalistic letters of the white man, the longing to know. Mission and night schools began in the smoke of battle, ran the gauntlet of reconstruction, and at last developed into permanent foundations. Here at last seemed to have been discovered the mountain path to Canaan; longer than the highway of emancipation and law, steep and rugged, but straight, leading to heights high enough to overlook life.

Up the new path the advance guard toiled, slowly, heavily, doggedly; only those who have watched and guided the faltering feet, the misty minds, the dull understandings of the dark pupils of these schools know how faithfully, how piteously, this people strove to learn. It was weary work. The cold statistician wrote down the inches of progress here and there, noted also where here and there a foot had slipped or some one had fallen. To the tired climbers, the horizon was ever dark, the mists were often cold, the Canaan was always dim and far away. If, however, the vistas disclosed as yet no goal, no resting-place, little but flattery and criticism, the journey at least gave leisure for reflection and self-examination; it changed the child of emancipation to the youth with dawning self-consciousness, self-realization, self-respect. In those sombre forests of his striving his own soul rose before him, and he saw himself,--darkly as through a veil; and yet he saw in himself some faint revelation of his power, of his mission. He began to have a dim feeling that, to attain his place in the world, he must be himself, and not another. For the first time he sought to analyze the burden he bore upon his back, that dead-weight of social degradation partially masked behind a half-named Negro problem. He felt

his poverty; without a cent, without a home, without land, tools, or savings, he had entered into competition with rich, landed, skilled neighbors. To be a poor man is hard, but to be a poor race in a land of dollars is the very bottom of hardships. He felt the weight of his ignorance,--not simply of letters, but of life, of business, of the humanities; the accumulated sloth and shirking and awkwardness of decades and centuries shackled his hands and feet. Nor was his burden all poverty and ignorance. The red stain of bastardy, which two centuries of systematic legal defilement of Negro women had stamped upon his race, meant not only the loss of ancient African chastity, but also the hereditary weight of a mass of filth from white whoremongers and adulterers, threatening almost the obliteration of the Negro home.

A people thus handicapped ought not to be asked to race with the world, but rather allowed to give all its time and thought to its own social problems. But alas! while sociologists gleefully count his bastards and his prostitutes, the very soul of the toiling, sweating black man is darkened by the shadow of a vast despair. Men call the shadow prejudice, and learnedly explain it as the natural defense of culture against barbarism, learning against ignorance, purity against crime, the "higher" against the "lower" races. To which the Negro cries Amen! and swears that to so much of this strange prejudice as is founded on just homage to civilization, culture, righteousness, and progress he humbly bows and meekly does obeisance. But before that nameless prejudice that leaps beyond all this he stands helpless, dismayed, and well-nigh speechless; before that personal disrespect and mockery, the ridicule and systematic humiliation, the distortion of fact and wanton license of fancy, the cynical ignoring of the better and boisterous welcoming of the worse, the all-pervading desire to inculcate disdain for everything black, from Toussaint to the devil,--before this there rises a sickening despair that would disarm and discourage any nation save that black host to whom "discouragement" is an unwritten word.

They still press on, they still nurse the dogged hope,--not a hope of nauseating patronage, not a hope of reception into charmed social circles of stock-jobbers, pork-packers, and earl-hunters, but the hope of a higher synthesis of civilization and humanity, a true progress, with which the chorus

"Peace, good will to men," "May make one music as before, But vaster."

Thus the second decade of the American Negro's freedom was a period of conflict, of inspiration and doubt, of faith and vain questionings, of Sturm and Drang. The ideals of physical freedom, of political power, of school training, as separate all-sufficient panaceas for social ills, became in the third decade dim and overcast. They were the vain dreams of credulous race childhood; not wrong, but incomplete and over-simple. The training of the schools we need to-day more than ever,--the training of deft hands, quick eyes and ears, and the broader, deeper, higher culture of gifted minds. The power of the ballot we need in sheer self-defense, and as a guarantee of good faith. We may misuse it, but we can scarce do worse in this respect than our whilom masters. Freedom, too, the long-sought, we still seek,--the freedom of life and limb, the freedom to work and think. Work, culture, and liberty,--all these we need, not singly, but together; for to-day these ideals among the Negro people are gradually coalescing, and finding a higher meaning in the unifying ideal of race,--the ideal of fostering the traits and talents of the Negro, not in opposition to, but in conformity with, the greater ideals of the American republic, in order that some day, on American soil, two world races may give each to each those characteristics which both so sadly lack. Already we come not altogether empty-handed: there is to-day no true American music but the sweet wild melodies of the Negro slave; the American fairy tales are Indian and African; we are the sole oasis of simple faith and reverence in a dusty desert of dollars and smartness. Will America be poorer if she replace her brutal, dyspeptic blundering with the light-hearted but determined Negro humility; or her coarse, cruel wit with loving, jovial good humor; or her Annie Rooney with Steal Away?

Merely a stern concrete test of the underlying principles of the great republic is the Negro problem, and the spiritual striving of the freedmen's sons is the travail of souls whose burden is almost beyond the measure of their strength, but who bear it in the name of an historic race, in the name of this land of their fathers' fathers, and in the name of human opportunity.

THE WIFE OF HIS YOUTH by Charles W. Chesnutt

I.

Mr. Ryder was going to give a ball. There were several reasons why this was an opportune time for such an event.

Mr. Ryder might aptly be called the dean of the Blue Veins. The original Blue Veins were a little society of colored persons organized in a certain Northern city shortly after the war. Its purpose was to establish and maintain correct social standards among

a people whose social condition presented almost unlimited room for improvement. By accident, combined perhaps with some natural affinity, the society consisted of individuals who were, generally speaking, more white than black. Some envious outsider made the suggestion that no one was eligible for membership who was not white enough to show blue veins. The suggestion was readily adopted by those who were not of the favored few, and since that time the society, though possessing a longer and more pretentious name, had been known far and wide as the "Blue Vein Society," and its members as the "Blue Veins."

The Blue Veins did not allow that any such requirement existed for admission to their circle, but, on the contrary, declared that character and culture were the only things considered; and that if most of their members were light-colored, it was because such persons, as a rule, had had better opportunities to qualify themselves for membership. Opinions differed, too, as to the usefulness of the society. There were those who had been known to assail it violently as a glaring example of the very prejudice from which the colored race had suffered most; and later, when such critics had succeeded in getting on the inside, they had been heard to maintain with zeal and earnestness that the society was a life-boat, an anchor, a bulwark and a shield, a pillar of cloud by day and of fire by night, to guide their people through the social wilderness. Another alleged prerequisite for Blue Vein membership was that of free birth; and while there was really no such requirement, it is doubtless true that very few of the members would have been unable to meet it if there had been. If there were one or two of the older members who had come up from the South and from slavery, their history presented enough romantic circumstances to rob their servile origin of its grosser aspects. While there were no such tests of eligibility, it is true that the Blue Veins had their notions on these subjects, and that not all of them were equally liberal in regard to the things they collectively disclaimed. Mr. Ryder was one of the most conservative. Though he had not been among the founders of the society, but had come in some years later, his genius for social leadership was such that he had speedily become its recognized adviser and head, the custodian of its standards, and the preserver of its traditions. He shaped its social policy, was active in providing for its entertainment, and when the interest fell off, as it sometimes did, he fanned the embers until they burst again into a cheerful flame. There were still other reasons for his popularity. While he was not as white as some of the Blue Veins, his appearance was such as to confer distinction upon them. His features were of a refined type, his hair was almost straight; he was always neatly dressed; his manners were irreproachable, and his morals above suspicion. He had come to Groveland a young man, and obtaining employment in the office of a railroad company as messenger had in time worked himself up to the position of stationery clerk, having charge of the distribution of the office supplies for the whole company. Although the lack of early training had hindered the orderly development of a naturally fine mind, it had not prevented him from doing a great deal of reading or from forming decidedly literary tastes. Poetry was his passion. He could repeat whole pages of the great English poets; and if his pronunciation was sometimes faulty, his eye, his voice, his gestures, would respond to the changing sentiment with a precision that revealed a poetic soul, and disarm criticism. He was economical, and had saved money; he owned and occupied a very comfortable house on a respectable street. His residence was handsomely furnished, containing among other things a good library, especially rich in poetry, a piano, and some choice engravings. He generally shared his house with some young couple, who looked after his wants and were company for him; for Mr. Ryder was a single man. In the early days of his connection with the Blue Veins he had been regarded as quite a catch, and ladies and their mothers had manoeuvred with much ingenuity to capture him. Not, however, until Mrs. Molly Dixon visited Groveland had any woman ever made him wish to change his condition to that of a married man.

Mrs. Dixon had come to Groveland from Washington in the spring, and before the summer was over she had won Mr. Ryder's heart. She possessed many attractive qualities. She was much younger than he; in fact, he was old enough to have been her father, though no one knew exactly how old he was. She was whiter than he, and better educated. She had moved in the best colored society of the country, at Washington, and had taught in the schools of that city. Such a superior person had been eagerly welcomed to the Blue Vein Society, and had taken a leading part in its activities. Mr. Ryder had at first been attracted by her charms of person, for she was very good looking and not over twenty-five; then by her refined manners and by the vivacity of her wit. Her husband had been a government clerk, and at his death had left a considerable life insurance. She was visiting friends in Groveland, and, finding the town and the people to her liking, had prolonged her stay indefinitely. She had not seemed displeased at Mr. Ryder's attentions, but on the contrary had given him every proper encouragement; indeed, a younger and less cautious man would long since have spoken. But he had made up his mind, and had only to determine the time when he would ask her to be his wife. He decided to give a ball in her honor, and at some time during the evening of the ball to offer her his heart and hand. He had no special fears about the outcotme, but, with a little touch of romance, he wanted the surroundings to be in harmony with his own feelings when he should have received the answer he expected.

Mr. Ryder resolved that this ball should mark an epoch in the social history of Groveland. He knew, of course,--no one could know better,--the entertainments that had taken place in past years, and what must be done to surpass them. His ball must be worthy of

the lady in whose honor it was to be given, and must, by the quality of its guests, set an example for the future. He had observed of late a growing liberality, almost a laxity, in social matters, even among members of his own set, and had several times been forced to meet in a social way persons whose complexions and callings in life were hardly up to the standard which he considered proper for the society to maintain. He had a theory of his own.

"I have no race prejudice," he would say, "but we people of mixed blood are ground between the upper and the nether millstone. Our fate lies between absorption by the white race and extinction in the black. The one doesn't want us yet, but may take us in time. The other would welcome us, but it would be for us a backward step. 'With malice towards none, with charity for all,' we must do the best we can for ourselves and those who are to follow us. Self-preservation is the first law of nature."

His ball would serve by its exclusiveness to counteract leveling tendencies, and his marriage with Mrs. Dixon would help to further the upward process of absorption he had been wishing and waiting for.

II.

The ball was to take place on Friday night. The house had been put in order, the carpets covered with canvas, the halls and stairs decorated with palms and potted plants; and in the afternoon Mr. Ryder sat on his front porch, which the shade of a vine running up over a wire netting made a cool and pleasant lounging-place. He expected to respond to the toast "The Ladies," at the supper, and from a volume of Tennyson--his favorite poet--was fortifying himself with apt quotations. The volume was open at A Dream of Fair Women. His eyes fell on these lines, and he read them aloud to judge better of their effect:--

"At length I saw a lady within call. Stiller than chisell'd marble, standing there; A daughter of the gods, divinely tall, And most divinely fair."

He marked the verse, and turning the page read the stanza beginning,--

"O sweet pale Margaret, O rare pale Margaret."

He weighed the passage a moment, and decided that it would not do. Mrs. Dixon was the palest lady he expected at the ball, and she was of a rather ruddy complexion, and of lively disposition and buxom build. So he ran over the leaves until his eye rested on the description of Queen Guinevere:--

"She seem'd a part of joyous Spring: A gown of grass-green silk she wore, Buckled with golden clasps before; A light-green tuft of plumes she bore Closed in a golden ring.

. . . . . .

"She look'd so lovely, as she sway'd The rein with dainty finger-tips, A man had given all other bliss, And all his worldly worth for this, To waste his whole heart in one kiss Upon her perfect lips."

As Mr. Ryder murmured these words audibly, with an appreciative thrill, he heard the latch of his gate click, and a light footfall sounding on the steps. He turned his head, and saw a woman standing before the door.

She was a little woman, not five feet tall, and proportioned to her height. Although she stood erect, and looked around her with very bright and restless eyes, she seemed quite old; for her face was crossed and recrossed with a hundred wrinkles, and around the edges of her bonnet could be seen protruding here and there a tuft of short gray wool. She wore a blue calico gown of ancient cut, a little red shawl fastened around her shoulders with an old-fashioned brass brooch, and a large bonnet profusely ornamented with faded red and yellow artificial flowers. And she was very black--so black that her toothless gums, revealed when she opened her mouth to speak, were not red, but blue. She looked like a bit of the old plantation life, summoned up from the past by the wave of a magician's wand, as the poet's fancy had called into being the gracious shapes of which Mr. Ryder had just been reading.

He rose from his chair and came over to where she stood.

"Good-afternoon, madam," he said.

"Good-evenin', suh," she answered, ducking suddenly with a quaint curtsy. Her voice was shrill and piping, but softened somewhat by age. "Is dis yere whar Mistuh Ryduh lib, suh?" she asked, looking around her doubtfully, and glancing into the open windows,

through which some of the preparations for the evening were visible.

"Yes," he replied, with an air of kindly patronage, unconsciously flattered by her manner, "I am Mr. Ryder. Did you want to see me?"

"Yas, suh, ef I ain't 'sturbin' of you too much."

"Not at all. Have a seat over here behind the vine, where it is cool. What can I do for you?"

"'Scuse me, suh," she continued, when she had sat down on the edge of a chair, "'scuse me, suh, I's lookin' for my husban'. I heerd you wuz a big man an' had libbed heah a long time, an' I 'lowed you wouldn't min' ef I'd come roun' an' ax you ef you'd eber heerd of a merlatter man by de name er Sam Taylor 'quirin' roun' in de chu'ches ermongs' de people fer his wife 'Liza Jane?"

Mr. Ryder seemed to think for a moment.

"There used to be many such cases right after the war," he said, "but it has been so long that I have forgotten them. There are very few now. But tell me your story, and it may refresh my memory."

She sat back farther in her chair so as to be more comfortable, and folded her withered hands in her lap.

"My name's 'Liza," she began, "'Liza Jane. Wen I wuz young I us'ter b'long ter Marse Bob Smif, down in old Missourn. I wuz bawn down dere. W'en I wuz a gal I wuz married ter a man named Jim. But Jim died, an' after dat I married a merlatter man named Sam Taylor. Sam wuz free-bawn, but his mammy and daddy died, an' de w'ite folks 'prenticed him ter my marster fer ter work fer 'im 'tel he wuz growed up. Sam worked in de fiel', an' I wuz de cook. One day Ma'y Ann, ole miss's maid, come rushin' out ter de kitchen, an' says she, "Liza Jane, ole marse gwine sell yo' Sam down de ribber.'

"'Go way f'm yere,' says I; 'my husban's free!'

"'Don' make no diff'ence. I heerd ole marse tell ole miss he wuz gwine take yo' Sam 'way wid 'im ter-morrow, fer he needed money, an' he knowed whar he could git a t'ousan' dollars fer Sam an' no questions axed.'

"W'en Sam come home f'm de fiel', dat night, I tole him 'bout ole marse gwine steal 'im, an' Sam run erway. His time wuz mos' up, an' he swo' dat w'en he wuz twenty-one he would come back an' he'p me run erway, er else save up de money ter buy my freedom. An' I know he'd 'a' done it, fer he thought a heap er me, Sam did. But w'en he come back he didn' fin' me, fer I wuzn' dere. Ole marse had heerd dat I warned Sam, so he had me whip' an' sol' down de ribber.

"Den de wah broke out, an' w'en it wuz ober de cullud folks wuz scattered. I went back ter de ole home; but Sam wuzn' dere, an' I couldn' l'arn nuffin' 'bout 'im. But I knowed he'd be'n dere to look fer me an' hadn' foun' me, an' had gone erway ter hunt fer me.

"I's be'n lookin' fer 'im eber sence," she added simply, as though twenty-five years were but a couple of weeks, "an' I knows he's be'n lookin' fer me. Fer he sot a heap er sto' by me, Sam did, an' I know he's be'n huntin' fer me all dese years,--'less'n he's be'n sick er sump'n, so he couldn' work, er out'n his head, so he couldn' 'member his promise. I went back down de ribber, fer I 'lowed he'd gone down dere lookin' fer me. I's be'n ter Noo Orleens, an' Atlanty, an' Charleston, an' Richmon'; an' w'en I'd be'n all ober de Souf I come ter de Norf. Fer I knows I'll fin' 'im some er dese days," she added softly, "er he'll fin' me, an' den we'll bofe be as happy in freedom as we wuz in de ole days befo' de wah." A smile stole over her withered countenance as she paused a moment, and her bright eyes softened into a far-away look.

This was the substance of the old woman's story. She had wandered a little here and there. Mr. Ryder was looking at her curiously when she finished.

"How have you lived all these years?" he asked.

"Cookin', suh. I's a good cook. Does you know anybody w'at needs a good cook, suh? I's stoppin' wid a cullud fam'ly roun' de corner yonder 'tel I kin fin' a place."

"Do you really expect to find your husband? He may be dead long ago."

She shook her head emphatically. "Oh no, he ain' dead. De signs an' de tokens tells me. I dremp three nights runnin' on'y dis las' week dat I foun' him."

"He may have married another woman. Your slave marriage would not have prevented him, for you never lived with him after the war, and without that your marriage doesn't count."

"Wouldn' make no diff'ence wid Sam. He wouldn' marry no yuther 'ooman 'tel he foun' out 'bout me. I knows it," she added. "Sump'n's be'n tellin' me all dese years dat I's gwine fin' Sam 'fo I dies."

"Perhaps he's outgrown you, and climbed up in the world where he wouldn't care to have you find him."

"No, indeed, suh," she replied, "Sam ain' dat kin' er man. He wuz good ter me, Sam wuz, but he wuzn' much good ter nobody e'se, fer he wuz one er de triflin'es' han's on de plantation. I 'spec's ter haf ter suppo't 'im w'en I fin' 'im, fer he nebber would work 'less'n he had ter. But den he wuz free, an' he didn' git no pay fer his work, an' I don' blame 'im much. Mebbe he's done better sence he run erway, but I ain' 'spectin' much."

"You may have passed him on the street a hundred times during the twenty-five years, and not have known him; time works great changes."

She smiled incredulously. "I'd know 'im 'mongs' a hund'ed men. Fer dey wuzn' no yuther merlatter man like my man Sam, an' I couldn' be mistook. I's toted his picture roun' wid me twenty-five years."

"May I see it?" asked Mr. Ryder. "It might help me to remember whether I have seen the original."

As she drew a small parcel from her bosom, he saw that it was fastened to a string that went around her neck. Removing several wrappers, she brought to light an old-fashioned daguerreotype in a black case. He looked long and intently at the portrait. It was faded with time, but the features were still distinct, and it was easy to see what manner of man it had represented.

He closed the case, and with a slow movement handed it back to her.

"I don't know of any man in town who goes by that name," he said, "nor have I heard of any one making such inquiries. But if you will leave me your address, I will give the matter some attention, and if I find out anything I will let you know."

She gave him the number of a house in the neighborhood, and went away, after thanking him warmly.

He wrote down the address on the flyleaf of the volume of Tennyson, and, when she had gone, rose to his feet and stood looking after her curiously. As she walked down the street with mincing step, he saw several persons whom she passed turn and look back at her with a smile of kindly amusement. When she had turned the corner, he went upstairs to his bedroom, and stood for a long time before the mirror of his dressing-case, gazing thoughtfully at the reflection of his own face.

III.

At eight o'clock the ballroom was a blaze of light and the guests had begun to assemble; for there was a literary programme and some routine business of the society to be gone through with before the dancing. A black servant in evening dress waited at the door and directed the guests to the dressing-rooms.

The occasion was long memorable among the colored people of the city; not alone for the dress and display, but for the high average of intelligence and culture that distinguished the gathering as a whole. There were a number of school-teachers, several young doctors, three or four lawyers, some professional singers, an editor, a lieutenant in the United States army spending his furlough in the city, and others in various polite callings; these were colored, though most of them would not have attracted even a casual glance because of any marked difference from white people. Most of the ladies were in evening costume, and dress coats and dancing-pumps were the rule among the men. A band of string music, stationed in an alcove behind a row of palms, played popular airs while the guests were gathering.

The dancing began at half past nine. At eleven o'clock supper was served. Mr. Ryder had left the ballroom some little time before the intermission, but reappeared at the supper-table. The spread was worthy of the occasion, and the guests did full justice to it. When the coffee had been served, the toastmaster, Mr. Solomon Sadler, rapped for order. He made a brief introductory speech, complimenting host and guests, and then presented in their order the toasts of the evening. They were responded to with a very fair display of after-dinner wit.

"The last toast," said the toast-master, when he reached the end of the list, "is one which must appeal to us all. There is no one of us of the sterner sex who is not at some time dependent upon woman,--in infancy for protection, in manhood for companionship, in old age for care and comforting. Our good host has been trying to live alone, but the fair faces I see around me to-night prove that he too is largely dependent upon the gentler sex for most that makes life worth living,--the society and love of friends,--and rumor is at fault if he does not soon yield entire subjection to one of them. Mr. Ryder will now respond to the toast,--The Ladies."

There was a pensive look in Mr. Ryder's eyes as he took the floor and adjusted his eyeglasses. He began by speaking of woman as the gift of Heaven to man, and after some general observations on the relations of the sexes he said: "But perhaps the quality which most distinguishes woman is her fidelity and devotion to those she loves. History is full of examples, but has recorded none more striking than one which only to-day came under my notice."

He then related, simply but effectively, the story told by his visitor of the afternoon. He told it in the same soft dialect, which came readily to his lips, while the company listened attentively and sympathetically. For the story had awakened a responsive thrill in many hearts. There were some present who had seen, and others who had heard their fathers and grandfathers tell, the wrongs and sufferings of this past generation, and all of them still felt, in their darker moments, the shadow hanging over them. Mr. Ryder went on:--

"Such devotion and such confidence are rare even among women. There are many who would have searched a year, some who would have waited five years, a few who might have hoped ten years; but for twenty-five years this woman has retained her affection for and her faith in a man she has not seen or heard of in all that time.

"She came to me to-day in the hope that I might be able to help her find this long-lost husband. And when she was gone I gave my fancy rein, and imagined a case I will put to you.

"Suppose that this husband, soon after his escape, had learned that his wife had been sold away, and that such inquiries as he could make brought no information of her whereabouts. Suppose that he was young, and she much older than he; that he was light, and she was black; that their marriage was a slave marriage, and legally binding only if they chose to make it so after the war. Suppose, too, that he made his way to the North, as some of us have done, and there, where he had larger opportunities, had improved them, and had in the course of all these years grown to be as different from the ignorant boy who ran away from fear of slavery as the day is from the night. Suppose, even, that he had qualified himself, by industry, by thrift, and by study, to win the friendship and be considered worthy the society of such people as these I see around me to-night, gracing my board and filling my heart with gladness; for I am old enough to remember the day when such a gathering would not have been possible in this land. Suppose, too, that, as the years went by, this man's memory of the past grew more and more indistinct, until at last it was rarely, except in his dreams, that any image of this bygone period rose before his mind. And then suppose that accident should bring to his knowledge the fact that the wife of his youth, the wife he had left behind him,--not one who had walked by his side and kept pace with him in his upward struggle, but one upon whom advancing years and a laborious life had set their mark,--was alive and seeking him, but that he was absolutely safe from recognition or discovery, unless he chose to reveal himself. My friends, what would the man do? I will suppose that he was one who loved honor, and tried to deal justly with all men. I will even carry the case further, and suppose that perhaps he had set his heart upon another, whom he had hoped to call his own. What would he do, or rather what ought he to do, in such a crisis of a lifetime?

"It seemed to me that he might hesitate, and I imagined that I was an old friend, a near friend, and that he had come to me for advice; and I argued the case with him. I tried to discuss it impartially. After we had looked upon the matter from every point of view, I said to him, in words that we all know:

'This above all: to thine own self be true, And it must follow, as the night the day, Thou canst not then be false to any man.'

Then, finally, I put the question to him, 'Shall you acknowledge her?'

"And now, ladies and gentlemen, friends and companions, I ask you, what should he have done?"

There was something in Mr. Ryder's voice that stirred the hearts of those who sat around him. It suggested more than mere sympathy with an imaginary situation; it seemed rather in the nature of a personal appeal. It was observed, too, that his look rested more especially upon Mrs. Dixon, with a mingled expression of renunciation and inquiry.

She had listened, with parted lips and streaming eyes. She was the first to speak: "He should have acknowledged her."

"Yes," they all echoed, "he should have acknowledged her."

"My friends and companions," responded Mr. Ryder, "I thank you, one and all. It is the answer I expected, for I knew your hearts."

He turned and walked toward the closed door of an adjoining room, while every eye followed him in wondering curiosity. He came back in a moment, leading by the hand his visitor of the afternoon, who stood startled and trembling at the sudden plunge into this scene of brilliant gayety. She was neatly dressed in gray, and wore the white cap of an elderly woman.

"Ladies and gentlemen," he said, "this is the woman, and I am the man, whose story I have told you. Permit me to introduce to you the wife of my youth."

THE BOUQUET by Charles W. Chesnutt

Mary Myrover's friends were somewhat surprised when she began to teach a colored school. Miss Myrover's friends are mentioned here, because nowhere more than in a Southern town is public opinion a force which cannot be lightly contravened. Public opinion, however, did not oppose Miss Myrover's teaching colored children; in fact, all the colored public schools in town--and there were several--were taught by white teachers, and had been so taught since the state had undertaken to provide free public instruction for all children within its boundaries. Previous to that time there had been a Freedman's Bureau school and a Presbyterian missionary school, but these had been withdrawn when the need for them became less pressing. The colored people of the town had been for some time agitating their right to teach their own schools, but as yet the claim had not been conceded.

The reason Miss Myrover's course created some surprise was not, therefore, the fact that a Southern white woman should teach a colored school; it lay in the fact that up to this time no woman of just her quality had taken up such work. Most of the teachers of colored schools were not of those who had constituted the aristocracy of the old regime; they might be said rather to represent the new order of things, in which labor was in time to become honorable, and men were, after a somewhat longer time, to depend, for their place in society, upon themselves rather than upon their ancestors. But Mary Myrover belonged to one of the proudest of the old families. Her ancestors had been people of distinction in Virginia before a collateral branch of the main stock had settled in North Carolina. Before the war they had been able to live up to their pedigree. But the war brought sad changes. Miss Myrover's father--the Colonel Myrover who led a gallant but desperate charge at Vicksburg--had fallen on the battlefield, and his tomb in the white cemetery was a shrine for the family. On the Confederate Memorial Day no other grave was so profusely decorated with flowers, and in the oration pronounced the name of Colonel Myrover was always used to illustrate the highest type of patriotic devotion and self-sacrifice. Miss Myrover's brother, too, had fallen in the conflict; but his bones lay in some unknown trench, with those of a thousand others who had fallen on the same field. Ay, more, her lover, who had hoped to come home in the full tide of victory and claim his bride as a reward for gallantry, had shared the fate of her father and brother. When the war was over, the remnant of the family found itself involved in the common ruin,--more deeply involved, indeed, than some others; for Colonel Myrover had believed in the ultimate triumph of his cause, and had invested most of his wealth in Confederate bonds, which were now only so much waste paper.

There had been a little left. Mrs. Myrover was thrifty, and had laid by a few hundred dollars, which she kept in the house to meet unforeseen contingencies. There remained, too, their home, with an ample garden and a well-stocked orchard, besides a considerable tract of country land, partly cleared, but productive of very little revenue.

With their shrunken resources, Miss Myrover and her mother were able to hold up their heads without embarrassment for some years after the close of the war. But when things were adjusted to the changed conditions, and the stream of life began to flow more vigorously in the new channels, they saw themselves in danger of dropping behind, unless in some way they could add to their meagre income. Miss Myrover looked over the field of employment, never very wide for women in the South, and found it occupied. The only available position she could be supposed prepared to fill, and which she could take without distinct loss of caste, was that of a teacher, and there was no vacancy except in one of the colored schools. Even teaching was a doubtful experiment; it was not what she would have preferred, but it was the best that could be done.

"I don't like it, Mary," said her mother. "It's a long step from owning such people to teaching them. What do they need with education? It will only make them unfit for work."

"They're free now, mother, and perhaps they'll work better if they're taught something. Besides, it's only a business arrangement, and doesn't involve any closer contact than we have with our servants."

"Well, I should say not!" sniffed the old lady. "Not one of them will ever dare to presume on your position to take any liberties with us. I'll see to that."

Miss Myrover began her work as a teacher in the autumn, at the opening of the school year. It was a novel experience at first. Though there always had been negro servants in the house, and though on the streets colored people were more numerous than her own people, and though she was so familiar with their dialect that she might almost be said to speak it, barring certain characteristic grammatical inaccuracies, she had never been brought in personal contact with so many of them at once as when she confronted the fifty or sixty faces--of colors ranging from a white almost as clear as her own to the darkest livery of the sun--which were gathered in the schoolroom on the morning when she began her duties. Some of the inherited prejudice of her caste, too, made itself felt, though she tried to repress any outward sign of it; and she could perceive that the children were not altogether responsive; they, likewise, were not entirely free from antagonism. The work was unfamiliar to her. She was not physically very strong, and at the close of the first day she went home with a splitting headache. If she could have resigned then and there without causing comment or annoyance to others, she would have felt it a privilege to do so. But a night's rest banished her headache and improved her spirits, and the next morning she went to her work with renewed vigor, fortified by the experience of the first day.

Miss Myrover's second day was more satisfactory. She had some natural talent for organization, though she had never known it, and in the course of the day she got her classes formed and lessons under way. In a week or two she began to classify her pupils in her own mind, as bright or stupid, mischievous or well behaved, lazy or industrious, as the case might be, and to regulate her discipline accordingly. That she had come of a long line of ancestors who had exercised authority and mastership was perhaps not without its effect upon her character, and enabled her more readily to maintain good order in the school. When she was fairly broken in she found the work rather to her liking, and derived much pleasure from such success as she achieved as a teacher.

It was natural that she should be more attracted to some of her pupils than to others. Perhaps her favorite--or rather, the one she liked best, for she was too fair and just for conscious favoritism--was Sophy Tucker. Just the ground for the teacher's liking for Sophy might not at first be apparent. The girl was far from the whitest of Miss Myrover's pupils; in fact, she was one of the darker ones. She was not the brightest in intellect, though she always tried to learn her lessons. She was not the best dressed, for her mother was a poor widow, who went out washing and scrubbing for a living. Perhaps the real tie between them was Sophy's intense devotion to the teacher. It had manifested itself almost from the first day of the school, in the rapt look of admiration Miss Myrover always saw on the little black face turned toward her. In it there was nothing of envy, nothing of regret; nothing but worship for the beautiful white lady--she was not especially handsome, but to Sophy her beauty was almost divine--who had come to teach her. If Miss Myrover dropped a book, Sophy was the first to spring and pick it up; if she wished a chair moved, Sophy seemed to anticipate her wish; and so of all the numberless little services that can be rendered in a school-room.

Miss Myrover was fond of flowers, and liked to have them about her. The children soon learned of this taste of hers, and kept the vases on her desk filled with blossoms during their season. Sophy was perhaps the most active in providing them. If she could not get garden flowers, she would make excursions to the woods in the early morning, and bring in great dew-laden bunches of bay, or jasmine, or some other fragrant forest flower which she knew the teacher loved.

"When I die, Sophy," Miss Myrover said to the child one day, "I want to be covered with roses. And when they bury me, I'm sure I shall rest better if my grave is banked with flowers, and roses are planted at my head and at my feet."

Miss Myrover was at first amused at Sophy's devotion; but when she grew more accustomed to it, she found it rather to her liking. It had a sort of flavor of the old regime, and she felt, when she bestowed her kindly notice upon her little black attendant, some of the feudal condescension of the mistress toward the slave. She was kind to Sophy, and permitted her to play the role she had assumed, which caused sometimes a little jealousy among the other girls. Once she gave Sophy a yellow ribbon which she took from her own hair. The child carried it home, and cherished it as a priceless treasure, to be worn only on the greatest occasions.

Sophy had a rival in her attachment to the teacher, but the rivalry was altogether friendly. Miss Myrover had a little dog, a white spaniel, answering to the name of Prince. Prince was a dog of high degree, and would have very little to do with the children of the school; he made an exception, however, in the case of Sophy, whose devotion for his mistress he seemed to comprehend. He was a clever dog, and could fetch and carry, sit up on his haunches, extend his paw to shake hands, and possessed several other canine accomplishments. He was very fond of his mistress, and always, unless shut up at home, accompanied her to school, where he spent most of his time lying under the teacher's desk, or, in cold weather, by the stove, except when he would go out now and

then and chase an imaginary rabbit round the yard, presumably for exercise.

At school Sophy and Prince vied with each other in their attentions to Miss Myrover. But when school was over, Prince went away with her, and Sophy stayed behind; for Miss Myrover was white and Sophy was black, which they both understood perfectly well. Miss Myrover taught the colored children, but she could not be seen with them in public. If they occasionally met her on the street, they did not expect her to speak to them, unless she happened to be alone and no other white person was in sight. If any of the children felt slighted, she was not aware of it, for she intended no slight; she had not been brought up to speak to negroes on the street, and she could not act differently from other people. And though she was a woman of sentiment and capable of deep feeling, her training had been such that she hardly expected to find in those of darker hue than herself the same susceptibility--varying in degree, perhaps, but yet the same in kind--that gave to her own life the alternations of feeling that made it most worth living.

Once Miss Myrover wished to carry home a parcel of books. She had the bundle in her hand when Sophy came up.

"Lemme tote yo' bundle fer yer, Miss Ma'y?" she asked eagerly. "I'm gwine yo' way."

"Thank you, Sophy," was the reply. "I'll be glad if you will."

Sophy followed the teacher at a respectful distance. When they reached Miss Myrover's home Sophy carried the bundle to the doorstep, where Miss Myrover took it and thanked her.

Mrs. Myrover came out on the piazza as Sophy was moving away. She said, in the child's hearing, and perhaps with the intention that she should hear: "Mary, I wish you wouldn't let those little darkies follow you to the house. I don't want them in the yard. I should think you'd have enough of them all day."

"Very well, mother," replied her daughter. "I won't bring any more of them. The child was only doing me a favor."

Mrs. Myrover was an invalid, and opposition or irritation of any kind brought on nervous paroxysms that made her miserable, and made life a burden to the rest of the household; so that Mary seldom crossed her whims. She did not bring Sophy to the house again, nor did Sophy again offer her services as porter.

One day in spring Sophy brought her teacher a bouquet of yellow roses.

"Dey come off'n my own bush, Miss Ma'y," she said proudly, "an' I didn' let nobody e'se pull 'em, but saved 'em all fer you, 'cause I know you likes roses so much. I'm gwine bring 'em all ter you as long as dey las'."

"Thank you, Sophy," said the teacher; "you are a very good girl."

For another year Mary Myrover taught the colored school, and did excellent service. The children made rapid progress under her tuition, and learned to love her well; for they saw and appreciated, as well as children could, her fidelity to a trust that she might have slighted, as some others did, without much fear of criticism. Toward the end of her second year she sickened, and after a brief illness died.

Old Mrs. Myrover was inconsolable. She ascribed her daughter's death to her labors as teacher of negro children. Just how the color of the pupils had produced the fatal effects she did not stop to explain. But she was too old, and had suffered too deeply from the war, in body and mind and estate, ever to reconcile herself to the changed order of things following the return of peace; and with an unsound yet not unnatural logic, she visited some of her displeasure upon those who had profited most, though passively, by her losses.

"I always feared something would happen to Mary," she said. "It seemed unnatural for her to be wearing herself out teaching little negroes who ought to have been working for her. But the world has hardly been a fit place to live in since the war, and when I follow her, as I must before long, I shall not be sorry to go."

She gave strict orders that no colored people should be admitted to the house. Some of her friends heard of this, and remonstrated. They knew the teacher was loved by the pupils, and felt that sincere respect from the humble would be a worthy tribute to the proudest. But Mrs. Myrover was obdurate.

"They had my daughter when she was alive," she said, "and they've killed her. But she's mine now, and I won't have them come near her. I don't want one of them at the funeral or anywhere around."

For a month before Miss Myrover's death Sophy had been watching her rosebush--the one that bore the yellow roses--for the first buds of spring, and when these appeared had awaited impatiently their gradual unfolding. But not

[... TRUNCATED at 800,000 chars for file-size management — full text in original source ...]

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The book of the cat

Frances Simpson

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[Illustration:

BLACK PERSIAN.

(_Painted specially by Madame Henriette Ronner._)]

THE BOOK OF THE CAT

BY ... FRANCES SIMPSON

WITH 12 COLOURED PLATES, AND NEARLY 350 ILLUSTRATIONS IN THE TEXT FROM PHOTOGRAPHS AND DRAWINGS

CASSELL AND COMPANY, LIMITED LONDON, PARIS, NEW YORK AND MELBOURNE. MCMIII

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CONTENTS.

CHAPTER PAGE I.— CATS OF THE PAST 1 II.— CATS OF TO-DAY 18 III.— CARE AND MANAGEMENT 37 IV.— HOUSING OF CATS 49 V.— EXHIBITING 61 VI.— THE POINTS OF A CAT 96 VII.— LONG-HAIRED OR PERSIAN CATS 98 VIII.— SOME NOTABLE CATTERIES 101 IX.— BLACK PERSIANS 112 X.— WHITE PERSIANS 118 XI.— BLUE PERSIANS 125 XII.— SILVER OR CHINCHILLA PERSIANS 137 XIII.— SILVER TABBY PERSIANS 165 XIV.— SMOKE PERSIANS 178 XV.— ORANGE PERSIANS 187 XVI.— CREAM OR FAWN PERSIANS 201 XVII.— TORTOISESHELL PERSIANS 208 XVIII.— TORTOISESHELL-AND-WHITE PERSIANS 212 XIX.— BROWN TABBY PERSIANS 215 XX.— “ANY OTHER COLOUR” PERSIANS 231 XXI.— NEUTER CATS 237 XXII.— MANX CATS 244 XXIII.— SIAMESE CATS 254 XXIV.— SHORT-HAIRED CATS 274 XXV.— SHORT-HAIRED CATS (_continued_) 282 XXVI.— SOME FOREIGN CATS 297 XXVII.— CATS IN AMERICA 303 XXVIII.— MAINE CATS 325 XXIX.— CAT PHOTOGRAPHY FOR AMATEURS 332 XXX.— REARING OF KITTENS 337 XXXI.— COLOUR BREEDING 344 XXXII.— THE PLACE OF THE CAT IN NATURE 350 THE DISEASES OF CATS, AND THEIR TREATMENT 358 INDEX 377

LIST OF COLOURED PLATES.

BLACK PERSIAN _Frontispiece_ BLACK-AND-WHITE PERSIAN CATS _To face page_ 116 BLUE AND CREAM PERSIANS 126 BROWN TABBY AND SILVER PERSIANS 160 SMOKE AND ORANGE PERSIANS 186 TORTOISESHELL AND TORTOISESHELL-AND-WHITE PERSIANS 210 SILVER TABBY AND ORANGE-AND-WHITE PERSIANS 234 BROWN TABBY AND ORANGE TABBY SHORT-HAIRED CATS 252 TORTOISESHELL TOM, AND SILVER TABBY SHORT-HAIRED CATS 274 BLUE-AND-WHITE SHORT-HAIRED CATS 288 MANX AND SIAMESE 294 FOREIGN CATS 300

LIST OF ILLUSTRATIONS.

PAGE “White to Move” 1 Mummy of a Cat 1 The God Cat 2 An Egyptian Wall-Painting: The Adoration of the Goddess Pasht 2 The Worship of Pasht in the Temple of Bubastes 3 Mummified Kitten 3 A Cat God of Egypt 3 Puss as a Retriever: An Egyptian Wall-Painting 4 An Egyptian Toy Cat 5 A Mineral Lusus 6 Puss in Warfare 7 A Group of Cats in Pottery 9 Tomb of a Cat which belonged to Madame de Lesdiguières 10 The Printer’s Mark of Melchior Sessa of Venice 12 A Cat in Heraldry 12 A Merchant’s Mark 12 Alice and the Cheshire Cat 13 A Study 14 Madame Ronner at Work 15 “Crystal,” the property of Mrs. Finnie Young 16 Lady Alexander’s “Brother Bump” 17 Sleeping Beauties 18 Miss F. Simpson’s “Bonnie Boy” 18 Kitten at Work and Play 19 Kitten belonging to Mrs. Owen 20 The Antiquaries 21 “Kepwick Violet” and “Kepwick Hyacinth” 22 Miss Savery’s Blue Persian Kitten 23 A Pair of Short-haired Brown Tabbies 23 Cat Calendar 24 Cat Calendar 24 Cat Calendar 25 Mr. Harrison Weir 26 Mr. Louis Wain 27

Lady Marcus Beresford 28 Litter of Siamese Kittens 29 “Puck III.” 30 Mrs. Clinton Locke and her Siamese Kittens “Calif” and “Bangkok” 31 The Cat’s Playground 32 Royal London Institution for Lost and Starving Cats 33 The Cart of the R. L. I. 34 The Hon. Philip Wodehouse’s “Silver Saint” 35 A Bevy of Blues belonging to Miss Savery 35 Cats’ Tombstones at the Dogs’ Cemetery, Hyde Park 36 Tabbies up a Tree 37 Blue Persian belonging to Her Majesty the Queen 37 Three Little Maids 39 A Perilous Perch 40 Mrs. Hardy’s Neuter “Pharaoh” 41 “The Raiders” Caught 43 Kittens belonging to Miss Bromley 45 Neuter Pets owned by Mrs. Hastings Lees 46 Carolling 48 In a Playful Sort of Way 49 A Musical Party 50 The Ideal Cattery 53 A Litter Box 55 A Useful Cat House 55 A Portable Hutch 56 Lethal Chamber, R.L.I. 57 Spratt’s Travelling Basket 58 A Useful Cat Basket 58 A Gang of Poachers 59 Waking Beauties 61 Richmond Cat Show: Arrangement of Tents 65 Mrs. Gregory’s “Skellingthorpe Patrick” 67 “Inquiry” 67 Richmond Cat Show: Judges at Work 69 Type of Cage at the Richmond Cat Show 71 Mr. C. A. House 72 Mr. T. B. Mason 72 The Toilet 73 Blue Persian Kittens 74 Kits with a Taste for Flowers 75 Two Kittens bred by Miss Williams 75 Richmond Cat Show: The Ring Class 77 Minding Shop 78 Thieves 79 Mrs. Drury’s Brown Tabby “Periwig” 80 Miss Simpson’s “Cambyses” 80 A Litter of Blues 81 Judging in the Ring at the Crystal Palace 83 Miss Kirkpatrick’s Blue Kittens 84 “Rose of Persia” 85 Mischief 88 Our Play-room 89 Mr. F. W. Western 91 Officials of the N.C.C.C. 92 Sandy Stealing the Milk 94 Silver Cats belonging to Mrs. Clark of Ashbrittle 95 The Points of a Cat 96 Tailpiece 97 Blue Persians belonging to Mrs. Wells 98 “Gentian,” owned by Lady Marcus Beresford 99 Mrs. Herring’s “Champion Jimmy” 100 The Hon. Mrs. McLaren Morrison’s Cattery 101 Scenes at “Bishopsgate” 103 A Sleeping Box at Lady Decies’ Cattery 104 Lady Decies Visiting her Pets 104 Mrs. Mackenzie Stewart’s Cattery 105 The Imitation Tree, Mrs. Clarke’s Cattery 106 Mrs. Clarke’s Cattery 107 The Hon. Mrs. McLaren Morrison 108 Mrs. Collingwood and “James II.” 109 A Morning Meal at Bossington 111 Black Persian “Johnny Fawe” 112 “Champion Menelik III.” 113 Kitten Bred by Miss Kirkpatrick 115 Mrs. Little’s Black Persian “Colleen” 115 The Carol Singers 116 “Jungfrau” 118 Mrs. McLaren’s White Persian “Ladysmith” 119 Mrs. Pettit with her White Persians 121 “Crystal” 122 “White Butterfly” 123 “Musafer” 124 “Jack” and “Jill” 125 The Artist 128 Blue Kittens bred by Miss Kirkpatrick 129 Mrs. Robinson’s Blue Kittens 129 Mrs. Wells’s Cattery 130 “Rokeles Kissi” 131 Scared 132 Cast of the Cat Club Medal 133 Miss G. Jay’s Cattery 134 Rev. P. L. Cosway’s “Imperial Blue” 135 “_Un Saut Périlleux_” 136 “Jack Frost” 137 “Star Duvals” 138 “The Absent-Minded Beggar” 138 “Omar” 139 Three Pretty Silvers 140 “Shah of Persia” 141 “Fulmer Zaida” 142 “Troubadour” 143 A Perfect Chinchilla (two views) 145 Mrs. Balding’s “Silver Lambkin” 146 Mrs. Balding’s “Fluffie Tod” 147 “Sea Foam” 148 Mrs. Wellbye’s “Silver Lotus” 149 Mrs. Wellbye’s “Silver Dossie” 150 Mrs. Wellbye’s Silver “Veronica” 151 Two Views of Woodheys Cattery 153 “Silver Blossom” 154 “Silver Blossom’s” Two Buds 155 “Wild Tom” 156 “Fur and Feather” 158 “The Silver Lambkins” 159 “Jupiter Duvals” 161 “The Elder Miss Blossom” 162 “Dolly Daydream” 163 “I want to go home!” 164 “The Marquis of Dingley” 165 Miss Leake’s Summer Cattery 166 Silver Tabby Kittens owned by Princess Victoria of Schleswig-Holstein 167 “Beautiful Duchess” 168 Winter Quarters at Dingley Hill 169 In the Studio 171 Miss Cope’s “Starlet” 172 A Pair of Silver Tabbies 173 “Thames Valley Silver King” 174 “Roiall Fluffball” 177 Mrs. Stead’s Smoke Litter by “Ranji” 178 “Jo” and “Tiny” 178 Miss Bartlett’s Two Smoke Kittens 179 Mrs. James’s Cat Houses at Backwell 181 Mrs. Stead’s Smoke Persian “Champion Ranji” 182 “Champion Backwell Jogram” 183 Mrs. Sinkins’ Smoke Persian “Teufel” 185 “Lucy Claire” 186 Mrs. Singleton’s “Orange Girl” 187 “Puck” 188 “Swagger” 188 “Benjamin of the Durhams” 189 “Torrington Sunnysides” 190 “Lifeguard” 191 One of Mrs. Neate’s Outdoor Catteries at Wernham 192 “Curiosity” 193 Mrs. Neate’s Cat Houses (two views) 194 “Musing” 197 “Out in the Cold” 199 “Higher Education” 200 Mrs. Clinton Locke’s Cream Kitten 201 A Creamy Smile 201 Mrs. Norris’s Cream Kitten 202 “Kew Ronald” and “Kew Laddie” 203 Miss Beal and her Kittens 204 Mrs. D’Arcy Hildyard’s Cream Kittens 204 “Miriam of the Durhams” 205 “Champion Romaldkirk Admiral” 206 Mrs. F. Western’s “Matthew of the Durhams” 207 “Topsy of Merevale” 208 Miss H. Cochran’s Tortoiseshell “Brunette” 209 Miss Sargent’s “Topsy” 210 Miss Kate Sangster’s “Royal Yum Yum” 211 “Peggy Primrose” 212 Miss Yeoman’s “Mary II.” 213 “At Home” 214 Miss Simpson’s “Persimmon” 215 Miss Mellor’s “Lady Sholto” 216 “Champion Crystal” (American) 217 A Room in Brayfort Cattery 218 Miss Whitney and her Neuter Brown Tabby 219 “Brayfort Princess” and “Brayfort Fina” 220 “Lonsdale Chrysalis” and “Lonsdale Moth” 221 Mrs. D’Arcy Hildyard’s “Sulpherland” 222 “Pioneer Bobs” 223 “Lorna Doone” 225 “Birkdale Ruffie” 226 “Birkdale Ruffie’s” Cattery 227 Brown Tabby “Goozie” 229 A Trio of Tabbies 230 A Picturesque Group 231 A Grotesquely-marked Kitten 232 “Lockhaven Colburn” 233 “The Conquest of the Air” 234 “Grace before Meat” 235 “Marcus Superbus,” a Silver Smoke 235 “Blue Robin” 236 Miss Kirkpatrick’s “Chili” 237 “King Cy” 237 Miss Chamberlayne’s “Belvedere Tiger” 238 “Benoni” 239 Miss Adamson’s Chinchilla Neuter 240 “Nigel the Raven” 241 Madame Portier’s Neuter “Blue Boy” 242 Rascals 243 Type of Manx Kitten 244 “Golfsticks” 245 Specimen of a Manx Tabby 246 Orange Manx 248 Mrs. H. C. Brooke’s Manx “Katzenjammer” 249 “Ballochmyle Bell Spitz” 250 Manx Cat 251 Mr. Ward’s Manx “Silverwing” 253 A Litter by “Tachin” 254 The Garden Cattery at Bishopsgate 255 Mrs. Roberts Locke, with “Calif,” “Siam,” and “Bangkok” 256 “Si” 257 “Tiam-o-Shian” 257 “It” 258 Mr. Ratcliffe’s Siamese 259 Lady Marcus Beresford’s “Ursula” 260 Miss Armitage’s “Cora” 262 Pair of Siamese belonging to Mrs. Armitage 263 Mrs. Robinson’s “Ah Choo” 265 “Champion Wankee” 265 “Mafeking” 266 The late “King Kesho” 267 Lady Marcus Beresford’s “Cambodia” 268 Pugs Paying a Visit to the Siamese, Mrs. Hawkins’ Cattery 269 “Romeo” and

"Juliette" 271 A Cosy Corner 273 "Ashbrittle Peter" 274 "Ballochmyle Blue Queen" 275 Mrs. Carew Cox's Blue male "Bayard" 276 "Sherdley Michael" 277 "Sherdley Alexis" 277 "Sherdley Sacha I." and "II." 277 Maria 278 Mrs. Carew Cox's "Yula" 279 Lady Alexander of Ballochmyle 280 "Champion Ballochmyle Brother Bump" 281 Short-haired Tabby Kittens 282 Another View of Lady Decies' Cattery 283 Lady Decies' "Champion Xenophon" 284 An American Begging Cat 285 "Ebony of Wigan" 286 Sleeping and Waking Tabbies 287 A Black-and-White Britisher 288 "Champion Ballochmyle Otter" 289 "Champion Ballochmyle Perfection" 290 Mrs. Barker's "Tyneside Lily" 291 Two Views of Briarlea Catteries 292 A Corner of the Bossington Catteries 293 Tortoiseshell Male "Samson" 294 Mrs. A. M. Stead's Brown Tabby 295 Mrs. Collingwood's "James II." 295 "Ben My Chree" 296 Burmese Cat 297 Mexican Hairless Cats 299 African Cat 300 Manx and Abyssinian 301 Geoffroy's Wild Cat 302 "The Storm King" 303 "Rado" 303 The Old Fort Cattery 305 Mrs. Colburn and her White Persian "Paris" 306 Brushwood Cattery 307 Miss Johnston's "Persimmon Squirrel" 308 A Reception Room in a Chicago Cattery 309 Mrs. E. N. Barker 311 "Silver Hair" and "Tiptoe" 312 Miss Ward's "Robin" 313 Three Little Grandchildren of "Persimmon" 314 An American Beauty 317 "Champion Miss Detroit" 318 "The Commissioner" 319 "Ajax" 321 Orchard Ridge Cattery 322 Mrs. Charles A. White 323 "The Blessed Damozel" 324 "Tobey," a Maine Trick Cat 325 "Henessey" 326 "Blue Danube" 327 "Leo," owned by Mrs. Martin 329 "Yellow H. 14th Beauty" 330 Mrs. Bagster's "Demidoff" 331 A Snapshot 332 Amateur Photographers 334 Playing at Work 335 In the Studio 336 Tabitha's Afternoon Tea 337 A Happy Mother 338 Mrs. Bonny's "Dame Fortune" 339 "Derebie" 339 A Litter of Eight belonging to Miss Savery 341 "Star of the Spheres" and "Son of Roy" 342 The Foster-Mother 343 The Foster-Mother in Action 343 "Arrived Safely" 344 "Patricia" 345 Miss Goddard's Pair of Kittens 346 "Lollypop" 347 Three Little Americans 348 "Holmlea Thistledown" 349 Brain of Cat 350 Skull of the Great Sabre-toothed Cat 351 Superficial Flexor Tendons of a Cat's Left Foot 352 Bones and Principal Ligaments of a Cat's Toe 352 Pads of Cat's Left Fore-foot 352 Skull of a Cat 353 Skeleton of a Cat 354 Skeleton of a Cat 355 A Cat's Eye 356 Tongue of a Cat 357 Giving Medicine 358

INTRODUCTION

Fanciers have long felt the want of a work dealing in a popular manner with cats, and it was therefore with great pleasure that I undertook to write THE BOOK OF THE CAT, and to give the results of a long experience in as simple and interesting a form as possible, so that the book might be instructive to cat fanciers, and also readable to that portion of the community which loves cats for themselves and not only for their prizes and pedigrees. It is possible that the beautiful reproductions in this work may result in the conversion of some cat haters, who, seeing the error of their ways, may give poor puss a corner in their hearts. Dogs are more essentially the friends of men, and cats may be considered as the chosen allies of womankind.

In the past, as I have endeavoured to show, many noted celebrities of the sterner sex have shown a sympathetic feeling for the feline race. At the present time the number of men fanciers on our cat club lists and exhibitors at our shows tends to prove that the cat is gradually creeping into the affections of mankind, even in this busy work-a-day world. I have given a full description of the various breeds, and have suggested advice as to the feeding, housing, and general treatment of cats. The chapters on the management of shows, containing also simple rules for the guidance of exhibitors, will, I trust, prove useful and instructive.

In my work I have received most valuable assistance, for which I am deeply grateful, from Mr. H. Gray, the well-known veterinary surgeon, whose chapter on the diseases of cats will, I am sure, be very interesting to breeders and fanciers. To Mr. H. C. Brooke I must tender my sincere thanks for his chapter on foreign cats, and to Mr. E. N. Barker for his excellent survey of the American cat fancy, and to Mrs. Pierce for her notes on Maine cats. Mr. Robert Holding's chapter on the anatomy of the cat, with its excellent diagrams, forms a valuable addition to the work. To Mrs. S. F. Clarke I am greatly indebted for the number of clever photographs with which she has so kindly supplied me.

To many of my "catty" friends I offer grateful thanks for interesting items, paragraphs, and pretty photographs; and last, but not least, I have to thank that veteran, Harrison Weir, for his kindly encouragement, and I feel I cannot do better than quote from his letter, received on the completion of my work—enclosing a few remarks for my preface:—

"Miss Frances Simpson has kindly dedicated her labour of love, the fascinating BOOK OF THE CAT, to me, and truly the honour is great. Words cannot convey my feelings, but out of its fulness the heart speaketh—Thanks! I carry my mind back to the long, long ago, when the cat was a god or ideal, and worshipped. Then later, 'our gentle Will' called it 'the harmless, necessary cat,' and that it has ever been, and more than that to many. It is a lonely home without a cat; and for awhile—and I hope for long—cats are the fashion. Thirty years ago it was apparent to me that cats were not valued at their true worth, and then I suggested a show of cats! Let anyone try to start anything new, though novelty is said to charm! Many were the gibes, jokes, and jeers that were thrown at me

then. But nothing succeeds like success. Now, if I may without offence say a few words as to present-day shows, it is that they have not answered my expectations. Why? Because particular breeds are catered for and run after. Why such breathless talk all about long-haired cats, be they blues or silvers? This is not cat breeding. I want, I wish, and, if I live, I hope to see far more of the 'harmless, necessary cat' at our shows; for a high-class short-haired cat is one of the most perfect animals ever created.

"Far more I might, and perhaps am expected to add; but my life's work is well-nigh done. He who fights honourably the good fight sinks at last. Miss Frances Simpson has rendered me her debtor; and others, beside myself, will tender her grateful thanks for her work in the cause of the cat and for the welfare of the fancy. Adieu!"

Mr. Harrison Weir's words are precious to me, and now that my "labour of love" is ended I can only re-echo his wish and express a hope that the many pages I have devoted to the "harmless, necessary cat," whose fireside friendship I have enjoyed all the years of my life, may awaken and arouse a greater interest in and admiration for these gentle, complex creatures, who in return for a little understanding will give a great deal of love.

FRANCES SIMPSON.

KENSINGTON, _August, 1903_.

[Illustration:

"WHITE TO MOVE."

Photo: Mrs. S. F. Clarke]

THE BOOK OF THE CAT.

CHAPTER I. CATS OF THE PAST.

[Illustration:

MUMMY OF A CAT.

(_At the British Museum._)]

The origin of the cat has puzzled the learned, and the stock from whence it sprang is still, in the opinion of some, a mystery for the zoologist to solve.

Historians tell us that the feline race came into existence about the same time as the horse. Reference is made to the cat in Sanskrit writings over 2,000 years old, and still earlier records are found in the monumental figures, inscriptions, and cat mummies of ancient Egypt. These carefully-preserved relics of the past assist us in answering the question as to how this least tameable of animals became domesticated.

There are many legends concerning Puss and the manner in which she first sprang into existence. A surprising account of the cat's creation is found in the works of an Arabian naturalist. It is as follows: "When Noah made a couple of each kind of animal enter the Ark, his companions, as well as the members of his family, said to him, 'What security can there be for us and for the animals so long as the lion shall dwell with us in the same vessel?' The patriarch betook himself to prayer and entreated the Lord God. Immediately fever came down from Heaven and seized upon the king of beasts, so that tranquility of mind was restored to the inhabitants of the Ark. But there was in the vessel an enemy no less harmful—this was the mouse. The companions of Noah called his attention to the fact that it would be impossible for them to preserve their provisions and their clothes intact. After the patriarch had addressed renewed supplications to the Most High, the lion sneezed, and a cat ran out of his nostrils. From that time forth the mouse became so timid that it contracted the habit of hiding itself in holes."

[Illustration:

THE GOD CAT.

(_From an old Wood-cut._)]

So runs the legend, and in an old Italian picture representing the departure from the Ark we may observe a big brindled cat leading the procession of animals with an air of dignity and self-satisfaction. According to the Arabic scholar Damirei, there was no cat in the Garden of Eden. It is a singular fact that nowhere in the canonical books of the Old Testament nor in the New Testament is the cat mentioned, and if we take into consideration the number of books connected with the life, manners, customs, and religions of the Egyptians, this omission is the more striking. The only Biblical reference to cats occurs in the Book of Baruch, chap, vi., v. 22. This is a letter by Jeremy to the Children of Israel, who were taken captive by Nebuchadnezzar to Babylon. Some Hebrew scholars have asserted that the animals that prowled and cried among the ruins of Babylon were jackals, and not cats.

But however much the origin of the feline tribe is wrapped in mystery, we are certain that more than 3,000 years ago the cat lived and was loved along the banks of the Nile. The ancient city of the Pharaohs paid her homage; she was admitted into the ranks of sacred animals, she was worshipped in the temples. Jewels were placed in her ears and necklaces about her neck. Figures of cats were kept in the home and buried in the tomb. Trinkets representing both the goddess and the cat were worn upon the person, to indicate special devotion on the part of the wearer.

There seems but little doubt that the ancient and well-beloved cat of the Egyptians was a barred or marked animal, answering to some extent to our homely tabby. Paintings and statuettes of this type frequently occur, and therefore we may it take for granted that the Egyptians, who were so realistic and true to Nature when dealing with the animal world, would have presented cats of other species had they existed.

According to the historian, animal worship was first introduced into Egypt by Chores, the second king of the Second Dynasty.

[Illustration:

AN EGYPTIAN WALL-PAINTING: THE ADORATION OF THE GODDESS PASHT.

(_British Museum._)]

The Egyptians made gods of many living creatures of all kinds, amongst others the bull, the crocodile, the ibis, the hawk, the beetle, and the asp; but the cat appears to have held the highest place in their hearts. Not only was it preserved from injury, beloved and venerated during life, but at its death it was buried with all respect, and everyone mourned for it with outward and visible signs of grief, even to the extent of shaving off their eyebrows. The Egyptian's idea of a correct burial involved mummification, so that all the parts might be preserved and thus kept from annihilation against the day of resurrection. A rich man's cat was very elaborately mummified. Different-coloured stuffs were twisted round and round the body, forming curious patterns in two colours. The head would be carefully encased and sometimes gilded; the ears were always standing upright. These curious mummies look something like bottles of rare wine done up in plaited straw. Sometimes the mummy would be enclosed in a bronze box with a statue of a cat seated on the top. Mummies of cats with painted faces have been found in wooden coffins at Bubastes, Speos, Artemidos, Thebes, and elsewhere. Here is an illustration of a kitten brought to me from the Boulak Museum. The picture gives but little idea of the care and neatness which must have been employed in wrapping up the dear little dead bodies. The linen used is of the finest. The ears of the tiny kitten are each separate and distinct, and the muzzle of the creature shows distinctly through the delicate wrappings. Scarcely a good museum in the country now that has not some specimens of cat mummies. In some of these we notice that eyes have been added after the mummy has been encased and the embalmment completed. Most of the cats that died in the far-away time were thus embalmed and sent for burial to the holy city of Bubastes, near Thebes, on the banks of the Nile.

[Illustration:

MUMMIFIED KITTEN.

(_In the possession of Miss Simpson._)]

The Temple of Bubastes, according to Herodotus, was the fairest in all Egypt, and here special reverence was paid the cat. The local goddess of this city was Pasht, who was represented as a woman with a cat's head. Cats were kept in the temples sacred to them, and doubtless the head cat of the Pasht's temple was a very splendid specimen, who, living the life of great luxury, would be buried with the pomp and magnificence of a royal personage.

[Illustration:

THE WORSHIP OF PASHT IN THE TEMPLE OF BUBASTES.

(_British Museum._)]

[Illustration:

A CAT GOD OF EGYPT.

(_From the British Museum._)]

It was at Bubastes, on the banks of the Nile, that an annual festival in honour of the goddess Pasht was held. We are not told whether the cats took any part in the proceedings. From the towns and villages within hail, pleasure parties were sent in boats up and down the river to the city, and on their passage the men and women who crowded these boats made merry all the long summer day. The women clashed their cymbals and danced, and the men played on their flutes. Seventy thousand people, it is said, assembled at this feast, and they sacrificed victims and drank a good deal of wine. Perhaps the cats were treated to an extra dish of some dainty to mark this red-letter day in the annals of their patroness and goddess.

A curious custom, which probably had its origin in these pilgrimages to the sacred shrine, had until recent years survived amongst the Egyptian Moslems, who when they were starting on their way to Mecca always set apart one camel for the conveyance of several cats, and some ancient dame was told off to take charge of the precious animals. She was honoured with the title of "Mother of Cats." Her office was not an enviable one, and probably it was found that a woman was unable to wrestle satisfactorily with the refractory travellers, for at a later date a man was substituted to carry the pussies to the Holy City.

[Illustration:

PUSS AS A RETRIEVER: AN EGYPTIAN WALL-PAINTING.

(_At the British Museum._)]

Thebes appears to have been a favourite burying-place for cats, and also a place called Beni Hasan, one hundred miles from Cairo. A few years ago some excavations were made near this town, and thousands of little mummied bodies were found that had rested peacefully for centuries. Their graves were desecrated, their burying ground plundered, and tons and tons of mummied forms were carted away to the neighbouring fields to serve the useful, if not romantic, purpose of manure! According to Horopollo, the cat was worshipped in the temple of Heliopolis, because the size of the pupil of the animal's eye is regulated by the rising and waning of the sun. Plutarch, however, states in his treatise on "Isis and Osiris" that the image of a female cat was placed at the top of the sistrum as an emblem of the moon. "This," says the historian, "was on account of the variety of her fur, and because she is astir at night; and furthermore, because she bears firstly one kitten at a birth, and at the second two, at the third three, and then four, and then five, until the seventh time, so that she bears in all twenty-eight, as many as the moon has days. Now this, perchance, is fabulous, but 'tis most true that her eyes do enlarge and grow full at the full moon, and that on the contrary they contract and diminish at the decline of the same."

Among other fables of classic naturalists and historians may be mentioned the following by Herodotus: "If a fire occurs, cats are subject to supernatural impulses; and while the Egyptians ranged in lines with gaps between them, are much more solicitous to save their cats than to extinguish the fire, these animals slip through the empty spaces, spring over the men's shoulders, and fling themselves into the flames. When such accidents happen, profound grief falls upon the Egyptians."

Whether these frenzied cats did or did not commit suicide is open to doubt, but that they would plunge fearlessly into water is an acknowledged fact. This is attested by paintings representing sporting scenes in the valley of the Nile. Men and women used to go out on fowling excursions in a boat to the jungles and thickets of the marsh land, or to lakes in their own grounds, which abounded with wild fowl, and there among the tall reeds knock down the bird with a stick. Into these happy hunting grounds they took a cat who would jump into the water and retrieve the game as it fell. There is a painting taken and brought from a tomb in Thebes, which is now in the British Museum, and Wilkinson, in his "Manners and Customs of Ancient Egyptians," writes as follows: "A favourite cat sometimes accompanied the Egyptian sportsmen on these occasions, and the artist intends to show us, by the exactness with which he represents the animal seizing the game, that cats were trained to hunt and carry the water-fowl."

[Illustration:

AN EGYPTIAN TOY CAT.

(_At the British Museum._)]

One of the earliest representations of the cat is to be found in the Necropolis of Thebes, which contains the tomb of Hana, who probably belonged to the Eleventh Dynasty. There is a statue of the king standing erect, with his cat Bouhaki between his feet. The large basalt statues, of which there are so many in the British Museum, both seated and standing, are examples of great interest. They have mostly the disc of lunar divinity above their heads and the royal asp above the forehead.

M. Champfleury, in his delightful book, "Les Chats," gives a good deal of information regarding the cats of ancient Egypt, and mentions the existence of funerary statues of women which bear the inscription Techau, the cat, in token of the patronage of the goddess Bast. Frenchmen occasionally call their wives _ma chatte_ without attaching any hieratic association to that term of endearment.

According to ancient documents in the Louvre, we are enabled to surmise the name by which the cat was known in Egypt. It was Mau-Maï, Maau, or Maon. A tablet in the Berlin Museum, bearing the representation of a cat, dates from 1600 B.C., and another, two hundred years older, has an inscription in which the word "Mau" appears.

Amongst old Egyptian images in bronze and earthenware, we may often find the cat crouching with the symbolic eye, emblem of the sun, engraved upon its collar. In the British Museum there is a curious example of a toy in the shape of a wooden cat with inlaid glass eyes and a movable lower jaw well lined with teeth.

There is a tradition that Cambyses devised a scheme for the capture of the town of Peluse, which, if true, is one example among many of the devotion of the Egyptians to cats. It was in the fourteenth year of his reign that this king of Persia tried to effect an entry into Egypt, and he is said to have hit upon a clever strategy. Knowing that the garrison of the town was entirely comprised of Egyptians, he put at the head of his army soldiers each carrying in their arms a cat. The Egyptians, alarmed lest they might injure the sacred animals when destroying their enemies, consented rather to be vanquished. But for their scruples they might perhaps have repulsed the invaders, for the Persian soldiers could not well have done their share of the fighting while clasping in their arms restless and terrified cats!

It is strange that the cat was almost neglected by the Greeks and Romans. It is true that Grecian art working on such grand sweeping lines might fail to follow the insignificant yet graceful curves of the cat. Therefore no Greek monument is adorned with a figure of the idol of Egypt, and Homer never gives a passing mention of the cat. Among the Greeks the cat was sacred to the goddess Diana. Mythologists pretend that Diana created the cat in order to throw ridicule upon the lion, an animal supposed to have been called into existence by Apollo with the intention of frightening his sister. This he followed up by producing a mouse, which Hecate's cat immediately ate up. A cat was often emblazoned on the shields and flags of Roman soldiers. That the cat was known at an early period in Italy we have proof in the curious mosaic in the Museum at Naples, which depicts one pouncing upon a bird. The date of this has been fixed at about one hundred years prior to the Christian era. In the Bordeaux Museum there is a tomb of the Gallo-Roman period with a representation of a girl holding a cat in her arms and with a cock at her feet. In those days the playthings and domestic animals belonging to children were buried with them.

From some of the oldest Indian fables we learn that the cat was domesticated in that country at a very early period. Her first appearance into China would seem to have been about 400 A.D. There is a curious ancient Chinese saying to the effect that "A lame cat is better than a swift horse when rats infest a palace."

Amongst the curious freaks in the natural world are mineral _lusus_. These are stones, agates, or marbles, which, by the action of the soil, air, or water during thousands of years, have assumed various forms, which we may interpret to represent human heads, trees, animals, and so forth. This illustration of a mineral _lusus_ is taken on a reduced scale from a book by Aldrovandus, an Italian naturalist of the seventeenth century. The figure of the cat occurs, he says, in a slab of marble. It was also reproduced by Athanasius Kircher, the Jesuit, who copied many of Aldrovandus's engravings.

[Illustration:

A MINERAL LUSUS.

(_From an old Engraving._)]

I think the most casual observer would pronounce this illustration to be the representation of a cat; and if, as we are led to believe, this and other figures are really the result of natural causes, we can only marvel at the wonderful correctness of outline and form in which through countless ages the substances comprising the specimen have arranged themselves.

We have no record that the cat became domesticated in Great Britain and France before the ninth century, when it would seem that she was by no means common, and considered of great value; for in the time of one of the old Princes of Wales, who died in 948, the price of a kitten before it could see was fixed at a penny, after it had captured a mouse, twopence; and if it gave further proofs of its usefulness it was rated at fourpence. This same prince, Howel the Good, issued an order that anyone who stole or killed a cat that guarded the prince's granary was to forfeit a milch ewe, its fleece, and lamb, or as much wheat as when poured on the cat suspended by its tail (the head touching the floor) would form a heap high enough to cover the top of the tail.

This is not only curious, as being an evidence of the simplicity of ancient customs, but it goes far to prove that cats were not aborigines of these islands. The large price set on them—if we consider the high value of specie at that time—and the great care taken of the improvement and breed of an animal that multiplies so quickly, are almost certain proofs of their being little known at that period. No doubt wild cats abounded in our islands, and this creature is described by Pennant as being three or four times as large as the house cat. The teeth and claws are, to use his expression, "tremendous," and the animal is altogether more robust. The tail of the wild cat is thick and as large at the extremity as it is in the centre and at the base; that of the house cat tapers to the tip. This ferocious creature, well named the British tiger, was formerly common enough in the wooded and mountainous districts of England, Scotland, and Wales, but owing to the attention paid to the preservation of game it has gradually become almost if not entirely exterminated. In olden times, when wild cats were hunted and captured, the principal use they were put to was to trim with their fur the garments of the ladies in the various nunneries scattered over the land. A writer of the Middle Ages says: "The peasants wore cat skins, badger skins, &c." It would appear that lambs' and cats' skins were of equal value at that period.

Harrison Weir, in his work on cats, tells us that in 1871 and 1872 a wild cat was exhibited at the Crystal Palace by the Earl of Hopetoun; he also mentions that as late as 1889 Mr. Edward Hamilton, M.D., writing to the _Field_, gives information of a wild cat being shot at Inverness-shire. He states: "A fine specimen of a wild cat was sent to me on May 3rd, trapped on the Ben Nevis range. Its dimensions were: from nose to base of tail, 1 foot; height at shoulders, 1 foot 2 inches." In July, 1900, a paragraph to the following effect appeared in the _Stock-Keeper_:—

"The Zoological Society have just acquired a litter of wild cats. This is the only instance where a whole litter has been sent to the Gardens. It was taken not far from Spean Bridge, Inverness-shire."

[Illustration:

PUSS IN WARFARE (_vide p. 8_).

(_From a 16th Century MS._)]

The late Professor Rolleston, in an article on the "Domestic Cats of Ancient and Modern Times" (_Journal of Anatomy and Physiology_), has well explained much of the confusion about cats in former writers and their so-called interpreters. He shows how loosely now, as long ago, the word "cat" and its classic equivalents may be employed. Just as we still speak of civet cats and martens. Up to the beginning of this century the wild cat was wrongly thought to be the original of the tame species. Yet apart from more exact evidence this is shown to be an error if we note the value set upon domestic cats in former centuries. The Rev. Dr. Fleming, in his "History of British Animals" (1828), points out some of the distinctions between the two species. He also alludes to the spotted variety, termed the Cypress Cat, as noticed by Menet, who wrote the earliest book on British Natural History in 1667.

"It is a curious fact," says Mr. J. E. Herting, an eminent naturalist, "that in Ireland, notwithstanding reports to the contrary, all endeavours to find a genuine wild cat have failed, the so-called 'wild cat' of the natives proving to be the 'marten cat,' a very different animal."

In the early Middle Ages, according to tradition, cats were utilised in a strange manner. The illustration on p. 7 depicts a German fortress which it was desired by the enemy to set on fire. Not being able, one may suppose, to effect this by treachery, the foes pressed into their service both biped and quadruped. On the back of the pigeon and cat alike, a flask of inflammable matter is attached, and furnished with a time fuse to ignite at the proper moment. There is a broad road for the cat to travel, and we must presume that the gate of the fortress was left open for her entrance. The pigeon would be supposed to cut the cord of the flask with her beak when just over the magazine and let it drop at an auspicious moment. This cut is reduced from a coloured drawing in an unpublished manuscript volume dated 1575, in which is a great variety of illustrations of fireworks for war and recreation.

It is strange that the cat, which was an object of worship and adoration to the Egyptians, should, during the long, dark years of mediæval history, be looked upon as a diabolical creature. The only pleasant legend handed down to us from the Middle Ages is that of "Dick Whittington and his Cat." There are records to show that this worthy citizen was thrice Lord Mayor of London, and we have always been led to believe that it was to his cat he owed his wealth and prosperity. At all events, so long as London is London, Whittington will ever be associated with his cat.

Innumerable are the legends that gather round the cat during the Middle Ages. It was believed that the devil borrowed the coat of a black cat when he wished to torment his victims. Sorcerers pretended to cure epilepsy by the help of three drops of blood taken from the vein under a cat's tail. At numerous trials for witchcraft, puss figured as the wicked associate of the accused. Cats were offered by sorcerers as oblations to Satan, and they were flung into the fire at the Festival of St. John. All praise to Louis XIII., who as the Dauphin interceded for the lives of these poor pussies thus annually sacrificed. It was thought to bring good luck to a house if a cat were cooked alive in a brick oven, and in Scotland she was roasted before a slow fire as a means of divining the future.

The mania of witchcraft had pervaded all ranks, even the holy profession, whose duty it should be to preach peace and goodwill. Hundreds of wretched old women were sent out of life "in a red gown" (the slang of that day for being burnt "quick" or alive), after undergoing the most excruciating tortures to make them confess the impossibilities for which they suffered.

In 1591, when King James of Scotland was crossing from Denmark, a great tempest arose at sea. This was supposed to have been caused by a "christened cat" being placed in the vessel by witches. The following is an extract from an old pamphlet: "Againe it is confessed that the said christened cat was the cause that the Kings Majestie's shippe had a contrarie wind to the rest of the shippes in his companie, for when the rest of the shippes had a fair and good winde, then was the winde contrarie and altogether against his Majestie." Thus, in the past as in the present day, blame was laid upon the poor harmless puss, where no blame was due.

In an old book called "Twenty Lookes over all the Roundheads of the World," published in 1643, we read:—

[Illustration:

A GROUP OF CATS IN POTTERY.

(_From Figures in Cases at the British Museum._)]

"In the Reigne of Queene Mary (at which time Popery was much exalted) then were the Roundheads (namely, the monks and friars) so odious to the people, that in derision of them a cat was taken on a Sabbath day, with her head shorne as a Fryer's and the likeness of a vestment cast over her, with her feet tied together, and a round piece of paper like a singing Celse between them; and thus was she hanged in a gallows in Cheapside, neere to the Crosse, in the Parish of St. Matthew. Which cat, being taken down, was sent to Doctor Pendleton (who was then preaching at St. Paul's Cross), commanding it to be shown to the congregation. The Round-head Fryers cannot abide to heare of this cat."

At the coronation of Elizabeth there is an account given, in the Hatton correspondence, of an effigy of the Pope being carried through the streets and afterwards burnt with several live cats, which, we are told, "squalled in a most hideous manner" as soon as they felt the fire.

After a famous French trial in the seventeenth century, a woman condemned as a murderess was hung in an iron cage over a slow fire, and fourteen poor unoffending cats were made to share the same fate. It is difficult to conceive by what train of thought civilised beings could arrive at such a pitch of wicked and horrible cruelty. Why should a gentle, shrinking, graceful little creature be thus made the savage sport of devils in human form?

There seems, however, to have been one haven of rest for poor persecuted pussy during the Middle Ages, and that was in the nunneries. Here, at least, she would be kindly treated, let us hope. It is said that this fact has something to do with the cat's traditional association with old maids.

And now let us quit this dark page of history, where the shameful treatment of an innocent race makes the lover of the poor pussies sorrowful and indignant. It was in France that, after the period when the cat was given over to the ways of the witch and the sorcerer, we find her yet again taking her proper place in the home and the heart of the highest in the land. Writers of natural history and others frequently denounce the cat as an animal incapable of personal attachment, yet puss has wooed and won the friendship

and affection of many notable men.

Cats, the most politic, the most polite, and in proportion to their size the most powerful of beasts—realising almost literally Napoleon's favourite maxim, "Iron hand in velvet glove"—have the permanent fame of being loved by that most eminent of Frenchmen, Cardinal Richelieu, who delighted to watch the frolics of a number of kittens by which he was generally surrounded in his leisure hours. In this _tendresse_ he resembled a still more famous Churchman! A cat went to sleep once, we are told, on the sleeve of Mahomet's robe. The hour of prayer arrived, and he chose rather to cut away his sleeve than to disturb the slumbers of his beloved Muezza.

[Illustration:

TOMB OF A CAT WHICH BELONGED TO MADAME DE LESDIGUIÈRES.]

Chateaubriand makes frequent mention of the cat in his "Memoires." He received a present of a cat from the Pope. Moncrieff wrote a series of quaintly worded letters on cats, and the book has some curious illustrations. In this we read of the pussies of many grand dames of the French Court of that day. We give an illustration taken from this book, which represents the tomb of a cat which belonged to Madame Lesdiguières, and bears this inscription:—

UNE CHATTE JOLIE. Sa maitresse qui n'aima rien L'aima jusques à la folie. Pourquoi le dire? On le voit bien.

Moncrieff had to suffer an immense amount of ridicule on account of his charming "Lettres sur les Chats," which the author himself calls "a gravely frivolous book." Victor Hugo had a favourite cat he called "Chanoine," and Gautier's cat slept in his bed, and always kept him company at meals. Petrarch loved his cat as he loved his Laura. Dr. Johnson used to indulge his cat Hodge with oysters, which he would go out himself to purchase. Chesterfield provided for his cat in his will. Sir Walter Scott's love of dogs did not prevent him delighting in the company of a "conversable cat," and Hunse, of Hunsefield, seems to have possessed a large share of the great man's affection, and when he died his master wrote thus to Richardson: "Alack-a-day! my poor cat, Hime, my acquaintance, and in some sort my friend of fifteen years, was snapped at even by that paynim, Nimrod. What could I say to him, but what Brantôme said to some _ferrailleur_ who had been too successful in a duel: 'Ah, mon grand ami, vous avez tué mon autre grand ami.'" Amongst famous French novelists several have been cat lovers, especially Dumas, who in his "Mémoires" makes notable mention of "Le Docteur." Cowper, Shelley, Wordsworth, Swinburne, and Matthew Arnold all wrote lovingly of cats. But Shakespeare, although he makes forty-four distinct mentions of cats, never has a good word for poor pussy. In "All's Well that Ends Well" he gives vent to his dislike. Bertram rages forth:—

"I could endure anything before me but a cat, and now he's cat to me."

In "Cymbeline" occurs this passage:—"In killing creatures vile as cats and dogs"; and in "Midsummer Night's Dream" Lysander is made to exclaim:—"Hang off, thou cat, thou burr, thou vile thing."

Romeo cries out:—

"Every cat and dog And little mouse, every unworthy thing."

From these quotations alone we may infer that, at any rate, dogs and cats were not favourites with the great bard. There is only one mention of cats in Dante. He compares to cats the demons who, with their hooks, claw the "barterers" (_i.e._ abusers of their office as magistrates), when these sinners try to emerge from the hot pitch wherein they are punished. He says of one of these wretches:—"Tra male gatte era venuto il sorco." (_Inf. XXII._, 58.) Translation:—"Among wicked cats the mouse came."

In the "Westlosthcher Divan" of Goethe, written in his old age, but full of youthful spirit and of the freshest allusions to Eastern things, the cat is called one of the four "favoured beasts," _i.e._ animals in a state of grace, admitted into Paradise, in a verse very near the end of the poem, which being literally translated, reads thus:—

"This cat of Abuherriras" (a friend of the prophet Mahomet) "purrs about the Lord, and coaxes. Since he is ever a holy beast whom the Prophet stroked."

Robert Liston, who, as everyone knows, was the leading London surgeon in the middle of the nineteenth century, was passionately attached to his cat, and used to introduce it to his guests at the dinner parties which, according to the custom of a past generation, he gave his medical friends. On these occasions the cat would gravely walk round the dinner table during dessert to be admired by

the guests in succession, and it once happened that the top of its tail got into the wineglass of Dr. Anthony Todd Thoruson, Liston's famous colleague at University College Hospital. This man promptly struck the animal. Liston was so enraged that he started from his seat and denounced his guest in language more forcible than elegant.

Jeremy Bentham, who introduced by their names to Lord Brougham the cats seated on chairs round his table, deserves honour, not only as the foremost of modern jurists but also because, in his "Principles of Morals and Legislation," he had expressed better than others the claims of brutes to kind treatment.

The great scholar and eminent writer, St. George Mivart, has given the world a wonderfully comprehensive work on the Cat, and has used the maligned feline as his type for an introduction to the study of back-boned animals. It is he who remarks:—"We cannot, without becoming cats, perfectly understand the cat mind."

[Illustration:

THE CAT IN HERALDRY.

(_From Frank's Collection of Book Plates._)]

Perhaps the unkindest picture given to us of a cat is from the pen of the naturalist Buffon. "The cat" (says this unsympathetic student) "is an unfaithful animal, kept only from necessity in order to suppress a less domestic and more unpleasant one, and although these animals are pretty creatures, especially when they are young, they have a treacherous and perverse disposition, which increases with age, and is only disguised by training. They are inveterate thieves; only when they are well brought up they become as cunning and flattering as human rascals."

[Illustration:

THE PRINTER'S MARK OF MELCHIOR SESSA, OF VENICE.

(_From a Print at the British Museum._)]

Chateaubriand, referring to these scathing remarks, says:—"Buffon has belied this animal. I am labouring at her rehabilitation, and hope to make her appear a tolerably good sort of beast."

[Illustration:

A MERCHANT'S MARK.

(_From a Print at the British Museum._)]

A charming reference to the ways of cats occurs in a curious and interesting book by a once famous Jesuit, Father Bougeant, who lived in the first half of the eighteenth century. There is an English translation of this work, which has passed also into other languages and several editions. This is the passage translated:—

"Such is one of those big-whiskered and well-furred tom cats, that you see quiet in a corner, digesting at his leisure, sleeping if it seems good to him, sometimes giving himself the pleasure of hunting, for the rest enjoying life peaceably, without being troubled by the events which agitate us, without tiring his mind by a thousand useless reflections, and little caring to communicate his thoughts to others. Truly it needs only that a female cat (_une chatte_) come on the scene to derange all his philosophy; but are our philosophers wiser on such occasions?"

The cat, as the emblem of independence and liberty, has been used in heraldry, statuary, and signboards. In the sixteenth century a well-known firm of printers named Sessa, at Venice, adopted the device of a cat surrounded by curious ornamentation, and Dibdin in one of his works tells us that whenever you see Sessa's cat you may be sure the book is a good one and worth reading. Ever since the days when the Romans carried on their banners the design of a cat, this combative and courageous animal has been a favourite symbol of warriors and nobles. The wife of King Clovis, Clotilde, had a cat sable upon her armorial bearings, springing at a rat, and on the famous Katzen family's shield was a cat holding a mouse in its mouth. In Scotland the Clan Chattan was known by the emblem of a wild cat with the significant motto, "Touch not the cat, but" (meaning without) "the glove." Their chief was called Mohr au chat, or the great wild cat.

M. Champfleury, dealing with cats in heraldry, tells us that the French Republic resumed heraldic possession of the cat and added it to its glorious shield of arms; and an illustration is given in his book of the republican painter's figure of Liberty holding a pike surmounted with a Phrygian cap, and at her feet is seated a cat.

In past, rather than in present, days the cat was used on signboards, especially in France. We read of "La Maison du chat pelote" (_i.e._ which rolls itself up), and "La Maison du chat qui pêche." In the Lombards' quarter of Paris, "Le Chat Noir" was formerly a familiar figure above restaurants and confectioners. In England we often come across "The Cat and the Fiddle" as a signboard to old country village inns, and in Cassell's "Old and New London" a writer says:—"Piccadilly was the place in which 'The Cat and Fiddle' first appeared as a publichouse sign. The story is that a Frenchwoman, a small shopkeeper, had a very faithful and favourite cat, and that in lack of any other sign, she put over her door the words: 'Voici un chat fidèle.' From some cause or other, the 'Chat Fidèle' soon became a popular sign in France, and was speedily Anglicised into 'The Cat and Fiddle,' because the words form part of one of our most popular nursery rhymes."

[Illustration:

ALICE AND THE CHESHIRE CAT.

From "Alice's Adventures in Wonderland," by Lewis Carroll.

(_By permission of Messrs. Macmillan & Co., Limited._)]

Many are the popular traditions, maxims, proverbs, and superstitions connected with the cat. In olden days her every movement was looked upon as a sign of ill-omen or of good luck. Old nurses would drive a cat out of the bedroom with much significance of manner, that it might not "suck the child's breath." There is a superstition that a cat will not remain in a house with an unburied corpse.

M. Presse d'Aveunes gives an account of a curious cat superstition. "When a woman gives birth to twins, boys or girls, the last born of the two, whom they call 'barecy' (sometimes both), has at times, and it may be all its life long, an irresistible craving for particular eatables; and in order to satisfy more easily its gluttonous desires, it assumes the shape of different animals, and especially that of the cat. During the transmigration of the spirit into another shell, the human body is as a corpse, but when the spirit has satisfied its desires it retakes its proper form."

He continues: "Having one day killed a cat which had made inroads upon my larder, a druggist of the neighbourhood came to me in a great fright and entreated me to spare all animals, for he said he had a daughter who had the misfortune to be a 'barecy,' and that she was often in the habit of assuming the shape of a cat in order to eat the sweetmeats served at my table."

[Illustration:

A STUDY.

(_From the painting by Madame Ronner._)]

Milton tells us "that when the cat washes her face over her eares, we shall have a great store of raine." A cat sneezing is supposed to bring luck to a bride on her wedding day. Sailors have in all times been prone to superstition as regards cats. A black cat's appearance on the ship foretells disaster, but if a cat should disappear overboard the greatest consternation is caused amongst the crew.

Very plentiful are the nursery rhymes, fairy tales, and stories concerning cats—a good-sized book would not contain them. "The cat," says M. Champfleury, "is the nurse's favourite and the baby's earliest friend. It plays its part in little rhythmical dramas, cunningly presented to the drowsy child, who falls asleep with a familiar image parading fantastically through his brain." French nursery rhymes are much prettier than English. For instance, this bald and commonplace statement is not calculated to catch the attention of the juvenile mind:—

"Great A, little A, bouncing B, Cat's in the cupboard, and can't see me."

How much softer and daintier are the following lines:—

"A, B, C, Le chat est allé Dans la neige; en retournant Il avait les souliers tout blancs."

In passing, I should say it is strange that to the French a cat is always masculine, and to the English feminine.

In the days of good Queen Anne the story of pussy's venturesome journey to London was put into verse, and what child has not listened eagerly to these lines from that time down to our present day?

"'Pussy-cat, Pussy-cat, Where have you been?' 'I've been to London To see the Queen.'

"'Pussy-cat, Pussy-cat, What did you do there?' 'I frightened a little mouse Under her chair.'"

In "Alice in Wonderland" Lewis Carroll has given the world "a childish story" which will never cease to delight both young and old. In this we read of the "Cheshire Cat" which grinned down upon the guests assembled at the royal croquet party, and having incurred the anger of the Queen, was in danger of having its head cut off by order of the infuriated monarch. The other volume by the same author—"Alice Through the Looking-Glass"—opens with a description of the way in which Dinah the cat washed her children's faces:—"First she held the poor thing down by its ear with one paw, and then with the other paw she rubbed its face all over the wrong way, beginning at the nose." Then follows an animated conversation between Alice and the kitten. All the world knows of the love Lewis Carroll had for children, and I can assert he had an affection also for cats, for when a child he spoilt and petted me and my kitten. I only wish I could remember the deliciously impossible stories he was wont to tell me of fairies, goblins, and pussy-cats.

Harrison Weir, in his book on cats, has gathered together a number of curious cat proverbs. Some are very familiar, such as: "A cat may look at a king"; "Care will kill the cat"; "When the cat is away the mice will play," and a very significant one is: "When the maid leaves the door open the cat's in fault." The quaint saying, "When candles are out all cats are gray" is a very expressive one.

When we consider the cat in art, it is among Eastern painters we find the most delicate and skilful studies. Next to the Egyptians, the Chinese and Japanese have excelled in the artistic treatment of animals. In many of the Dutch interiors given to us by Flemish artists, the domestic cat may be seen curled up on the hearth, or sitting erect, bearing somewhat the appearance of being stuffed with bran.

[Illustration:

MADAME RONNER AT WORK.

(_Photo: Alexandre, Brussels_)]

In many of the early Italian sacred pictures we find the cat depicted, but great painters, like Titian, Velasquez, and Murillo, seem to have preferred the dog as an adjunct to their portraits. Raphael and Salvator both considered puss a worthy subject for their brush. In M. Champfleury's interesting book on cats he gives a facsimile from the powerful pencil of Mind, whom Madame Lebrun has termed "the Raphael of Cats." The attitudes are so true to nature that the cat seems alive. Mind was a native of Berne, and in 1809, on account of a scare of madness amongst cats, eight hundred were put to death. This was a heartbreak to the cat-loving painter, who, however, managed to save his favourite pet Minette from the wholesale massacre.

Very quaint reproductions of cats have been made in the following wares: Whieldon, Salt Glaze, Agate, and Staffordshire. With Chinese and Japanese cat figures we are all familiar; they are grotesque rather than beautiful.

Coming down to the cat artists of the present day, we would mention Madame Henriette Ronner, who has justly deserved the great reputation that she has acquired in her own country as well as ours. It is in depicting kittens in their ever-varying moods that Madame Ronner most excels. Whether playing havoc with antique lace, as in "Un Bout de Toilette," scattering an artist's materials, as in "Mischief," or dragging jewels from a casket, her kittens are instinct with vitality, and are portrayed in a manner implying knowledge of their anatomical structure, as well as in a most appreciative perception of their youth and beauty. Most lovers of cats are acquainted with Madame Ronner's artistic volume containing so many faithful and lovely reproductions of several of her best pictures, and an interesting account of her life and work written by Mr. M. H. Spielmann.

Another famous painter of cats is M. Eugène Lambert, who may be said to divide the honours with Madame Ronner in portraying with fidelity and artistic taste the feline race. Among English animal painters we have none who can come anywhere near to these two celebrated French artists in their marvellous delicacy of touch and subtle skill in depicting cat and kittens.

In these latter days who is there amongst us, young and old, who has not enjoyed a hearty laugh over the comical cats of Louis Wain? In his particular line, he is unique, for no one has ever portrayed cats in such various attitudes and with such deliciously expressive countenances. The adjectives and adverbs of the Cataract of Lodore would not suffice to describe the varied emotions

of these funny felines. A Christmas without one of Louis Wain's clever catty pictures would be like a Christmas pudding without the currants!

[Illustration:

"CRYSTAL,"

THE PROPERTY OF MRS. FINNIE YOUNG. (_Photo: C. Reid, Wishaw._)]

To Harrison Weir cats and cat lovers owe a debt of gratitude. He has done much to raise the standard of the feline race, and in his excellent book called "Our Cats," he thus writes in his preface:—

"Long ages of neglect, ill treatment, and absolute cruelty, with little or no gentleness, kindness, or training, have made the cat self-reliant; and from this emanates the marvellous powers of observation, the concentration of which has produced a style analogous to reasoning, not unmixed with timidity, caution, wildness, and a retaliative nature. But should a new order of things arise, and it is nurtured, petted, cosseted, talked to, noticed, and tamed with mellowed firmness and tender gentleness, then in but a few generations much evil that bygone cruelty has stamped into its wretched existence will disappear, and it will be more than ever, not only a useful, serviceable helpmate, but an object of unceasing interest, admiration, and cultured beauty, and thus being of value, it will be profitable."

It was Harrison Weir who instituted and carried out the first Cat Show held at the Crystal Palace in 1871, and since then he has taken an active part in the cat world. Of late years, however, he has been failing in health, and it was suggested that some testimonial should be offered to him in his declining years by his many admirers and cat-loving friends.

Our Cats, that popular weekly publication, opened a list in their columns, the result being a handsome piece of plate, which the veteran F.R.H.S. was asked to accept. In his reply acknowledging the gift, he writes:—"Kindest and best wishes to those warm-hearted and truly unforgetful friends who have contributed towards the very handsome testimonial." Then he goes on to allude to the first cat show and to his prophecy regarding the growing popularity of the cat family:—"Did I expect the outcome to be what it is? Yes, and no. I fully expected large shows and more of them, and a 'Cat Press,' and in the papers cat columns for the universal and worthy favourite cat. But in another way I am disappointed, and that is for the neglect of the short-haired English cat by the ascendancy of the foreign long-hair. Both are truly beautiful, but the first in intelligence, in my opinion, is far in advance of the latter." Therefore, with a hope that Harrison Weir may yet live to see the English short-haired cats still more widely loved and appreciated, and given better classification at our shows, I will pass on to my chapter on present-day cats and cat clubs, and the many other institutions and societies which are the outcome of the rapid strides that have been made in the cat fancy since the day when Harrison Weir was laughed at by his incredulous and astonished railway companion as they travelled together to the first Cat Show held at the Crystal Palace in 1871.

[Illustration:

LADY ALEXANDER'S "BROTHER BUMP."

CHAMPION SHORT-HAIRED BLUE.]

[Illustration:

SLEEPING BEAUTIES.

(_Photo: Mrs. S. Francis Clarke._)]

CHAPTER II. CATS OF TO-DAY.

The term "Cat" is applied in its widest sense to all feline animals. The following are the various names by which the cat is known in different countries, and it is curious to note that, with two exceptions, they all begin with a "C" or a "K" and differ very little in pronunciation: Irish and Scotch, _Cat_; French, _Chat_; Dutch, _Kat_; Danish, _Kat_; Swedish, _Katt_; German, _Katti_ or _Katze_; Italian, _Gatto_; Portuguese and Spanish, _Gato_; Polish, _Kot_; Russian, _Kots_; Turkish, _Keti_; Welsh, _Cetti_; Cornish, _Katt_; American, _Katz_.

[Illustration:

MISS F. SIMPSON'S "BONNIE BOY."

(_Photo: Gunn & Stuart, Richmond._)]

In the English house and home we call her "puss," and it is the name which appeals most to our hearts. No woman likes to be called a "cat," but to be likened to a puss or pussy is suggestive of something or someone soft and pretty, with gentle, winning ways. Archbishop Whately has said that only one English noun had a true vocative case, "Nominative, cat; vocative, puss." I do not think that in any other country there is a pet name for the cat, just as there is no word in any foreign language that breathes the same tender truth to the hearts as "home." Puss and home! The terms seem so closely connected with each other, and suggest peaceful happiness and restful repose.

Truly, the history of the cat has been a strangely chequered one. Perhaps, because she is such a secret, complex, and independent creature she has remained somewhat of a puzzle to humankind, and is therefore to a great extent misunderstood; but those who will take the trouble to consider the cat and try to understand her, will find that puss is none of those things she has been accused of being. It is only those who are in constant contact with cats who understand how intelligent they really are; although their intelligence is quite in a different mould from that of the dog. I may mention that the household cat outnumbers, it is said, the household dog in London by the proportion of four to one. This fact may be accounted for by the non-taxation of cats. The question of the taxation of cats has very often been raised, and I do not think that anyone who really values his cat would object to pay a yearly tax; but the proposal is as unpractical as it is ridiculous, and it is certain that taxation would not help in exterminating the poor, disreputable, half-starved members of the feline tribe, who have no fixed abode and whose only means of existence is by plunder.

The figure and number nine seems to be an important one in connection with cats. There is a popular saying that a cat has nine lives. The expostulating tabby in Gay's Fables says to the old beldame:—

"'Tis infamy to serve a hag, Cats are thought imps, her broom a nag; And boys against our lives combine, Because, 'tis said, your cats have nine."

Cats probably owe this reputation to their extraordinary powers of endurance, and certain it is that they have a greater tenacity to life than any other animal. At the Battersea Home a dog and a cat have been placed in the lethal chamber, and it was observed that the dog died in five minutes, whereas the cat breathed for forty minutes longer. A short time ago I received the following letter from a cat fancier:—

"At 11 p.m. two kittens, a few hours old, were placed in a pail of water, and left there for rather over ten minutes. Seeing them at the bottom with their mouths open, it was taken for granted they were dead; the bodies were then transferred to the ashpit, and early next morning they were discovered to be alive and quite chirpy. Restoring them to the mother, they have grown nice, strong, healthy little kits, and have just left for comfortable homes."

In Thistleton Dyer's interesting book on "English Folk-lore," reference is made to this subject. "Cats," he says, "from their great suppleness and aptitude to fall on their feet, are commonly said to have nine lives; hence Ben Johnson, in 'Every Man in his Humour,' says, "Tis a pity you had not ten lives—a cat's and your own.'"

"In the Middle Ages a witch was empowered to take cat's body _nine_ times," so writes an eminent old zoologist.

[Illustration:

KITTEN AT WORK AND PLAY.

(_Photo: C. Reid, Wishaw._)]

The "cat-o'-_nine_-tails" is a dreaded object to some light-fingered and heavy-handed miscreants. I have heard a magistrate remark that he considers this form of punishment the best way in which to give hints to the wicked. Garrotting was virtually stamped out by its use. Wife-beating would be less common if the brute-husband were treated to a taste of the cat-o'-nine-tails. This implement of torture consists of nine pieces of cord put together, and in each cord are nine knots. Consequently every stroke inflicts a large number of long and severe marks not unlike the clawing and scratching of a savage cat, producing crossing and re-crossing

wounds.

[Illustration:

KITTEN BELONGING TO MRS. E. S. OWEN, DETROIT, MICHIGAN.

BY "KING OF THE SILVERS"—"BLESSED DAMOZEL." (_Photo: Albany Art Union, New York._)]

In my long and varied experience of cats, I have noticed that more of these creatures succumb to the common enemy at about _nine_ years of age than at any other period. We have heard of cats attaining the age of twenty years, but the following account surpasses all previous records of longevity in the feline world:—

TO THE EDITOR OF THE _Stock-Keeper_,

Sir,—Seeing you have a column in your paper devoted to cats, I thought it might interest your readers to hear that in our village there is a cat thirty-one years old. She is quite lively, and looks like living a few more years. It belongs to a poor widow, who told me she had it as a kitten when she married. (Her husband lived twenty-seven years, and has been dead four.)

Newbury, Bucks. W. B. HERMAN.

It is strange that the poor dead bodies of cats have often been used as objects of foolish and vulgar so-called sport. Dead cats and rotten eggs were, and are sometimes still, considered legitimate missiles to make use of at borough and county elections.

All sorts of stories are related of pussy's superhuman intelligence, but the most uncanny one of very recent date I will refer to here. It may be remembered that in the winter of 1901 a vessel named the _Salmon_ was wrecked. On the morning of the accident, this vessel was lying alongside the _Sturgeon_, and her two cats, who had all their lives shown the most perfect contentment with their home and surroundings, made desperate efforts to get on board the _Sturgeon_. The crew drove them off again and again, and the ship's dog attacked them, but they would not be deterred, and when the _Salmon_ at last cast off, the two cats landed with one frantic and final spring on to the _Sturgeon's_ deck. It seems absurd to argue that those cats knew of the coming disaster, yet why should they take such a sudden and utterly unreasonable aversion to the ship which had always been their home? And why should they insist on making their way to another vessel from which they had been so inhospitably repulsed?

We have many proofs of the extraordinary extent to which a cat's sense of hearing and smell are developed. On my voyage out to Australia flying fish would sometimes fall on to the deck. The cats that are always somewhere about the ship might be comfortably curled up asleep below, but the peculiar sound would fetch them up in a great hurry, and they would rush to secure the prize. The crew used to amuse themselves sometimes by trying to imitate the noise in various ways to deceive them; but the cats were not to be "had"—they could distinguish the peculiar thud of the flying fish from all other sounds.

[Illustration:

THE ANTIQUARIES.

(_From the painting by Madame Ronner._)]

Various theories have been put forward to account for the marvellous instinct which a cat possesses, enabling her to find her way home although miles and miles of untraversed country lay between her and the place from which she has been taken. It is contended that a cat which is conveyed in a bag or blindfolded will have its sense of smell in full exercise, and will, by this means take note of the successive odours encountered on the way, and that these will leave in its mind sufficient information of the route so as to make it an easy matter for the animal to find its way back again. Be this as it may, many of us can state facts which are even stranger than fiction of mysterious reappearances of cats who, with a homing instinct as true as any carrier-pigeon, return to the haven where they would be.

[Illustration:

"KEPWICK VIOLET" and "KEPWICK HYACINTH."

BLUES BELONGING TO THE HON. MRS. MCLAREN MORRISON. (_Photo: J. R. Clarke, Thirsk._)]

The instinct of maternity is, perhaps, more largely developed in the cat than in any other animal. No creature shows such anxiety for the safety and welfare of her offspring as she does, and often her natural timidness will give place to bold and fearless courage when her little ones have been in any difficulty or danger. Mivart tells us of a cat that plunged into a swiftly running stream and rescued her three drowning kittens, bringing them one by one in safety to the shore. During a fire in a London theatre, which took place a few years ago, a poor cat with her family was left forgotten at the back of the stage. Three times the faithful mother rushed into the flaming building and reappeared each time with a kitten in her mouth. But alas! with fatal persistence the devoted creature returned to rescue the remaining one, and that she reached the spot was proved, for after the fire was extinguished, the charred bodies of mother and child were found lying side by side.

A clever writer has stated that "the human race may be divided into people who love cats and people who hate them; the neutrals being few in numbers." This is very true. There are also differences of opinion as to whether cats are desirable inmates of a household or not, but there can be no question as to the great utility of these animals, and it is only natural to suppose that they were created for the purpose of suppressing rats and mice and other vermin. There is a popular notion that if a cat is petted and well fed she will become less useful as a mouser. This is a fallacy, for the cat's inclination is to hunt the mouse or rat, not for food, but for sport, and an animal that is enfeebled by neglect and starvation is not in the best condition to successfully catch its prey. This love of sport is not, however, inherent in all cats, but is hereditary in the feline tribe as it is in the human race.

It may not be generally known that the Government pays annual sums for the purpose of providing, keeping, and feeding numerous "harmless, necessary cats" in their public offices, dockyards, and stores, thereby attesting to the worth and capability of pussy's services.

In the National Printing Office in France a considerable number of cats are employed in keeping the premises clear of rats and mice which would otherwise work havoc amongst the stock of paper always stored in large quantities. In Vienna, cats are placed on active service in the municipal buildings. At many of our great railway stations there is a feline staff engaged in the various warehouses and offices. The farmer will readily admit the usefulness of puss in his barns, stables, outhouses and fields. Farmers are notorious grumblers, but they would have greater cause for discontent and disappointment if rats and mice were allowed to live and thrive, and breed and multiply on their premises. The newly sown peas and corn stacks would suffer to a terrible extent, and the broods of ducklings and chickens would speedily vanish if puss did not keep a vigilant eye and silently but surely fulfil the duties of her calling.

[Illustration:

MISS SAVERY'S BLUE PERSIAN KITTEN.

(_Photo: H. Warschawski, St Leonards-on-Sea._)]

In the live stock department of the Army and Navy Stores in London, an orange Persian cat may be seen strolling about amongst the cages of birds of every sort. The attendant informed me she had been on the premises three or four years, and had saved the company a "tidy sum." Previous to obtaining her services the packets of bird-seed disappeared like magic, for they were demolished wholesale by the swarms of mice. Now rarely one is nibbled, and every morning dozens of lifeless bodies are cleared away. Curiously enough these dead mice have their tails eaten off, for apparently this cat has a weakness for the appendage, whereas, usually the head is considered the delicate morsel amongst the feline race. It seems that although the cat is left alone with all the fluttering birds at night, she never has attempted to molest them in any way.

[Illustration:

A PAIR OF SHORT-HAIRED BROWN TABBIES.

(_Photo: T. Fall, Baker St., W._)]

I lately had occasion to visit one of our London theatres during the daytime, when it was empty; and observing a big brown cat walking about amongst the stalls, I made some remark about him to the official who accompanied me. He said they found it quite impossible to get along without a cat; they had tried, but the place became overrun with mice. During pussy's occupation of the empty playhouse plenty of bodies were discovered, but never a live mouse had been seen disporting itself.

The cats in Government service in America are very numerous. The army has a regular corps of them kept at the commissary depôts of the great cities. It is customary for the officer in charge of each depôt to submit to the War Department a request for an

allowance for the cats of meat and milk. More than three hundred cats are in the employ of the Post Office Department, distributed among about fifty of the largest offices. The New York City office expends sixty dollars annually in cats'-meat. At Pittsburg, there is a "cold storage" breed of cats, which has special qualifications for enduring extreme cold. These cats are short tailed, with long and heavy fur, and their eyebrows and whiskers are extraordinarily long and strong. It is said they do not thrive when transferred to an ordinary atmosphere.

[Illustration:

CAT CALENDAR.

(_By kind permission of Raphael Tuck & Co._)]

The following extract from the _Daily Mail_ of February 1st, 1902, gives us an account of a most exemplary, well trained, and up-to-date cat, and opens up a fresh field for the utility and agility of our domestic pets—not an absolutely fresh field indeed, if one recalls the fact that Puss was already a "retriever" in ancient Egypt.

A PING-PONG CAT.

Hunting for balls is undoubtedly the one great drawback to ping-pong. Might I suggest a novel and easy method of accomplishing this difficult and unpleasant task?

My cat is now an expert in the art of finding ping-pong balls. Immediately the ball touches the floor the cat is after it, and brings it from its hiding-place to the side of the table at which I am playing, thus saving me from unnecessary exertion.

F. S. W.

The thought suggests itself that pussy's teeth and claws might work serious havoc amongst the ping-pong balls, and that some of these would be produced in a mutilated condition.

Of all animals the cat appears most to resent being taught or trained to do tricks. Puss has a natural antipathy to be forced to do anything, or remain anywhere against her will. Hence the few exhibitions of really clever performing cats in comparison with the marvellous feats achieved by dogs. It has been stated that the cat is the hardest animal to teach; it takes years to train a cat to perform some simple trick which a dog would learn in as many weeks. Once a cat is trained, it becomes a very valuable possession. We have all seen the Happy Family, consisting of monkeys, guinea-pigs, canaries, pigeons, and mice, whilst a cat is seated demurely in the midst of this incongruous assembly. No doubt some training was required to cause puss to disregard the natural instincts of her race.

The cat is a most cleanly creature, and perhaps more particular about her appearance than any other animal. As Miss Agnes Repplier, in her delightful book, "The Fireside Sphinx," says: "Pussy's adroitness is equalled only by her delicacy and tact. Her cleanliness and her careful attention to her toilet show respect for herself and for us."

[Illustration:

CAT CALENDAR.

(_By kind permission of Raphael Tuck & Co._)]

One of the strangest and most profitable trades in London is the wholesale and retail business of horsemeat for cats. In barrows and carts the hawkers of this horse-flesh cry their wares throughout the city and suburbs, and find a ready sale for them. It is stated that 26,000 horses, maimed, or past work, are slaughtered and cut up every year to feed our household pets. Each horse means on an average 275 pounds of meat, and this is sold by pussy's butcher in half pennyworths skewered on bits of wood. The magnitude of this trade can be estimated by the fact that it keeps constantly employed thirty wholesale salesmen. I may here mention that a cats'-meat men's supper was organised last year in London by the editor of _Our Cats_, assisted by Mr. Louis Wain and others; and a most successful entertainment was given at the City of New York Restaurant. The applications for tickets were so numerous that 400 men had to be refused; and when the 250 guests were seated, it was clearly proved that every available inch of accommodation had been utilised. Having been present, I can testify to the excellent supper and entertainment provided for the cats'-meat men of London.

[Illustration:

CAT CALENDAR.

(_By kind permission of Raphael Tuck & Co._)]

The most casual observer cannot have failed to remark the wonderful development of late years in "Catty" Christmas souvenirs, thus giving proof of the growth of love and admiration for pussy. We have cat almanacks, cat calendars, and cat annuals, and I can testify to the innumerable Christmas cards with designs of cats of all sorts and conditions which have found their way into my hands expressive of good wishes at the festive season.

The official mind would probably frown at the suggestion that the census returns should be enlivened with incidental humour. However, after the last census, the following statement appeared in the press:—

"An enumerator in going over a return paper found that the household cat had been included as a member of the family. It was described as 'Jim,' the relationship to the head of the family being 'lodger.' The entry then stated that he was of the male sex, single, aged one last birthday. His occupation was also given—'mouse-catcher, worker on his own account.'"

A description of the ordinary domestic cat is hardly necessary, but before I pass on to mention matters of general interest concerning cats of to-day, I will give a quotation from a Board School boy's essay, which speaks for itself:—

"The house cat is a four-legged quadruped, the legs as usual being at the corners. It is what is sometimes called a tame animal, though it feeds on mice and birds of prey. Its colours are striped, it does not bark, but breathes through its nose instead of its mouth. Cats also mow, which you have all heard. Cats have nine lives, but which is seldom wanted in this country, coz' of Christianity. Cats eat meat and most anythink speshuelly where you can't afford. This is all about cats."

Perhaps my readers may think that after such a lucid description of the subject in hand, further comments are unnecessary!

I will proceed, however, to give a glance round at the Cat Fancy in general before mentioning particulars of Clubs and Cats of the present day. The question has often been asked whether the Cat Fancy will ever become as popular and fashionable as the breeding of dogs, poultry, and birds? I think this question may be answered in the affirmative, when we consider that during last year a dozen and more large cat shows have been held in different parts of England and Scotland, to say nothing of numerous mixed shows where a section for cats was provided. Every year the number of fanciers increases, and although this particular hobby is almost entirely confined to the gentler sex, yet it is really surprising to find how many more men are beginning to take an interest in the pussies, and are keenly excited in the winnings of the household pet or the king of the cattery. As a friend once said to me, "You know what men are; if only the cats win prizes, my husband does not mind, but it is a different matter if I return from a show with no award; then he declares we must get rid of all the cats!" I am afraid that cat fanciers must be looked upon as a rather quarrelsome set, and there is no doubt that petty jealousies and spiteful gossip retard in many ways the development and improvement of the fancy.

Another question that is often asked is whether cats can be made to pay—or, in other words, whether cat breeding is a profitable undertaking. From my own experience, which has extended over a number of years, I can unhesitatingly say I have derived not only much pleasure but a good deal of profit from keeping cats, and also I have started many friends in the fancy who have gone on and prospered. The dangers that beset beginners are many, and the chief difficulty is to know how to limit the number of our pussies and so avoid overcrowding, or retaining poor stock which will not prove creditable or profitable. Cat keeping on an extensive scale means a large outlay, followed by constant and untiring attention. I do not intend, however, in this chapter to enter into any details as to the care and management of cats, for this and other subjects connected with their interests will be fully dealt with later on.

[Illustration:

MR. HARRISON WEIR.

(_Photo: C. E. Corke, Sevenoaks._)]

In my preceding chapter I alluded to the first Cat Show held at the Crystal Palace in 1871. This exhibition of cats has become an annual fixture, and year by year greater interest has been manifested, better classification given, and a larger number of cats

exhibited. It was, therefore, considered advisable to have some definite organisation, and the National Cat Club was instituted in 1887, with Mr. Harrison Weir as president. I will now proceed to give a list, which I believe to be complete and correct, of the various other clubs and societies in England and America which have been organised and which are all at this present time in thoroughly good working order.

LIST OF CAT CLUBS AND SOCIETIES.

The National Cat Club, founded 1887. Hon. sec., Mrs. A. Stennard Robinson, 5, Great James Street, Bedford Row, London, W.C. Annual subscription, 1 guinea.

The Cat Club, founded 1898. Hon. sec., Mrs. Bagster, 15A, Paternoster Row, London, E.C. Annual subscription, 1 guinea.

The Northern Counties' Cat Club, founded 1900. Hon. sec., Mrs. Herbert Ransome, Altrincham. Annual subscription, 10s.

The Silver and Smoke Persian Cat Society, founded 1900. Hon. sec., Mrs. H. V. James, Backwell, near Bristol. Annual subscription, 5s.

Black-and-White Club. Hon. secs., Miss Kerswill and Miss White Atkins. Entrance fee, 1s.; annual subscription, 4s.

The Blue Persian Cat Society, founded 1901. Hon. sec., Miss Frances Simpson, Durdans House, St. Margaret's-on-Thames. Annual subscription, 5s.

The Siamese Club, founded 1900. Hon. sec., Mrs. Baker, 13, Wyndham Place, Bryanston Square, W. Annual subscription, 4s.; to working classes, 2s. 6d.

The Orange, Cream, Fawn and Tortoisshell Society, founded 1900. Hon. sec., Miss Mildred Beal, Ronaldkirk Rectory, Darlington. Annual subscription, 10s.

The Chinchilla Cat Club, founded May, 1901. Hon. sec., Mrs. Balding, 92, Goldsmith Avenue, Acton. Annual subscription, 5s.

The Short-haired Cat Club, founded 1901. Hon. sec., Mrs. Middleton, 67, Cheyne Court, Chelsea.

The Scottish Cat Club, founded 1894. Hon. sec., J. F. Dewar, 2, St. Patrick Square, Edinburgh. Annual subscription, 5s.

The Midland Counties Cat Club, founded at Wolverhampton, 1901. Hon sec., Miss Cope, 136, Bristol Road, Birmingham. Annual subscription, 5s.

The British Cat Club, founded 1901: Hon. sec., Sir Claude Alexander, Faygate Wood, Sussex. Subscription, 5s.

The Manx Cat Club, founded 1901. Miss Hester Cochran, Witchampton, Wimborne. Subscription, 5s.

The Beresford Cat Club (Chicago), founded 1899. President, Mrs. Clinton Locke; corresponding secretary, Mrs. A. Michelson, 220, East Sixtieth Street, Chicago. Annual subscription, resident members, 2 dollars; non-resident, 1 dollar.

The Chicago Cat Club, founded 1899. President, Mrs. Leland Norton, Drexel Kennels, Drexel Boulevarde, Chicago.

The Louisville Cat Club, founded 1900. Corresponding secretary, Miss E. Converse. Annual subscription, 50 cents.

The Pacific Cat Club, founded 1900. Corresponding secretary, Mrs. A. H. Brod, 114, Broderick Street, San Francisco. Annual subscription, 1 dollar.

The Atlantic Club, founded in New York, 1902. Corresponding secretary, Dr. Ottolengui, 80, West Fortieth Street, New York.

[Illustration:

MR. LOUIS WAIN.

(_Photo: Lascelles & Co._)]

Since the formation of the National Cat Club, many changes in its constitution have taken place. On the retirement of Mr. Harrison Weir from the presidency, Mr. Louis Wain was appointed, and still holds the office. The N.C.C. is fortunate in having so energetic a hon. sec. and treasurer as Mrs. Stennard Robinson, whose name is so well known in the "doggy" world. The following is a list of

officers of the National Cat Club at the time of writing, and a summary of the objects for which the Club was organised:—

THE NATIONAL CAT CLUB.

Patron.—H.H. Princess Victoria of Schleswig-Holstein.

President.—Her Grace the Duchess of Bedford.

Vice-Presidents.—The Right Hon. the Countess of Warwick, The Viscountess Maitland, The Marchioness of Dufferin and Ava, The Countess of Aberdeen, The Lady Hothfield, Lady Willoughby, Lady Reid, The Hon. Mrs. McLaren Morrison, The Lady Granville Gordon, Lady Decies, The Hon. Mrs. Baillie, Madame Ronner, Mr. Isaac Woodiwiss, Mr. Sam Woodiwiss.

Committee.—Louis Wain (President), Lady Decies, Lady Alexander, The Hon. Mrs. McLaren Morrison, Mrs. Vallance, Mrs. Balding, Miss Hamilton, Dr. Roper, Mrs. Herring, Mrs. Ransome, Mrs. G. H. Walker.

Hon. Sec. and Treasurer.—Mrs. A. Stennard Robinson, 13, Wyndham Place, Bryanstone Square, W. (Telegraphic address—"Bow-wow, London.")

The National Cat Club was organised (1) to promote honesty in the breeding of Cats, so as to ensure purity in each distinct breed or variety; (2) to determine the classification required, and to encourage the adoption of such classification by breeders, exhibitors, judges, and the committees of all Cat Shows; (3) to maintain and keep the National Register of Cats; (4) to assist the Showing and Breeding of Cats, by holding Cat Shows under the best sanitary conditions, giving Championship and other prizes, and otherwise doing all in its power to protect and advance the interests of Cats and their owners.

The National Cat Club is also a Court of Inquiry and Appeal in all matters relating to Cats, or affecting the ownership of Cats, and so saves the expense to its Members of litigation.

The National Cat Club founded its Stud Book some twelve years ago, and it is the only reliable source of information concerning the pedigree of Cats. The Registration Fee is 1s. for the Register of Names, but for the Stud Book the fee is 5s. for _Approved_ Cats exhibited under N.C.C. Rules.

The two principal shows of the National Cat Club are held annually at the Botanical Gardens in connection with the Ladies' Kennel Association in June, and at the Crystal Palace in October. In 1901 the total number of cats shown at the Palace was 601, and the entries numbered 1,021. There were 106 classes provided for long- and short-haired cats. The following is the definition of the classes:—

DEFINITION OF CLASSES.

Open Classes.—Open to all Cats, Prize-winners or Novices.

Limit Classes.—For Cats of any age that have not won Three First Prizes.

Novice Classes.—For Cats of any age that have never won a First Prize at any Show.

Special Novice Cats.—For Cats or Kittens over 6 months that have never won a Prize of any sort at a Crystal Palace Show.

Neuter Classes.—For Gelded Cats.

Stud Classes.—For Male Cats that have sired Kittens which are entered and on exhibition in this Show.

Brood Queen Class.—For Queen Cats whose Kittens are entered in this Show.

Selling Class.—For Cats of any colour or Sex to be sold at a price not exceeding 3 guineas in Long-haired or 2 guineas in Short-haired and Foreign.

Ring Class.—For Cats shown in collar, and lead.

Kitten Classes.—Single entries to be over 3 months and under 8 months, unless otherwise stated.

Brace.—For 2 Cats, age over 6 months.

Team.—For three or more Cats, age over 6 months.

No Cats can be entered in brace or teams unless also entered in one other class.

The money prizes in each class are First, £1; Second, 10s.; Third, 5s. The list of special prizes, including Challenge Trophies and medals, numbered 262 at the last Crystal Palace Show in 1901.

In addition to the two regular fixtures of the N.C.C., other cat shows are held in different places in connection with the Club and under its rules.

[Illustration:

LADY MARCUS BERESFORD.

(_From a painting by Edward Hughes._)]

The National Cat Club reigned alone until 1898, when Lady Marcus Beresford started and founded the Cat Club. This ardent cat lover has done more for pussy than anyone in the fancy. She is most lavish in her generosity and unwearying in her efforts to promote the welfare of the Club. It was Lady Marcus who first started the idea of holding cat shows in aid of charity. The Cat Club's first show, held at St. Stephen's Hall, Westminster, in 1899, was in aid of the Children's Guild of the Deptford Fund.

In 1900 the families of the soldiers and sailors who had fallen in the Transvaal were benefited to a large extent by the proceeds of the show. In 1901 the Children's Hospital, Great Ormond Street, was the charity selected to receive a handsome donation of £100. The Westminster shows have always been splendidly managed, a noticeable feature being the wonderful array of beautiful special prizes offered for competition. The following is the list of officials connected with the Cat Club:—

THE CAT CLUB.

(_Founded by Lady Marcus Beresford._)

The objects of the Club are the general good of the Cat, the promoting of true breeding of Cats, the holding of a Winter Show, so that Cats may be exhibited at their best, and taking other steps that shall be for the welfare of the Cat.

The annual Subscription is £1 1s., payable on election, and on the 1st of January in each succeeding year.

A Stud Book and a Register of Cats are kept by the Club.

Presidents.—Lily, Duchess of Marlborough; Edith, Duchess of Wellington; Lord Marcus Beresford.

Vice-Presidents.—Isabella, Countess Howe; Viscountess Maitland, Viscountess Esher, Lady Ridley, Lady de Trafford, The Hon. Mrs. Bampfylde, Lady Lister, Lady Gooch, Mrs. Barnet, Mrs. Alfred Bles, Mrs. Walter Campbell, Mrs. Chaine, Mrs. George Dawkins, Mrs. Cary Elwes, Mrs. C. Hill, Mrs. King, Mrs. Nicholay, Mrs. Tottie, Mrs. Peston Whyte, Lord Walter Gordon Lennox, A. E. Bateman, Esq., Colonel Chaine, Henry King, Esq.

Committee.—Lady Marcus Beresford, Mrs. Vary Campbell, Mrs. Dean, Mrs. Paul Hardy, Mrs. C. Hill, Miss Anderson Leake, Mrs. R. Blair Maconochie, Mrs. Neild, Mrs. Simon, Mrs. Mackenzie Stewart, Mr. L. P. C. Astley, Mr. Gambier Bolton, Rev. P. L. Cosway, Mr. W. R. Hawkins, Mr. E. W. Witt.

Hon. Treasurer.—Lord Marcus Beresford.

Hon. Secretary.—Mrs. C. J. Bagster, 15A, Paternoster Row, London, E.C.

[Illustration:

LITTER OF SIAMESE KITTENS.

BELONGING TO LADY MARCUS BERESFORD.

(_Photo: T. Fall, Baker St., W._)]

There is really ample room for two parent clubs, as the Fancy is making such rapid strides, and, no doubt, well-appointed shows with good classification do a great deal to benefit breeders and assist fanciers. Between the National Cat Club and the Cat Club there is one point of serious disagreement, namely, as regards registration. At present members are expected and required to register their cats in each club if they exhibit at the respective shows. It would be a great benefit to the cat world in general and to the exhibitor in particular if some arrangement could be made whereby one independent register should be kept, and that both clubs might work together and assist each other in endeavouring to scrutinise and verify all entries made in the joint register, so that inaccuracies should be detected and fraud prevented.

The Northern Counties Cat Club is affiliated with the N.C.C., and has quite a large number of members. This enterprising club holds two shows in Manchester every year, which hitherto have been capitally managed by the energetic hon. sec. As a natural sequence a Midland Counties Club has lately been started, having its working centre at Birmingham. No doubt arrangements will be made for holding a cat show in this or some other equally central Midland town.

The Scottish Cat Club is in a flourishing condition, and has been steadily working up members since 1894. A show is annually held in Edinburgh, and fanciers over the border are taking a much keener interest in cats.

In America the fancy has gone ahead in a wonderful way. It was in 1895 that the first cat show of general interest was held at Madison Square Gardens, New York. There had previously been some private attempts to have exhibitions of cats in connection with poultry and pigeon shows. In 1896 an American Cat Club was organised, which did some good work. Then Chicago started a Cat Club in January, 1899, and this was followed by a most successful enterprise on the part of Mrs. Clinton Locke, who founded the Beresford Cat Club, called after Lady Marcus Beresford, and now numbering about 200 members. In January, 1900, the club held its first big show. The classification was of a most comprehensive nature, and the list of special prizes a very liberal one. This show is now an annual fixture, and the Cat Club of England sends medals and prizes to be competed for. Many of the best cats exhibited at these shows have been exported from England, and Americans are very keen in trying to procure the very best possible stock—high prices in many cases being offered to induce English fanciers to part with prize-winning specimens.

The following is a list of officials of the

BERESFORD CAT CLUB OF AMERICA.

Officers.

Mrs. Clinton Locke, 2825 Indiana Ave., (_President_); Mrs. Charles H. Lane, 5323 Madison Ave., (_First Vice-President_); Mrs. F. A. Howe, 3941 Grand Boulevard (_Second Vice-President_); Mrs. A. A. Michelson, 220 E. 60th Street (_Corresponding Secretary_); Miss L. C. Johnstone, 5323 Madison Ave. (_Recording Secretary_); Mrs. Elwood H. Tolman, 5403 Madison Ave. (_Treasurer_).

Directors.

Mrs. J. H. Pratt, 5816 Rosalie Court; Mrs. Lincoln Nicholson, Lee Centre, Illinois; Miss Louise Fergus, 3229 Sheridan Road; Mrs. Blanch P. Robinson, 6, Langley Place; Mrs. Vincent E. Gregg, 736 North Park Avenue.

[Illustration:

“PUCK III.”

THE PROPERTY OF THE PRINCESS VICTORIA OF SCHLESWIG-HOLSTEIN.]

At the Cat Show held in January, 1902, as many as 75 classes were provided, and it is plain to see from these that Americans have not the same antipathy for broken colours—that is, cats with white markings—as we have in England, as there are classes specially for orange-and-white, and black-and-white cats. In another part of this work I shall refer to varieties and breeds of cats existing in America which differ from those in England. The Beresford Cat Club have an extremely well-arranged stud book and register, which is published annually. I am sure that the Cat Fancy in America has a great future before it, and we cannot help being greatly struck with the earnestness, thoroughness, and enthusiasm with which Americans have taken up this hobby. When we consider the great distances in the States and the paucity of good stud cats, and the few opportunities of exhibiting at well organised shows, we cannot fail to admire the energy and enterprise displayed by our American fellow fanciers.

Specialist Clubs for Cats are of very recent growth. The first was started by an ardent breeder of silver Persians in 1900. It was then called the Silver Society, and it included smokes and silver tabbies. The title of this society has since been changed to the Silver and Smoke Persian Cat Society. In the following year Blue Persian Breeders bestirred themselves and formed a society for this most popular breed. In the same year the Orange, Cream, and Tortoiseshell Society, the Siamese Club, and the Chinchilla Club were inaugurated, also a Manx Club came into existence, and two clubs for short-haired cats were started. Particulars concerning these specialist societies and their objects will be found in future chapters on the various breeds of cats. It will be noticed by the list of clubs given that for brown tabby and black-and-white Persians no societies have as yet been formed, but doubtless ere long these varieties will be gathered into the fold of specialist clubs.

A good deal of discussion has taken place in catty circles as to the desirability of having specialist societies, but I am sure a vast and marked improvement has taken place in the different breeds since their formation, and the fact of publishing a standard of points has certainly assisted breeders in coming to a more correct idea of what constitutes a good cat of a particular breed. The number of challenge prizes, medals and specials offered by these societies at various shows act as an incentive to exhibitors, and thus entries increase and competition becomes keener. Specialist clubs are not altogether popular with the parent clubs, who regard them with rather a suspicious and jealous eye. They think that exhibitors may join these less expensive societies and yet continue to show and win prizes without subscribing to the club that holds the show. No doubt there is something in this, and specialist clubs should be ready and willing not only to offer prizes for which their members only can compete, but they ought also to guarantee classes, and perhaps give a donation towards the expenses of the show.

[Illustration:

MRS. CLINTON LOCKE AND HER SIAMESE KITTENS “CALIF” AND “BANGKOK.”]

There have been quite a number of catty cases in our courts of late years, and these generally seem to cause considerable amusement to the legal as well as to the public mind. At a recent trial, where a lady was wrongfully accused of starving a Persian cat, the magistrate, wishing for information, inquired of the witness (who was a veterinary surgeon) how long a cat could live without food. The reply was, “I am sure I could not say, sir, for cats are the funniest animals we have to deal with.” And it is very true that these creatures, being so complex, require to be specially studied, and our principal veterinaries, who lead busy lives, are just a little superior to the many ailments and infirmities of these too often despised animals. It is therefore a subject of satisfaction for cat fanciers that two clever and kind animal loving men have taken up the doctoring of cats, and by personal experience are learning “pretty pussy’s ways” in sickness and in health. Mr. Ward, of Manchester, and “Salvo,” of Hertford Heath, are now two household names in the cat fancier’s vocabulary. To the many excellent remedies prepared by these clever specialists I shall refer later on in my work. Suffice it here to say that when in doubt or difficulty about your pussy’s state of health I would recommend you to write to either of these common-sense practitioners.

The cat literature of the present day has been steadily on the increase. The first paper to supply special cat columns was _Fur and Feather_, which, as its title infers, treats besides of birds, rabbits, poultry, cavies, mice. This weekly paper has a large circulation amongst the various fanciers. In 1899 _Our Cats_ was started, and is widely read by the ever-growing circle of cat lovers, and claims the unique distinction of being “The only newspaper in the world solely devoted to cats.” In both these papers there are stud advertisements of cats and a register of visits of queens and births of kittens.

In America the chief organs in the cat world are _The Cat Journal_, _The Pet Stock News_, and _Field and Fancy_.

And now a few words on those most excellent institutions which should appeal to the hearts of the animal loving public—I mean the homes for poor stray and starving cats. It is a mercy that there are now several of these refuges in our great metropolis. I have personally visited Gordon Cottage at Argyle Road, Hammersmith, and the London Institution in Camden Town. The objects of both these institutions are practically the same, namely:—

(1) To receive and collect homeless and diseased cats and painlessly destroy them.

(2) To provide a temporary home for lost cats.

(3) To board cats at a moderate weekly charge.

[Illustration:

THE CATS’ PLAYGROUND: ROYAL LONDON INSTITUTION FOR STARVING CATS AT CAMDEN TOWN.

(_Photo: Cassell & Company, Limited._)]

The Camden Town Institution to which Her Majesty the Queen has graciously given Her Patronage, was founded by Mrs. Morgan in 1896, and up to the end of 1901 has received the enormous number of 47,212 lost and starving cats. The average received weekly is 300, and in one day as many as 91 cats have been taken in. Not a day passes without several wretched cats having to be destroyed at once on admission, and 80 per cent. are destroyed within twenty-four hours of admittance. No charge is made to the poor, and only 1s. 6d. for a painless death in the lethal chamber is asked from those who can afford this most merciful mode of destroying life. The dead cats are cremated at the Battersea Dogs' Home at a charge of 3d. each body. A motorcar is employed to go round and collect stray cats, and will call at any house if due notice has been given to the hon. manageress. It is estimated that the number of cats in London is close upon three quarters of a million, of which from 80,000 to 100,000 are homeless. It is during the summer months, when householders leave town for their holidays, that poor pussy is forsaken and forgotten, and no provision being made for her, she is forced to take to the streets, where she seeks in vain to stalk the wily London sparrow or pick up any scraps from the gutter. The humbler folk very frequently manifest vastly greater solicitude for the Tom or the Tabby of their hearths than do their social superiors. All lovers of cats owe a debt of gratitude to those truly noble ladies who have begun and carry on such a merciful work in our midst. To attempt to alleviate suffering must appeal to all; and even those who have an instinctive dislike to harmless cats cannot fail to see the immense benefit to be derived by the public at large from the noble endeavour to clear our London streets, squares, parks, and empty houses of these poor forlorn and friendless creatures.

[Illustration:

ROYAL LONDON INSTITUTION FOR LOST AND STARVING CATS.

(_Photo: Cassell & Company, Limited._)]

At the Battersea Home for Lost Dogs there are also splendid arrangements for stray cats, and at a very small charge per week cats can be taken in to board. The catteries are capitally arranged, and the feeding is excellent.

In our sister isle there is a Cats' Home, established sixteen years ago by Miss Swifte in Dublin, and she has most gallantly carried out the beneficent objects with which she started her humane work. No doubt she and other founders of similar institutions have had to suffer a considerable amount of ridicule, for with many human beings the cat is regarded as little deserving of commiseration or kindness. It is, however, a sign of increased justice and benevolence that these homes for cats do exist and obtain public support, although the funds received are, according to all accounts, very inadequate to meet all the expenses. This must surely be partly because these splendid institutions are so little known to the general public.

Our American cousins are not behindhand in their laudable endeavours to cope with the question of lost and starving cats, and an institution similar to our Battersea Home was started in the early 'eighties in the district of Boston, and is called the "Ellen M. Gifford Sheltering Home for Animals." The lady giving her name to this humane institution left a large sum of money to endow the home, and over the office is a tablet bearing the following extract from one of Miss Gifford's letters about the time the home was opened:—

"If only the waifs, the strays, the sick, the abused would be sure to get entrance to the home, and anybody could feel at liberty to bring in a starved or ill-treated animal and have it cared for without pay, my object would be attained. March 27, 1884."

According to Miss Helen Winslow, the authoress of "Concerning Cats," there is another institution in Philadelphia which does not limit its good work to tending cats and dogs, but cares for all living and suffering animals, bringing relief to the unfortunate creatures by means of a painless death.

It was as early as 1874 that this institution was founded, and in 1889 it was reorganised and incorporated as the "Morris Refuge for Homeless and Suffering Animals," having for its motto "The Lord is good to all, and His tender mercies are over all His works."

[Illustration:

THE CART OF THE ROYAL LONDON INSTITUTION FOR LOST AND STARVING CATS.

(_Photo: Cassell & Company, Limited._)]

The efforts of the charitable ladies who so ably assisted in the establishment of these institutions have been followed by others, and a proposal to found a home for animals in Montreal has, I believe, proved successful. Miss Winslow tells us that there are several

cat asylums and refuges in the Far West, and a Sheltering Home at Brighton, Mass. In 1901 a Cat Refuge was started in Chicago by a well-known cat lover, Mrs. Leland Norton, and probably, as time goes on, some further organised attempt will be made to deal with the question of lost and starving cats in American towns.

The love of the cat still lingers in Egypt, and I have been told that free rations to starving cats are dealt out every day at the Palace of the Cadi and the Bazàr of Khan Kheleel; also that a cats' home has been founded in Cairo for the lodging and feeding of homeless cats.

[Illustration:

THE HON. PHILIP WODEHOUSE'S "SILVER SAINT."

(_Photo: Clarke & Co., Norwich._)]

There was a report that in order to cope with the innumerable lost and starving cats the American Legislature had decided to enforce a bill for licensing cats, but if such a law came into existence in any country the result would surely be that thousands of cats with good homes would be thrust out into the streets, and that rats and mice would multiply to an alarming extent. It is estimated that in New York city alone 60,000 cats depend for their daily food on garbage and the mice and rats that they capture. Therefore, if each cat catches three mice or rats a week, the sum total amounts to over 9,000,000 a year!

I have often wondered why some of our numerous "distressed ladies" do not set up private homes for the care of cats. A really comfortable country home for cats is an enterprise in which many a woman, who is hopelessly at sea for some means of earning an honest livelihood in this overcrowded work-a-day world, might thus combine pleasure with profit. Many fanciers feel the difficulty and well-nigh impossibility of leaving their catteries for any length of time, and few have a permanent and responsible caretaker on the premises. An opening, therefore, presents itself not only for boarding homes for cats, but for temporary helps who could be engaged by the week or month to take charge of the cattery during the absence of the owner. Of course, such a person should have had experience with cats and kittens, and above all should be an animal lover. To dwellers in any of our large cities the sojourn in some country place would come as a boon and a blessing, and if the owner of the cattery is fully assured of the capabilities of the caretaker, then all anxiety of mind as to the welfare of the pets would be allayed.

There is a secluded corner in Hyde Park known as the Dog's Cemetery, and amongst the many headstones I noticed two or three erected in memory of lost pussies who have been privileged to rest in this quiet burying ground.

[Illustration:

A BEVY OF BLUES BELONGING TO MISS SAVERY.

(_Photo: Waschenki, St. Leonards-on-Sea._)]

When we see poor pussies packed into dirty cages in the shops of dealers of beasts and birds in our great metropolis, and when we are made sad by the sight of the wretched starving cats of our streets, we can breathe no better wish for them than a speedy deliverance from their life of misery, even if it be to embark with the grim ferryman in their free transportation to the Feline Elysium.

"There shall the worthies of the whiskered race, Elysian mice o'er floors of sapphire chace, 'Midst beds of aromatic marum stray, Or raptur'd rove beside the milky way."

A French writer of the early part of the eighteenth century, a famous Jesuit Father, suggests a very strange theory on the old idea as to the nature of the soul of animals. I am sure that the question of a future existence for those pets who during so short a time in this world have been our faithful and loving companions must have often entered into the hearts and minds of true animal lovers.

A wise and good man—a writer of some of our most beautiful hymns, and who passed to his rest within the last year—wrote and gave me these lines when he lost his faithful dog:—

SANCHO: AN OLD FRIEND.

A large brown Irish retriever: buried in the Vicarage Garden of St. Paul's, Haggerston: a stone to his memory is on the school wall, with this inscription:—

"In the centre of this lawn lies

SANCHO,

a gentleman in all but humanity; thoroughbred, single in mind, true of heart; for seventeen years the faithful and affectionate friend of his master, who loved him, and now for him 'faintly trusts the larger Hope' contained, it may be, in Romans viii. 19–21.

He died April 26, 1883."

NOT sparse of friends the world has been to me By grace of GOD; sweetness and light to life Their love has given; many a stormy strife, Many a pulseless torpor, on my sea, Through them—their presence or their memory— Have been or stilled or quickened; and to thee, My Dog, the tribute, as the term, is due, My _Friend_! not least of all dear, near, and true These seventeen years—and through the years to be Sure in my heart of immortality. Must this be all? I' the great Day of the LORD, Shall aught that is of good and beauty now Be missing? Shall not each gift be restored? Paul says "the whole creation"—why not thou?

[Illustration:

CATS' TOMBSTONES IN THE DOGS' CEMETERY, HYDE PARK.

(_Photo: Cassell & Co., Ltd._)]

[Illustration:

TABBIES UP A TREE.

Photo: C. Reid, Wishaw.]

CHAPTER III. CARE AND MANAGEMENT.

In the care, management, and feeding of cats no hard-and-fast rule can be laid down, for the dispositions and constitutions of these animals differ just as much as do those of human beings. Fanciers must therefore learn to treat their cats individually and not collectively; they must study their character and make allowances for the fads and fancies of the feline race. I am convinced that a varied diet is the best for cats, and fanciers should bear in mind the importance of regularity in the hours of feeding, whether two or three or four times a day. Fresh water should always be supplied, and unfinished food should not be left standing about. For one or two pet cats the scraps from the table given with judgment will probably suffice; but in the case of a large cattery with several inmates, some sort of system in feeding is necessary. I would suggest that the chief meal for two days a week should be fish, mixed perhaps with rice or Freeman's Scientific Food, raw meat twice or three times a week cut up into fairly small pieces, horse-flesh (if obtained from a reliable source) twice a week. Lights, liver, or sardines may be given occasionally. Sloppy food in any large quantity should be avoided; but oatmeal well boiled, cornflour, arrowroot, and several of the well-known foods, such as Neave's or Mellin's, make a nice change. Spratt's biscuits of various kinds, soaked and mixed with stock, are relished by some cats. Vegetables should be given frequently, and grass supplied, as green food purifies the blood and keeps the bowels in good condition. Persian cats require special attention as regards their coats, and should be combed and brushed regularly, and, if the fur becomes matted, the knots should be cut away. Avoid washing your cats; there are other means of cleansing their coats, particulars of which will be given in the chapter on exhibiting.

[Illustration:

BLUE PERSIAN.

PRESENTED BY MISS PATTERSON TO HER MAJESTY THE QUEEN.]

FEMALE CATS AND KITTENS.

As regards the management of female cats, it is necessary to start from the time when they first arrive at maturity, viz. when they are first capable of becoming mothers. This usually takes place—or they "come in season," as it is called—after they are seven or eight months old; and though cases have been known when this has happened before six months, it is very unusual. It may therefore be laid down as a rule that if a kitten exhibits extraordinary high spirits, racing and tearing about, it should be carefully watched, and not allowed its freedom without supervision, either out of doors or in the house.

Queens may be known to be in season by several symptoms, such as rolling on the ground, rubbing up against furniture, increased affection for their owners, and often by the curious cries they utter, at times by a soft note of invitation, at other times by shouts of impatience or distress which resound through the house. Cats should not be mated until they are nine or ten months old at least; twelve months is a better age, though if they are insistent it will not do to put them off more than three times, as there are records of cats who, having been kept back on account of extreme youth, have been seriously ill or have never had families at all.

On the other hand, it is possible these cats may have had the reproductive instinct abnormally strong, though for some cause or another they would always have been unfertile. Powders are sold to quiet cats who are considered too young to become mothers, and two or three small doses of bromide have a decidedly calming effect. This drug should, however, be given with caution, as it is a dangerous one in unskilled hands. Cats come in season about every three weeks during the spring and summer; but in the autumn and early winter months nature seems to intend that they should rest; therefore, as soon as the year has turned, and in very mild winters even before Christmas, no time should be lost in selecting the best sires for the various breeding queens, and arrangements made with their respective owners, so that as soon as ever a queen is ready she may be mated without delay, as some cats go off in two or three days, while others are not safe for a fortnight. If possible, it is well to select a stud cat near at hand, especially if your queen is timid and frightened, as a long railway journey may upset her.

It is most essential that female cats should be freed from worms before being allowed to mate or breed, otherwise the kittens will probably fall victims to these pests by sucking in the disease with the mother's milk. Most cat fanciers know the symptoms which are suggestive of worms; and whenever there is a reasonable suspicion of their presence, then it is best at once to resort to some of the many remedies to be obtained from veterinaries and cat specialists.

A cat's period of gestation is nine weeks, but this is often extended to a day or two longer, so that it is best to expect a litter about nine weeks from the date of the queen's return from visiting the stud cat. An experienced breeder will most likely see symptoms of a cat coming in season, and will then do well to give a worm powder. Salvo's No. 3 powder may be given one morning, and the cat sent off the next day quite safely. Visiting queens should be despatched as early in the morning as possible and insured, to save delay on the road, with the owner's name and address inside package, also the name of the cat, as poor pussie will be far happier if on her arrival she hears herself called by her pet name. Full instructions should be sent as to the return journey; also it should be stated if the cat is kept out of doors or indoors, and what food she is accustomed to have, number of meals per diem, etc. If going a very long journey the queen should not be nailed into a box, or padlocked, as occasional delays occur, and the railway authorities will feed and look after an insured cat if packed in a hamper or box where they can get at the occupant. Boxes or hampers with skeleton lids are by far the best on this account. If the weather is very cold and a basket is used, it should be lined, and round the sides brown paper is an additional safeguard against draughts, for which all stations are proverbial. A very delicate cat or young kitten finds great comfort in winter from a hot-water bottle placed inside the hamper for it to rest against. Queens should have a good meal an hour or two before starting, as they often arrive upset with the journey, and in their strange new home will not at first touch any food. Do not put any food in the travelling basket. It is not well for a queen to mate just after a heavy meal.

Fish and warm milk, if these agree with the queen, or a small meat meal, may be offered after a long, cold journey, and, if eaten, the queen should be allowed to rest an hour or two before introducing her to the stud cat.

[Illustration:

THREE LITTLE MAIDS.

(_Photo: E. Landor, Ealing._)]

After mating, a queen should be kept quiet for a few days on her return home, as much apart from other cats as possible; but no uneasiness need be felt if the visit does not seem to have quieted the queen, as she will settle down in a few days and cease to think about her mate. With regard to treatment of cats in kitten, some queens are gentle and quiet, and very careful of themselves, others are exceedingly bad-tempered, fighting and quarrelling, while some amuse themselves by climbing up high places and jumping down, behaving in such a wild and excitable fashion that they not only endanger their own lives, but run the risk of bringing maimed and deformed offspring into the world. Cats such as these should be kept isolated, if possible, or at most with only one other quiet queen, and all high shelves or tall articles of furniture should be removed. It is always well to be very careful in handling cats in kitten. They must never be lifted up by their fore legs, but when absolutely necessary to move or carry them, both hands should be used to do so, one being placed under the body by the shoulders to carry the weight, while the other hand gently supports the hind quarters; but the less a cat is lifted about the better. All medicines should be given quietly and quickly, so that

there may be no struggling. The cat's head should be grasped firmly with the left hand, the fingers and thumb on each side of the corners of the mouth, and forced back on the shoulders with a firm pressure; this will cause her to open her mouth, when medicine can be popped quickly down the throat from a spoon held in the right hand. In the case of a very restless cat, it is advisable to have an assistant in administering medicine. Amateurs would do well to practise giving water in a spoon to queens who are in health, so that they may become used to this simple method of administering medicine. Cats in kit require three or four meals daily of nourishing food—raw meat from four to six ounces night and morning, and fish and scraps and vegetables or biscuit, etc., for the midday meal. Half a teaspoonful of cod-liver oil on their food two or three times a week is very good for the queens in cold weather; but if sickness ensues, of course the oil must be discontinued. _Never suffer diarrhœa to go on unchecked._ This applies to all cats and kittens of whatever age, sex, or condition, but is especially dangerous when a cat is in kit or nursing her young. Mr. Ward and Salvo prepare powders which will stop the diarrhœa, and if persevered with will restore the bowels to their normal condition. Change of diet is also very helpful. If the diarrhœa is very violent or persistent, or if no medicine can be procured, a small quantity of powdered chalk, as much as will lie on a sixpence, may be given every hour or two, three or four times; but the primary cause, of which diarrhœa is only a symptom, should be sought out, and if not discoverable, the advice of a cat doctor should be obtained.

[Illustration:

A PERILOUS PERCH.

(_Photo: C. Reid, Wishaw._)]

Persistent diarrhœa (if not the accompaniment of diseases, such as inflammation of the bowels, etc.), is usually caused by indigestion or worms, and sometimes by a stoppage of fur or food imperfectly digested, which nature in this way tries to get rid of; and if this is the case, or there is even reason to suspect it may be, a dose or two of warm salad oil, a teaspoonful every two hours, will often bring away the obstruction. Cats in kitten frequently suffer from constipation, for which also warm salad oil is far better than castor-oil, as the latter is irritative to the bowels, and though acting as an aperient, the after effects are increased costiveness. Warm salad oil, given a few hours before the birth of kittens, is helpful to the mother. For at least a week before the kittens are expected, a nice cosy bed should be prepared in some retired spot; and, to a novice, the caution would not be amiss—do not let a cat in kitten sleep on your bed, or she will either have her kittens there, or will drag the poor little things into the bed the first chance she gets. If a box is to be made ready for the cat, it should be of a fair size (about twenty-six inches by eighteen inches), and should be placed on its side, and a bit of wood about three inches deep nailed on to the bottom of the side, standing up to keep the bedding in its place and the kittens from rolling out. This box may be placed on a table or two chairs, so arranged that the cat can step in and out from another chair.

The floor of the box should be covered with several thicknesses of flannel or blanket in the winter and paper in the summer. Avoid coloured materials, as the dye will come out if they get wet. A bolster may be placed at one side of the box stuffed with straw, or hay or paper torn up very small, to support the cat's back; but should the weather be very cold and the mother delicate, a hot-water bottle covered with flannel may be used instead, and is a great comfort. A covering should be thrown over the box, which may be pulled down to hide the interior, as cats love to be screened from observation; and also it is very essential that the tiny babies should be kept almost in the dark for the first fortnight, after which time, when their eyes are open, the covering can be raised in the day and lowered at night in cold weather. This box must be placed on the ground as soon as the kittens can walk about, but retaining the ledge already referred to, which will keep them from ground draughts to a great extent. A nice little box with run attached is the best house for a cat and kittens; but as these cost about 25s. each, a number of them become costly and beyond the means of some breeders. The bed described is the next best thing, far better for shy queens than a box or basket used in the ordinary way. An empty drawer makes a good place, but the kittens should be moved out of it as soon as they can see, as it is rather too dark and close after the blind period is past.

[Illustration:

MRS. HARDY'S NEUTER "PHARAOH."

(_Photo: Schutk's Photographic Galleries._)]

A cat should sleep in whatever bed is arranged for her for at least a week before the kittens are expected, and when that day arrives the queen should be carefully watched, as some cats will have their kittens anywhere if not looked after. For the sake of those new to the fancy, it may be as well to remark that cats become very restless, walking about sometimes purring loudly, and

looking in cupboards and dark corners, while occasionally the first noticeable indication that the event is about to come off is that the fur behind is wet, and if this should be the case no time should be lost in carrying the cat most carefully to her bed, as the kittens may then be expected any moment. Some animals like to be left entirely alone while giving birth to their young; others, especially pets, prefer to have their owners near to them; but if there is any uncertainty it is better to leave her to herself.

Experienced breeders will know that should the labour be dry or very prolonged it is a great help to a cat to pass the hand firmly and slowly down the side during an expulsive pain, as the pressure will help the mother and hasten the birth of the kittens.

After the first is born, the rest come comparatively easily. Very occasionally there is a cross presentation; but as only those really competent should attempt to do anything in this case, no time should be lost in sending for the nearest cat doctor or veterinary. After the first kitten has arrived—the birth of which is usually heralded by a loud cry of pain from the mother—some milk should be made hot, and as soon as the new baby has been cleaned the mother will gladly drink this; but on no account should cold or even lukewarm milk be given the same day, or, indeed, for two or three days. Novices are sometimes startled at seeing the cat eating a lump of something which they fear may be a kitten; but there is no occasion for alarm, as it is merely the afterbirth, the consumption of which is probably Nature's provision for affording sustenance to the mother, as an animal in a wild state could get no food for at least several hours after the birth of its offspring. If a cat is wild or shy, it is better to leave her alone (with the exception of offering hot milk from time to time) until all the kittens are born, and they should not be examined or handled for some days.

With a gentle queen the first kitten may be taken away when the second is born, well wrapped up in warm flannel and put by the fire, and so on, always leaving one kitten until the last is warm and dry, when the others should be returned to the mother. This plan is most necessary in cold weather (especially if the kittens are born out of doors), for if the labour is easy and quick it is quite impossible for the queen to dry one kitten before the advent of the next, and by the time they are all born they are frequently stone cold, and so wet that the mother gives up the attempt to dry them in despair; and many kittens, thought to be stillborn, have died in the night in this way. Kittens quite cold and nearly dead have been restored (and have lived to a good old age) by being taken at once to the fire and warmed and dried, and though at first life may appear extinct, time and patience will work wonders. If the kittens are taken away from the mother at birth as described above, it is a good opportunity for destroying any that are not wanted, because of sex or colour. When the litter is given to the mother she should be offered milk again, and should after that be left alone several hours; but she will most likely welcome a few kind words and loving pats as a reward for all she has gone through, and will then cuddle down contentedly with her little ones.

In giving milk do not take the mother out, or even make her get up to drink it, on the day of her confinement; if she cannot reach it comfortably, raise her head and shoulders with one hand, until she can reach the saucer held in the other conveniently, and do not be in a hurry, as she knows well the temperature the milk ought to be, and will not take it if too hot or too cold. Milk should be given night and morning, and offered during the day, for some days after the kittens are born. Cats that never like it at other times are thankful for it when nursing; but, on the other hand, cats that have been fond of milk will turn away from it at these times. Queens usually come out every few hours for food, and their meat or ordinary meal should be ready for them, as they will want to eat it quickly and return to their little ones. After the second or third day a warm, clean blanket should be substituted for the one on which the kittens were born, and it is well to do this when the mother is present, as some cats resent interference during their absence.

As soon as the kittens are about a week old, a finger should be passed over their eyes, and if there is a little ridge on the lids, the eye should be moistened with eye-lotion twice daily with a camel-hair brush. If, after ten days, they do not open as is usual, the eyes should be sponged with warm water, as in this case they must have become glued together with mucus, which should be cleared away, and the eye moistened with eye-lotion, taking care a little goes well into the eye. The lid should then be smeared with olive oil to prevent adhesion. It is this adhesion of the lids which causes inflammation, and the eyes must be frequently attended to, so that they may be kept open, avoiding any very strong light.

If the kittens are born indoors in the summer, windows should be kept open during the day, and when the little creatures are about a fortnight old put them out in the sunshine for an hour or so daily. The mother must be as well fed as she was before the kittens were born, but carefully notice if she suffers from diarrhœa, for if this is the case, and change of diet does not cure it, you may be certain that she is nursing too many kittens, and if some of them are not speedily removed you will lose them all.

If a foster mother can be procured, by all means have one, accompanied by one of her own kittens if possible. Make a cosy bed for her, warming the blanket, and leave her in it till night, when, if she seems settled down, give her two or more kittens as the case may be, removing her own the following night. Do not attempt to interfere with the kittens while the mother is away, and act very

gently, talking to, and stroking her so that she may not resent your interference. If no foster-mother can be procured, Mr. Ward, of Manchester, has a clever little appliance which he claims can be used instead of a foster-mother.

[Illustration:

"THE RAIDERS" CAUGHT!

(_Photo: E. Landor, Ealing._)]

Some fanciers may take upon themselves the task of bringing up the kittens by hand, and in that case wrap them up in warm flannel, keeping them by the fire by day, and giving them a hot bottle at night, feeding with weak milk and water about every two hours (this should be about half and half), with a teaspoonful of lime-water to each cup of milk and water. It should be given warm, not hot, and the milk scalded, not boiled. In London or large towns unsweetened condensed milk is better than cow's milk, as the colouring or preservative acids used by dairymen in the latter is very injurious to kittens. This condensed milk should be much diluted, and flavoured with small quantities of salt and sugar. If too strong or too sweet, the food will cause diarrhœa. Kittens will soon learn to suck out of an eggspoon; but do not give too much at once, or force the food down their little throats when they object to take any more.

At about five weeks old the kittens will begin to lap and possibly to eat. Many fanciers are delighted if they will eat and drink before a month old, and some make the serious mistake of trying to coax the little ones to eat solid food at this tender age. Such persons do not stop to think how weak are all the digestive organs of these tiny creatures. The milk of the mother supplies all that is needful for their growth and well-being until such time as Nature makes itself heard in her demands for further nourishment, and if substantial food is given to them too soon, or too strong, it merely goes through the stomach, passing out into the bowels undigested, decomposes, and forms slimy mucus which is the hotbed for worms, even if it does not set up inflammation of the bowels. More kittens die from worms and consumption of the bowels than from any other complaint, and much of this loss of life is directly traceable to strong food at too tender an age.

Lung disease, gastric catarrh, gastro-enteritis, are all directly or indirectly set up by the non-assimilation of food; hence the supreme importance of giving nourishment which can be digested easily. After six weeks scraped raw beef may be given (if the kittens want to eat) three times daily in very small quantities, about half a teaspoonful to start with, and they may have warm milk and water with lime in it. This should be followed by Mellin's, or Benger's Frame Food, as directed for infants. It is advisable not to allow kittens to overload their stomachs, but to feed them about four times daily. If healthy they will eat eagerly, but not ravenously; a kitten who is greedy and precipitates itself into the saucer in its anxiety to get its dinner may be suspected of worms, and when about eight weeks old a course of Salvo's No. 1 powders may be given with safety.

As soon as the kittens are about a month old, a shallow tin of dry earth or ashes (I do not recommend sawdust) should be provided for them, and it will well repay their owners to spend some portion of the day with the little ones and lift them into the earth pan when necessary. If this is done two or three times, the lesson is probably learnt for life. Kittens are naturally clean, and will get out of their beds, and run about crying loudly for some accommodation for their wants; and if this is neglected the seeds of dirty habits are sown, and the poor untaught little ones reap a sad harvest of cuffs and sometimes kicks from servants, who naturally dislike the trouble caused by dirty house pets. Even in catteries cleanly habits in cats are much to be desired. If a cat or kitten gets into dirty ways, it should never be beaten and put into the tin, but should be gently stroked and coaxed into good habits. Those who only keep one or two queens will find that if they spend a few minutes playing with the kittens before their meals, they will be well rewarded by the quicker growth and better digestion of the little ones; but, of course, this is out of the question in a large cattery.

In summer, kittens should be combed daily with a small tooth tomb, as the insects which inhabit their coats not only worry them and cause them to scratch out their fur, but they convey disease from one to another, to say nothing of sucking out so much blood that the poor little creatures become absolutely anæmic, and in this state they fall an easy prey to the first disease that attacks them. Fleas were formerly treated as irritating but otherwise harmless insects; but we are assured on the best authority that they are a dangerous medium of disease, and that tapeworms are generated in dogs and cats by their means. The poor animals, wildly resenting the annoyance of these pests, hunt for them with teeth and tongue, and, swallowing their enemy, may also swallow a number of undeveloped tapeworms, which in their larval or grub state are secreted in the abdomen of the flea. Tapeworms are said to undergo certain metamorphoses or transformations, and require to pass through the body of some other creature than the one they exist in in their mature state of being.

[Illustration:

KITTENS BELONGING TO MISS BROMLEY.]

It is a great mistake to keep kittens in heated rooms, and worse still to allow them to be close to a fire by day and then to let the room get cold at night. An even temperature, cold and dry, is better than sudden changes; cats and kittens love warmth and comfort, but, at the same time, all extremes of heat and cold are bad. Never neglect the first symptoms of illness; note the signs, and if you are not able to dose the invalid yourself send off a wire to some competent cat doctor describing the form the indisposition has taken, and while waiting for medicine no harm can be done by giving as much carbonate of soda as will lie on a threepenny-bit in a little water two or three times daily. Salvo has lately advertised a medicine which is said to be very valuable for giving on the first signs of a cat or kitten being out of sorts, and which, he says, will take down fever, stop colds, and modify attacks of bronchitis, pneumonia, etc.; and for such fragile little beings as kittens fanciers would do well to keep this medicine by them. People often say that their cats and kittens seem ill or out of sorts, and allow this sort of thing to go on quite calmly for a week or so, when one day they wake up to the fact that the poor creature is very seriously ill, and they then send off in a hurry for medicine which frequently arrives too late; and the sufferer may be beyond all human aid.

Double pneumonia, which is perhaps the quickest and most fatal of all diseases, is not so sudden but that it is ushered in by various symptoms, beginning often a week before the attack becomes acute. An animal will seem cold, will creep near the fire, or sit in the fender, mope about, refusing to play, sit in a hunch with its back up, or is very sleepy and stupid; the fur is rough; there may be sickness, and the evacuations are of a bright yellow colour; perhaps it has not quite finished its meals for a few days; and the nose is hot and dry, and, if taken up, the cat feels hot and dry all over. When there are several of these symptoms, no time should be lost in administering the remedies named above every hour or two until suitable remedies can be obtained; but do not rely upon them alone, or think if you give them persistently they will pull the animal through the illness, for they will not, special remedies being needed for special symptoms and for various stages of disease. No two animals are exactly alike, and the experienced cat doctor will prescribe carefully for each individual cat in the same way as a physician will give different prescriptions to suit the needs of different patients.

One thing should _never_ be neglected, and this is keeping up the strength from the first with beef-tea, eggs and milk, Brand's Essence, or animal Kreochyle— a teaspoonful every hour. As soon as an animal has refused two meals, begin feeding with spoon, as it will have so much more strength with which to battle against disease if fed up well from the first.

People who desire to sell kittens for profit will do well to part with them at about two months old, before they start teething, for at this period of their little lives fresh troubles begin. Occasionally they suffer from fits, but though these are sometimes caused by cutting their teeth, they are oftener due to the presence of worms. If the gums are swollen and inflamed, a quarter of one of Steedman's teething powders will soothe them, or a few doses of bromide, as prescribed before for kittens desiring to mate too early, may be given, and excitable kittens should be kept quiet. If kittens are troubled with diarrhœa, all starchy food should be avoided, as it is never easily digested by animals. The reason of this is not far to seek, when we know that the saliva partly digests starch, while the juices of the stomach act directly on meat.

[Illustration:

NEUTER PETS OWNED BY MRS. HASTINGS LEES.

(_Photo: The Royal Central Photo Co., Bournemouth._)]

Animals, instead of masticating their food, by which means the saliva acts upon it, often bolt it, and it goes into the stomach and is passed out into the large bowel practically undigested, where it decomposes, working off in noxious gases which escape through the skin, causing eczema, or in many cases producing inflammation of the bowels or enteritis. Nothing needs more careful attention than the diet of kittens, and nothing is so little studied. It would be no exaggeration to say that all disease, apart from outside or accidental causes, such as draughts, cold winds, contagion, etc., is in the first place set up by undigested food, and even what may be called external causes would often not be harmful to an animal if the digestive organs were in proper working order. Remember, it is not the quantity of food a kitten takes that benefits it. The secret of its health and well-being is in the quantity it digests. A kitten should only digest certain things in certain proportions, and whatever remains undigested produces irritation, and in this case the kitten cannot possibly develop, and is generally weakly and fretful.

Those who have never cared much for cats will be interested and amused if they bring up a family of kittens, and the love and trust of the little creatures will well repay them for all their care.

STUD CATS.

A male cat should not be allowed to mate under a year old, and if you wish to keep your stud in good condition do not allow more than two, or at most three, lady visitors a week. There is no doubt that a really reliable stud cat is a very profitable possession. The most essential recommendations are a sound constitution and absolute health, combined with a good pedigree and a list of prize-winning progeny. It is necessary to exhibit your stud cat at the best cat shows from time to time, and thus to keep him before the public. It is also advisable to advertise him in the cat papers, and it is often useful to have a photograph to forward to fanciers who may be unable otherwise to obtain any idea of your cat. Needless to say that for stud purposes a cat should possess the highest possible qualifications of the breed to which he belongs, and a massive frame and broad head are most desirable in all stud cats. It is a good plan to allow the visiting queen to be within sight of the male for a short time before she is put in the stud cat's house, and for this purpose it is convenient to have a small movable pen or hutch to place where the two pussies can hold catty conversation.

A stud cat cannot, for many and obvious reasons, be allowed his full freedom; but it is essential that his dwelling place should have as long and roomy an exercise ground as possible. It is also possible with some male cats to tether them out of doors for a short period during the day, in which case great care should be taken to have the lead only as long as will permit of exercise within a safe distance of dangerous pitfalls or spreading trees and shrubs. The best time for mating is about one hour after feeding.

It is most important that stud cats should be in good coat at the time of mating, and that they should be free from worms.

The usual fee for a visit to a stud cat is £1 1s., and this should be sent at the same time as the request for permission to send a queen. A second visit is generally considered allowable if the first one has proved unsuccessful. An additional amount of food may be given to a cat whilst he is being used at stud, and always remember to provide grass in some form or other in your stud cat's house.

There is no universal remedy for all cats, neither can there be any rule for feeding them. Different cats need different treatment, and those which are kept in a captive state, as are stud cats, should not be fed on the same lines as those that are allowed full liberty.

NEUTER CATS.

Opinions differ as to the best period for a cat to be made neuter, but it is generally considered advisable to have the operation performed between the ages of five and eight months. A male cat can be kept as a household pet till he is about nine or ten months old without any unpleasantness, but after that period he must be relegated to an outside cattery or stud house. It is cruel to put off gelding a cat till he shows signs of wishing to mate. A duly qualified veterinary ought to be employed, and an anæsthetic used. The cat should be kept on a low diet for a day or two before and after the operation. It is very seldom that any evil effects ensue, and after a few days the puss is quite himself again. Neuter cats grow to an immense size, and the Persian varieties develop great length of fur, which is generally not shed so frequently or to such an extent as in the males and females. Neuter cats are very docile, and generally rather lazy and listless; for this reason they are not accounted such good mousers.

Female cats can also be rendered sexless, but in their case the operation is more likely to be attended with dangerous results. I have heard it stated that a female cat ought to be allowed one litter of kittens before being operated upon. There are not many very fine neuters on exhibition at our shows, and this fact may perhaps be accounted for by reason of fanciers picking out weedy and altogether below the mark specimens of their litters to be gelded because they do not consider them worth keeping to breed from. In this way several poor specimens of neuters are to be seen with indifferent markings, white spots, incorrect coloured eyes, and long noses. For a home pet there is, of course, nothing to come up to a fine neuter cat who will not roam, who does not attract amorous females, and who is content to lie for hours stretched out on the drawing-room rug or the kitchen hearth, the admired of all admirers. From the lips of many noted breeders of Persian cats who have been troubled by wandering males and prolific females, I have heard the exclamation, "I shall end by keeping only neuters!"

Cat owners in general, and lovers of neuters in particular, might do worse than agitate for more consideration to be extended to these grand pets at our leading shows, and I cannot help thinking that a neuter club or society might be formed to assist in this and other objects connected with the general improvement of our neuter cats.

[Illustration:

CAROLLING.

(_Photo: Mrs. S. F. Clarke._)]

[Illustration:

"IN A PLAYFUL SORT OF WAY."

(_Photo: E. Landor, Ealing._)]

CHAPTER IV. HOUSING OF CATS.

The proper housing of valuable stock is the first essential subject to be studied by the beginner in the cat fancy, and one requiring both careful thought and attention. For I do not hesitate to say that, of all the domestic animals, the cat is the most difficult to keep healthy and happy in the unnatural condition of total or partial confinement. Belonging to the feræ, its original and savage nature still shows glimpses, not wholly tamed, in its independence of character and its roving habits; while yet its civilised side shows the keenest appreciation of the comforts to be found in the home life. A house cat that enjoys its freedom to go out as it pleases, to climb the garden walls, and anon to lie in purring contentment before the kitchen hearth, is a creature ailing little. It is the pedigreed pets, in their luxurious prisons, that too often fall a prey to disease. To establish a cattery, therefore, that shall be a pleasure and a pride to the owner, and not a source of worry and grief over perpetual illness amongst the inmates, it is necessary in the very first inception to study the chief needs of cat nature.

Let us consider these in order. How our typical healthy cattery may be best arranged. It must be dry—was ever a cat yet seen of choice sitting in the wet? It must have ample space, both of houses and runs, and inducements for exercise—a well-branched dead tree sunk in the gravelled run is good, besides divers posts, shelves, and benches. Let the aspect be bright, with lots of sunshine. A cat is a devotee of the sun—it is the life of young growing things, and the greatest destroyer of disease germs; and it is very easy by coverings or the growth of climbing plants to provide temporary shade during the height of summer. For this last, nothing is better than that most useful and least fastidious king of climbers, the Virginian creeper, as it bestows its leafy shade just when required, and harbours no damp, as the growth of thick, tall trees is apt to do.

[Illustration:

A MUSICAL PARTY.

(_Photo: E. Landor, Ealing._)]

Lastly, let the outlook of the cattery be cheerful. Do not select a spot so far from the house life that the attendant who feeds and cleans is practically the only person the cats see in the twenty-four hours. A cat loves to observe, preferably from some secure high perch, whence it may see all that passes—to exchange greetings with the dogs, the gardener, the maids, the tradesmen coming to the door, and thus fill its imprisoned hours with interest. If you disregard this, and put your cats out of sight in some back yard, they will mope badly, and also grow very stupid.

These principal requirements being borne in mind, individual fancy of building and arrangement may follow. Every breeder of experience has his own ideas of best design, according to means and circumstance. If a cat fancier is fortunate enough to be able to disregard expense, he can indulge in brick houses with every appliance for comfort and elegance of construction. For others, who can supply a working plan, an intelligent local carpenter (when found) can do much. Occasionally, also, it is possible to convert a portion of existing stabling to very efficient uses. But I must advise the beginner, as regards this last suggestion, to be careful. If the stabling is modern, and possesses the main requisites I have already spoken about (of dryness, and space, and cheerful light), then all is, and will be, well. But if, as is often the case, the stable of temptation is old, perhaps unused for some years, is dark, with more than a suspicion of damp, and a very certain habitat of rats, then our fancier is emphatically warned against making any trial of it, short of pulling down and rebuilding. Let him rest assured, it would in the end mean the loss of money, time, care, and, most likely, breeding stock too, and certain ill-health among the poor inmates. I know a case in point where a cat fancier thus utilised a stable. A converted portion of old stabling that looked most desirable, and kept scrupulously clean, was used for a number of young kittens. Very soon a peculiar and most violent form of skin disease appeared amongst them, at first as mere scurfy patches, but

swiftly assuming the form of contagious fever, which spread with frightful rapidity, infecting every cat with whom they came in contact. Not until after many deaths, and the most cruel sufferings of those who struggled through the disease, was it at last discovered to be acute blood poisoning, produced by the exhalation of sewer gas from an old sewer running underneath the floors. Rats were probably responsible, either by gnawing through the pipes, or coming up into the cattery, themselves stricken with the foul disease.

The site of the cattery selected, the preparation of the ground may be advisable, certainly on all clay soils. To ensure perfect dryness, the top soil should be removed a foot or so and filled in with brick rubble or builders' rubbish. On this foundation, cement concrete or asphalt may be laid down. Personally, for runs and floors, I prefer the cement; it is easier to keep clean—a bucket of water can swill it from end to end, while it dries much faster than the asphalt. Asphalt in outside runs is apt to soften in the summer sun, and depress into holes, and within the houses the smell of the tar remains strong for some months. The cost of the two is much about the same, but in very damp situations the asphalt is preferable, as it prevents all ground-damp rising through.

Now to plan out a medium-size cattery that shall be simple in construction and not ruinous to the modest beginner, let us suppose we have at our disposal a fair length of brick wall—say 60 to 70 feet in length—facing south, on slightly sloping ground. Our first proceeding will be to level and render damp-proof by a foot of rubble, as heretofore suggested, a strip 11 feet wide and about 45 feet along the wall, and to surface this strip with cement or asphalt. Upon this, and against the wall, we will erect our houses, a long wooden shed with lean-to roof, divided into three main divisions by matchboarding partitions, and with a smaller house at either end, as shown in plan.

A, the sleeping-room; B, a playroom for queens and kittens; and C, the third apartment for kittening, or cats it is desirable to isolate awhile. The smaller houses at the outside ends reserved for stud cats. D, doors from one apartment to another of wood. The outside woodwork is of 1-inch feather-edged matchboarding, well-seasoned deal, a roof of wood, felted and tarred, being preferable to the use of corrugated iron, which is very hot in summer and very cold in winter; an annual dressing of sand and tar keeps the felt watertight for many years. Allow good wide eaves, and have gutter pipes all round. Inside, line the walls with wall felt, and limewash; or an inner lining of 1-inch matchboarding, allowing a two-inch space to be packed with sawdust, keeps the house very warm and dry.

For the brick back wall, ¼-inch matchboarding should be sufficient as lining. The dimensions of the sleeping-room, A, are 12 feet long by 11 feet wide, and a wire frame partition with door subdivides this again into two equal parts. Against the back wall, at a height of about 20 inches from the floor, runs a broad shelf 4 feet wide, having inch mesh wire netting frontage, half to open on hinges, and movable wooden partitions sliding in a slot; these for the sleeping-pens, each 4 feet deep by 3 feet wide, two on either side the wire frame partition, or convertible into one 4 feet by 6 by removal of sliding wooden division. It will be warmer for the occupants if these pens are roofed in at a height of 3 feet. Cover the bench with oilcloth before putting up the divisions. This can be washed over daily if necessary, and will dry in a few moments, thus avoiding the dangers of scrubbing wood in damp weather. As nothing offensive can soak in, a pure atmosphere is preserved, and risk of infection is greatly minimised.

A comfortable sleeping box or basket should be provided for each pen, filled in winter with plenty of sweet hay, and in summer with sheets of newspaper or brown paper. A cat loves to repose on paper, and it has the advantage of being cheaply renewable and easily burnt after a day or two's use. Never use old packing straw for bedding. It is frequently full of infectious germs, and many skin complaints have been traced to its use. Neither are cushions, blankets, old bits of carpet, matting, etc., to be recommended. They are apt to become damp in prolonged wet weather, and retain both dirt and odour. A sanitary tin to hold dry earth or sawdust should be placed in each cat house, emptied and washed out every morning by the attendant, when the floors are also swept out or washed over.

A fair-sized window, to open, must be in the front, and a door, the upper half of which might also be of glass, to open out into a gravel run. Outside wooden shutters for cold nights are a great help in keeping the house warm, and should be provided.

Having arranged our first room, the playing room, B, next must come under consideration. This being the central division, the felt lining could here be dispensed with, and instead the boards can either be plainly stained and varnished—which is also easy to keep perfectly clean—or Willesden damp-proof paper might be nailed over the walls. This paper, made at the Willesden Company's works, Willesden Junction, N.W., is made in several good colours for interior lining, and a house so hung looks very comfortable, and shows to advantage such mural decorations as show prize cards, photos of winners, etc. The frontage of this room is to be entirely glazed, in small panes set in a wooden framework, with a 6-inch high weather board at floor to protect from draughts, the

glass protected on the inside by wire netting fastened over it. A window here to open outwards with a bolt, and fairly high up, to ensure fresh air in rainy weather without the wet and damp driving in on a level with the cats; a half-glass door also to run, but no outside shutters will be here needed, the cats not occupying this room at night. Cover the asphalt floor with linoleum or oilcloth, and put up some shelves 15 inches wide, fairly high up, but within leaping distance, against the walls; a movable bench too, to place the cats upon for brushing and attending to them. Old chairs that can be spared from the house might end their service here; or if the luxury of a plain wicker chair could be permitted, and furnished with one or two cushions in washable slip covers, it would be as pleasant for the owner when making her visits as for the pussies themselves. A ball for the kittens, a reel hanging from a string, will stimulate healthy romps, even amongst the staid grown-up cats, when weary of indoor dozing.

Room C. C is primarily intended for the interesting occasions when new little prize-winners are expected. This is subdivided by wire as in sleeping-room, but the partition three feet from back wall should be of wood, to ensure privacy to the anxious mother, and to temper the light; oilcloth on floor.

For the littering nests themselves I describe, and advise my friends to make trial of, the following plan. Have a sort of shallow wooden box, or tray with sides, made about 4 feet 6 inches long by 24 inches high and 4 inch sides. This is stained, varnished, and mounted on wooden feet at the four corners about two inches high; a good bed of hay is put in it, the box is put in a quiet corner away from the light, and a truss of new straw placed upright at one end of the box, leaning against the angle of the wall. A little of the straw at the bottom may be pulled out to suggest the idea of a hole to the cat; but as a rule she takes to the notion brilliantly, and will set to work to dig out a nest for herself with the greatest zest. In this the kittens are born, safe in a cosy nest at the end of a tunnel of straw. There is ample ventilation; they are protected from all draughts, so that doors may be left open to the fresh air with impunity; and they are in the dark, as kittens naturally should be till they walk out into the daylight of their own desire to explore the world. Then the rest of the tray forms a glorious playground for the first week or two, when one adventurous mite finds out he can climb up the shallow sides, and tumble out on a large strange world of floor and trot after mamma. A well-known fancier tells me she has not had one litter with weak or bad eyes since she adopted the straw truss plan.

[Illustration:

THE IDEAL CATTERY.]

One of these trays might be placed each side of the wooden partition, and if necessary to shut a nervous or surly cat up with her family, one might be enclosed in a wire frontage with door, as the sleeping-pens were arranged. Let there be a good large window in this room, as the kittens, when running about, will want all the sunshine and air possible. This run should be of asphalt, for dryness and warmth, with plenty of play places arranged in it. An old barrel with the bottom knocked out affords great games, also the tree I have before spoken of; a tree-stump or two, or a heap of dry brushwood stacked in a corner, will supply those climbing and hiding holes kittens so greatly enjoy, and afford protection from winds.

A grass run and a gravelled one are designed in the plan, each having access to the other, and will allow the cats ample exercising ground according to weather. An oval flower-bed in the centre of the grass plot, planted with some evergreen bushes, is a good idea. It affords shelter, and the cats can dig in the dry earth. For the benches in the gravel run, an old outhouse door, painted and mounted on stout legs, makes a very good one, which the cats love to sit upon.

The stud houses are simple: a wired-in space of 12 feet by 11 feet contains a house with lean-to roof 4 feet by 8 feet long, fitted with sleeping bench and box, wired windows, door for attendant, and small trapdoor for cat. _En passant_, all doors should be fitted with good locks, and locked up after feeding at night is done. The stud run is gravelled, but a border of grass might be left on two sides—grass is such a necessity for cats in confinement, and they prefer to select it growing for themselves. The design here suggested is capable of either modification or extension. The plan can be enlarged to any extent. For instance, if desired, an attendant's cottage could be built at one end instead of the stud house, and comprise a special kitchen, and also an upper room, fitted with convenient pens for a hospital for the sick members—a very necessary adjunct to the cattery, as a sick cat should be at once removed from its healthy companions and kept in a place quite apart. More stud houses could be arranged at an angle on one side of the chief runs, or, if only a very few cats are intended to be kept, one of the divisions could be dispensed with, perhaps, and the dimensions of the other two made smaller. But whatever your ambitions may be, great or small, when you are about it have the work well done.

The heating of catteries is a rather vexed question, many famous breeders affirming that stock raised without it are healthier and harder; others maintaining that a certain amount of heat is a necessity for producing a good coat. A very experienced breeder once

told me the heaviest-coated kittens she ever bred were reared over some hot-water pipes, in a temperature of 70°! With adult cats having partial freedom and allowed to come into the house in severe weather, and with stud cats, I consider the no-heat plan decidedly the best; but I do not think it possible to rear young stock during the colder part of the year in an outdoor cattery without artificial heat. It is the damp of the English winter which proves so fatal, and damp cannot be kept out of the very best constructed houses except by the admission of dry heat.

Kittens that are cold will not play, and if you see them huddled together on a cold day looking listless and uneasy, instead of romping, be sure it is fire heat they need.

A thermometer should hang in each house, and the heat be carefully regulated by that, a minimum of 48° and a maximum of 55° being suggested. In houses where a flue is practicable, a stove of the Tortoise pattern is to be recommended, but it needs a high guard around it. For a long range of brick-built houses, an outside flue and boiler, with hot-water pipes running the length of the cattery, would be found of most service, as it maintains an even and medium warmth throughout, keeps the building perfectly dry, and can be stoked with less trouble. In small wooden houses, very excellent results are given by the use of an oil stove with hot-water apparatus, such as are supplied for small greenhouses. The lamp will usually burn twenty-four hours without attention, is un-get-at-able by the cats, who can neither singe their tails nor knock it over during the wildest gambols, and if kept clean and looked to with care will not cause the slightest odour. A quart of paraffin in one of these oil stoves will burn twenty-four hours, and heat a building 12 feet by 10 feet to 50°. Now, in concluding this little discourse upon catteries, the final word of advice is always to remember the importance of _absolute cleanliness_. There should never be the least offensive smell in the cattery, and if such be noticed on entering the houses in the morning, discover the cause and remedy it at once. And do not rely solely upon disinfectants to do this. Too frequently this is but overcoming a bad smell by a stronger, the evil remaining. A good and non-injurious disinfectant should always be used in the water for the daily cleansing of pans and floors, etc. Camphaleyne or Salubrene are both safe and effective, but disinfectants that contain creosote in any quantity, or carbolic, I do not approve of, except in cases of illness of an infectious type, when stronger measures are obligatory.

No dirty food dishes, no unchanged water, no soil of any kind, should ever be left about on flooring or bedding. Let your cattery be kept as scrupulously clean and sweet as a hospital, then will your cats thrive and kittens be healthy and sturdy.

[Illustration:

A LITTER BOX.]

Do not elect to start a cattery unless you yourself intend to bestow both time and trouble upon it. In this, as in every other occupation or hobby, the one golden rule is, “Whatsoever thy hand findeth to do, do it with all thy might.”

APPLIANCES.

In the preceding section on the cattery proper, I have not spoken of the very useful variety of portable houses which are now made a speciality of many firms, considering them more or less as accessories to the well-appointed cattery. But in small town gardens, where space is valuable and it is not convenient to build a large permanent structure, it is quite possible to succeed extremely well when two or three cats only are kept by using these portable houses. They also have the advantage of being removable and a “tenant’s fixture” in the event of leaving one’s house.

[Illustration:

A USEFUL CAT HOUSE.]

A very good house is one built by Messrs. Boulton and Paul, of Norwich (_see_ illustration). It is a very pretty and well designed structure, and would be exceedingly ornamental in a sheltered corner of the garden. In putting up, however, it should be stood upon brick piers to raise it at least four inches from the ground, or the wooden flooring would soon show damp. Cats kept in these small houses, it must be understood, should have their liberty at least a portion of every fine and dry day, the runs being wholly inadequate for a cat to be shut in continuously without further scope for exercise.

Another illustration is a handy portable hutch, intended to be used chiefly in a house or room, although it is also convenient for penning young kittens out of doors on a sunny day, the wire run preventing their straying away. It consists of a sleeping box and small wire run hooked on, and can be made at the cost of a few shillings.

[Illustration:

A PORTABLE HUTCH.]

The sleeping box is 24 inches long by 17 inches wide and 22 inches high, is raised three inches from floor by a false bottom, and has a large door at back opening with a brass catch. In front, two side-pieces reduce the entry to 12 inches. A handle screwed on the top of the box is convenient for carrying. The run is 3 feet 6 inches by 24 inches, made in four sections, two sides, top and end piece, all fitted and hooked together with 1-inch mesh wire netting that it may be easily taken apart for carrying or storing away. It makes a useful sleeping-pen, too, for young toms that are inclined to quarrel together, and so have to be shut up separately at night. All the woodwork is stained and varnished, and a square of oilcloth laid on the floor of the sleeping box.

The next appliance to be considered is a somewhat gruesome adjunct to the cattery, and belongs to the darker side of our hobby. In spite of every care, illness and death must enter now and again, when we are fain to retire worsted from the conflict with disease, and the wisest and kindest thing to do is to put our pet to sleep. The illustration given on the opposite page depicts a lethal box, as used at the Royal London Institution for Lost and Starving Cats at Camden Town, and is capable of holding twelve animals at a time.

Mr. Ward, the well-known feline specialist of Manchester, has patented a lethal box of more moderate dimensions. Mr. Ward, not yet having an illustration of it, kindly writes me the description as follows:—"The box inside is 15 inches by 12 inches by 12 inches. A sheet of glass is inserted in the lid, so that the operator may watch the process. The vapour—coal gas passed through chloroform—enters through a tube at end. Two minutes is sufficient time."

Fanciers, I think, will agree that this simple peace-giving box is not among the least of Mr. Ward's kindly ministrations to the cats he loves so well. Few amongst us can bear to see unmoved the terrible last pains of a pet who in its days of health delighted us with its beauty.

Feeding utensils we turn to next. For them nothing is more satisfactory than the unbreakable enamelled ware in white or blue—except, perhaps, for the water pans, for which it is scarcely weighty enough, and it not infrequently happens that a gay and frolicsome company of kittens will knock against them, sending them spinning, and the water is spilt upon the floor.

The circular, heavy glazed earthenware dishes, spittoon-shaped, and generally inscribed "Pussy," are excellent, and cannot be overturned.

Besides the plates and saucers for feeding, let the cats have also a saucepan of their own, a deep stewpan-shaped one of blue enamel, large enough to cook a sheep's head with biscuits. Cook will be far less prone to grumble at the necessary cooking for the cats—I speak here of a small cattery, when no attendant is kept—if her saucepans are not pressed into the service.

But see that all are kept scrupulously clean, nothing "left over" in the saucepan to become sour or tainted in hot weather; and after each meal is cooked, the saucepan should be boiled out with soda and scoured clean.

Earth tins. A great mistake made in these necessary items is having them too deep. I have seen an old zinc footbath supplied to two months old kittens with quite six inches of sawdust in it, and the owner wondered why she could not teach her kittens to be cleanly in their habits!

A 4 inch deep tray is quite deep enough, and this should not be filled more than two thirds full, or the cat rakes so much earth out on the floor. Neither do they require to be very large, as their weight when filled with soil makes them very cumbersome to move, and they get the more quickly knocked out of shape. The best size is about 17 inches by 14 inches and 4 inches deep, made in stout galvanised iron, with a rim round the edge, and these might be painted some light colour with Aspinall's enamel paint. (I advocate "light paint" as any dirt stains are seen at once.) They will then last free from rust, and can be washed out every morning. Two or three tins of smaller size—say, 12 inches by 8 inches by 21 inches—are suggested for kittens, or for placing in small pens in an emergency. Baking tins answer this purpose.

After washing, it is well to stand these trays in the air to sweeten, as if they smell disagreeable the cats will not use them.

[Illustration:

LETHAL CHAMBER, ROYAL LONDON INSTITUTION AND HOME FOR LOST AND STARVING CATS.

(_Photo: Cassell & Company, Limited._)]

Messrs. Whiteley supply these zinc tins, or they can be made by any local ironmonger to dimensions given.

Hot-water appliances. These are very necessary in the cattery, and should by no means be forgotten.

Many a sick cat's life has been saved, and the critical corner in an illness turned, by the timely comfort and strength bestowed by the hot-water bottle or bag, or even a brick made hot in the oven and wrapped up. In the event of winter litters, too, a hot-water bag should be always in readiness, in case it is advisable to remove the first-born kittens from the mother for a few hours. Heat will restore a seemingly dead kitten, as I have said before. The outside dwellers also, how they appreciate on a bitter winter's night the hot bottle or wrapped up hot brick to keep them cosy!

I know a luxurious stud cat who has a hot-water tin made to fit his sleeping box, which is filled by the maid every cold night and slid beneath his hay bed. Assuredly, there is no greater safeguard against winter's chills and changes of temperature than to provide for your pets sleeping warmly and comfortably at night. The hot-bottle plan has many advantages over the heating of the sleeping houses by stove or lamp during the night. It is better for the animals themselves, as the air is not exhausted, and they are not so prone to take a chill going from heated air to the outside rawness of a winter's morning. It is much safer, and it is also much more economical.

[Illustration:

SPRATT'S TRAVELLING BASKET.]

Personally I prefer the indiarubber bag to the old-fashioned stone bottle, and in the smaller sizes (which are quite large enough) are not much more expensive than the latter. If not filled too full, and wrapped in a washable cover—flannelette is very good—it can be laid flat under the hay, and the cat will remain upon it all night. In the case of a sick cat the cover should always be of flannel, to avoid any chill as the bag grows colder.

Then, in our list of appliances, proper travelling baskets must come under consideration. I say "proper" advisedly, for how heterogeneous is the collection of hampers, boxes, baskets—I had almost added bundles—one sees brought in by the officials during the receiving hours before a big show! Every variety of package, very many of which are exactly what they ought not to be. Some unnecessarily elaborate, polished wooden cases with brass fittings—handsome and durable no doubt, but far too cumbersome, and by their very weight inflicting much jar on the occupant when moved about; while others are a disgrace to anyone pretending to care about a cat or even to know what a cat is, many deserving to be straightway brought under the notice of the Society for the Prevention of Cruelty to Animals.

I have seen big heavy cats jammed into margarine hampers, a thin wicker receptacle whose sides slope inwards like a flower-pot, where the animal must have suffered agonies of cramp in a veritable chamber of "little ease." Others are sent weary distances in shallow, rough grocery boxes with a few holes bored for ventilation, subject to be thrown about in transit, first on one side then on the other, the lid perchance nailed on, giving thereby much extra trouble to the penning officials. Little wonder if the cat arrives bruised, shaken, frightened nearly to death, and very probably wild and savage.

Now, as evil is wrought by want of thought (and common sense) as well as want of heart, I have thought it well to comment on these very wrong and stupid ways of sending our cats on their journeys before advising better arrangements.

Here are two illustrations of excellent travelling baskets, which fulfil pretty nearly all requirements for cats travelling singly.

The first is made by Messrs. Spratt, and has an inner skeleton lid, which is much to be recommended when sending a vicious or very timid cat that is likely to make a bolt on the basket being opened.

The second, beehive shaped, is designed by Mrs. Paul Hardy, of Chobham. It is of strong white wicker, the lid fastening with a rim of about two inches deep over the body of the basket, apertures in the rim allowing the wicker loops of the fastenings to project; when the cane stick is thrust through these the basket is absolutely secure—not a paw can get out.

[Illustration:

A USEFUL CAT BASKET.]

[Illustration:

"A GANG OF POACHERS"—KITTENS BELONGING TO MISS ALICE DELL.

(_Photo: E. Landor, Ealing._)]

This beehive shape has several advantages. The cat can stand up and stretch itself at ease, when tired of lying down. The handle being at the apex, it is carried—even by porters—without the cat being tilted off its legs; whilst the dome top prevents any other package being piled upon it—a disadvantage the flat-typed hamper always has. I line my baskets outside with brown paper or oil baize up to the rim, and inside with curtain serge, leaving the lid free for ventilation. Then, with plenty of hay at the bottom of the basket, the cat will travel from one end of England to the other in comfort and safety, with no danger of taking cold even if left about draughty platforms or in parcel offices. This basket is made by Messrs. Bull, of Guildford, at a very moderate cost, and lasts for years.

These baskets are, of course, intended for one cat only, or a pair of kittens. A really safe and capable travelling arrangement for a litter with the mother has yet, I think, to be devised. I have seen none I think good. The double compartment hamper I much dislike. The handles are perforce at each end, necessitating two carriers—who never do it—so the hamper is dragged by the porter or official with one end tilted (the other cat being nearly upside down), is leant up against other luggage, or dropped flat with a bang. With young kittens inside this leads to fatalities.

A label for the travelling basket seems an insignificant item to mention, but an efficient one is as important as that proverbial nail for whose absence the horse and the kingdom were lost.

I have just made the acquaintance of a first-rate label, devised and sent out by a Mr. Foalstone, at sixpence per dozen, from the Aerefair Engineering Works, near Ruabon. It is a stout linen label, printed "Valuable Live Cat" in big block letters; below is "Urgent" in red—a good idea, red being more likely to attract the casual eye of the railway official. Spaces are left below for line of travel, _viâ_, etc., and date and time of despatch. It is reversible, so the sender can fill up with the return address if necessary. I always prefer to fasten the label down at both ends, flat to the basket: it is less likely to be torn away than when left hanging loose from one eyelet.

It is by due attention to the details that cat fanciers can to some extent mitigate the dangers and risks that must necessarily attend the transit of live stock by rail.

[Illustration:

WAKING BEAUTIES.

(_Photo: Mrs. S. F. Clarke._)]

CHAPTER V. EXHIBITING.

Amongst cat fanciers there is a laudable ambition not only to breed good stock but to exhibit it. Certainly there is vastly more gratification and satisfaction in obtaining high honours for cats and kittens that we have bred ourselves, rather than for those specimens which money has purchased.

If we consider that our cats have sufficiently good points to merit their being entered for a show, we must bear in mind that all the beauty and form and feature will be thrown away unless our pussies are in good show condition. For exhibition purposes condition means everything, and this is more especially the case with the long-haired breeds. A first-class specimen whose coat is ragged and matted cannot fail to suffer in the judges' estimation when compared with another cat, of inferior quality perhaps as regards points, but yet in the pink of condition, with its coat well groomed, its eye bright, its fur soft and silky. In the present day many of the specimens penned are so close together in point of breed merit that a very little turns the scale one way or the other. I have often said to myself, when judging a class of cats, "This exhibit would be a winner but for its condition," and I have had to put it down in the list. There is no doubt that with long-haired cats a fine full coat will cover a multitude of sins, but it cannot alter a long nose or poor shape and bad-coloured eye; and in urging the importance of condition, I at the same time deprecate the awarding of prizes to cats that have nothing to recommend them but their pelage. Seeing, therefore, that a handsome specimen may go to the wall for the lack of attention on the part of the owner, it behoves all cat fanciers and would-be exhibitors to do everything in their power to make their cats look their very best, so that their pets may be things of beauty in the show pen. In the dog, rabbit, and pigeon fancy a great deal more attention is given to condition than amongst cat fanciers, who need waking up to the fact that nothing goes so far

to propitiate a judge as superb show form and general good appearance. There may be standards of points for the guidance of the awards, but assuredly a common-sense judge will look with disfavour on a specimen with excellence of breed and correct colour of eye if his coat is draggled and matted, his tail dirty, and his fur soiled. We have only to run our minds back to the various exhibits of well-known fanciers at our large shows, and we shall find that the most persistently successful exhibitors have been those who have sent their cats to the shows in the best condition. Some fanciers, wishing to help on entries at a show, will exhibit their Persian cats when quite out of coat. This is a mistake; send your entry money if you like to the secretary, but keep your coatless cats at home. As regards the short-haired breeds, these cats should have coats with a gloss and brilliancy like that of a well-groomed horse, shining like satin; a spiky appearance in the fur denotes poor condition in both long and short breeds.

In getting cats ready for exhibition owners should look to their comforts in every way. Their houses and beds should be kept clean, their coats combed and brushed daily. Attention should be paid to their ears, for if these are neglected a cat will continually scratch them, and thus injure its appearance by tearing out its fur. Some fanciers are in favour of washing their cats, but when we take into consideration the usually delicate constitutions of Persian cats, and the restless, impatient nature of these animals, it behoves us to try to find some other effectual means of cleansing their coats, which in the case of white and silver cats are naturally easily soiled. Experience has taught me that very good results can be obtained by damping the coats with a soft cloth dipped in a weak solution of ammonia and water. Follow this up by rubbing some white powder into the fur and well fingering the parts that are at all greasy. Pears' white precipitated fuller's earth is the best preparation, and is perfectly harmless. To clean away the powder use a fairly soft brush, and after this process has been gone through several times your cat will be fit for show. Another method of cleaning long-haired cats is to heat a quantity of bran in the oven. Put it into a large bowl or footbath, and stand the puss in it. Rub the hot bran well amongst the fur for some minutes, and afterwards carefully brush it out. This treatment will give a soft and silky appearance to the coat, but for light-coloured cats the powder is more cleansing.

Cats require to be educated to the show pen, and it is very necessary in some cases to give a course of training. For this purpose it is well to obtain a similar pen to those used at shows, and to place your puss in this for an hour or two daily. In time he will learn to come and sit and look out of his temporary prison, and when he makes his _début_ he will not spoil his chances by crouching at the back of the show pen, or vex his would-be admirers, who may have recourse to the use of an umbrella or stick to make the exhibit move into a more convenient and conspicuous position.

Taking it for granted you have decided to send your cat to a show, the first step is to register it in the club under whose rules the show is to be held. At present the National Cat Club and the Cat Club both require separate registration, the charge being one shilling. It is, however, to be hoped that the earnest wish of all cat fanciers and exhibitors will ere long be fulfilled, and that one register will be kept by an independent person, so that pedigrees can be verified and mistakes rectified, and the confusion caused by a double registration will cease to worry and perplex the cat-loving community. Registration forms are supplied by the secretaries of the respective clubs, and you must fill in the particulars of your cats as set forth on the forms, a sample of which is here given, together with the registration rules of the National Cat Club:—

REGISTRATION.

The registration rules of the National Cat Club are as follow:—

1. Every Cat exhibited at a show under National Cat Club Rules must (except such as are exhibited exclusively in Local Classes, or exhibited in Classes exclusively for litters of kittens), previous to the time of entry for such show, have been entered in a registry kept by the National Cat Club at their offices. A charge of 1s. each shall be made for registration. In such registry shall be inserted the name and breed of the cat, and its breeder's name, the date of birth, names of sire and dam, and of grand-sires and grand-dams, and if the dam was served by two or more cats their several names must be stated. If the age, pedigree, or breeder's name be not known the cat must be registered as breeder, age or pedigree "_unknown_," any or all, as the case may be. If the name of a cat be changed, or an old name re-assumed, such cat must be again registered and identified before exhibition in its altered name.

2. A name which has been duly registered in accordance with Rule 1 cannot be again accepted for registration of a cat of the same breed, without the addition of a distinguishing number, prefix, or affix, for a period of five years, calculated from the first day of the year next after the one in which the name was last registered; but the name of a cat after publication in _"Our Cats" and the Stud Book_, or which has become eligible for free entry therein, cannot again be assumed.

N.B.—The name of a cat that has become eligible for free entry in the _Stud Book_ in any year shall not be changed after the 31st of December of that year.

Cats do not receive a number on registration. Numbers are only assigned to Prize Winners or cats entered in the Stud Book on its publication, on payment of a fee of Five Shillings, in addition to One Shilling for registration.

The application for registration must be made on a form as follows:—

NUMBER OF BREED AS PER LIST IN MARGIN____COLOUR____

I wish to register the following __ (_Sex_) by the name of____

Previously registered by the name of_____

_Signature of Owner_____ (Mr., Mrs. or Miss)

_Address_____

LATE OWNER (if any)_____

SIRE_____ } G. SIRE_____ } OWNER OF SIRE___ } G. DAM_____

DAM_____ } G. SIRE_____ } OWNER OF DAM____ } G. DAM_____

DATE OF BIRTH_____

NAME & ADDRESS OF BREEDER_____

_____

NOTE.—If this name cannot be registered, I select one of the following, and name them in the order named: (1) _____ (2) _____ (3) _____

Only one cat must be entered on one form, which must be forwarded with a remittance of one shilling to Mrs. A. Stennard Robinson, Hon. Sec., at 5, Great James Street, Bedford Row, London, W.C.

The various varieties as recognised by the Club are as follow:—

SHORT-HAIRED CATS.

1. SIAMESE.

2. BLUE.

3. MANX.

4. FOREIGN.

5. TABBY.

6. SPOTTED.

7. BICOLOUR.

8. TRICOLOUR.

9. TORTOISESHELL.

10. BLACK.

11. WHITE.

12. SABLE.

13. TICKS.

14. ABYSSINIAN.

LONG-HAIRED CATS.

15. BLACK.

16. WHITE.

17. BLUE.

18. ORANGE.

19. CREAM.

20. SABLE.

21. SMOKE.

22. TABBY.

23. SPOTTED.

24. CHINCHILLA.

25. TORTOISESHELL.

26. BICOLOUR.

27. TRICOLOUR.

It will be seen that you are requested to give more than one name, and it is very desirable in the first instance to select an uncommon one, which may be considered your cat's exhibition title, but you will doubtless have some short pet name for home use. A prefix, probably the name of the town or village in which you live, can be used to specially identify your cat. For this an extra charge is made. It is well to fill in the pedigree as far as possible, and every exhibitor should strive to obtain correct particulars of date of birth and name of breeder of the cat to be exhibited. It is a pity to label your cat "unknown," if with a small amount of trouble exact details can be obtained. At any rate, it is important to state the names of the two parents. The age of kittens should be counted by months—that is, say, from the 20th to the 20th. Having registered your cat, you receive a notification of such registration, and whether you are intending to exhibit or not it is very necessary and advisable that your cat should be duly registered in at least one of the parent clubs.

A separate fee is charged for each cat or kitten in each class, and the amount must be forwarded at the same time as the entry is made. The following is a copy of the entry form used at the Cat Club's Show at Brighton in 1901, and I may mention that the fee for registration has since been raised from 6d. to 1s.:—

+----------+----------+ | _ENTRIES CLOSE MONDAY, NOVEMBER 4TH, 1901._ | Class as per Schedule. | | | | | BRIGHTON CHAMPIONSHIP SHOW OF THE CAT CLUB, | No. | | TO BE HELD AT | | | MELLISON'S HALL, WEST STREET, BRIGHTON, | | | ON WEDNESDAY AND THURSDAY, NOVEMBER 13TH AND 14TH, 1901, | | | Under the Exhibition Rules of The Cat Club. | | +----------+----------+ | RULE AS TO REGISTRATION OF NAMES OF CATS AND KITTENS. | Also Entered in Classes | | | numbered as per | | Every Cat or Kitten exhibited at a Show under The Cat | Schedule. | | Club Exhibition Rules MUST be Registered at the Cat Club.| | | Fee 6d. | Nos. | | | | | Every Cat or Kitten which may have changed ownership | | | since Registration MUST, before Exhibition, be | | | Transferred to its new owner in the books of The Cat +----------+ | Club. Fee One Shilling. | Please not to write in | | | this space | | To change the name of a Cat or Kitten, when allowable, | | | the fee is One Shilling. | | | | | | _See The Cat Club Exhibition Rules, Nos. 1 to 6,_ | | | _in the Schedule._ | | +----------+----------+ | CERTIFICATE OF ENTRY. | Kindly fill in the | | | amount enclosed for | | I hereby Certify that the Cat or Kitten to be exhibited | for Fees, &c., as | | by me as below is _bona fide_ my property, and I enter it| under:-- | | at my own risk, subject to the Exhibition Rules of The | | | Cat Club, and the Regulations of this Exhibition as | | £ | s.| d.| | arranged by the Committee. | Cheque | | | | | | | | | | Has this Cat been Registered at The Cat Club | Post Office | | | | | (_see note above_) ---- | Order | | | | | | | | | | | Has this Cat been Transferred (_if purchased_) to | Postal | | | | | yourself as owner in the books of The Cat Club | Order | | | | | (_see note above_) ---- | | | | | | | Cash | | | | | Name of

Exhibitor (in full) ---- | +----------+ | (Title, Rev., Mr., Mrs., or Miss. _See Rule 3._) | Total £ | | | | | | +----------+ | Address ---- | | | +----------+ | Name of Cat or Kitten (as registered at | | | The Cat Club) ---- | | | (If in Stud Book, add number.) | | | | | | Breed ---- Colour ---- | | | | | | See { Date of Birth ---- Sex ---- | | | Exhibition { (Male, Female or Neuter.)| | | Rules { Breeder ---- | | | 1 to 6 { | | | of The { Sire ---- | | | Cat Club { Dam ---- | | | in the { | | | Schedule. { Prizes won ---- | | | | | | Particulars must be given as registered at The Cat Club. | | | | | | Price £ : : (_If for Sale._) _Date_ ---- 1901. | | | | | | N.B.--No MILK will be given to any Cat or Kitten unless | | | specially requested here----. Water will be provided | | | otherwise. | | | | | | ONE FORM IS SUFFICIENT FOR ONE CAT OR KITTEN IN ANY | | | NUMBER OF CLASSES. | | +----------+----------+ | No Entries will be accepted without Fees. | | Postage Stamps taken Thirteen to the Shilling. | | | | Exhibitors are particularly requested to write distinctly, and also to be careful | | to name correctly the Class in which they intend to exhibit their Cat or Cats. | | | | All Correspondence and Entries to be addressed to Miss F. SIMPSON, Durdans House, | | St. Margaret's-on-Thames. | +----------+

The exhibiting rules should be carefully studied, and intending exhibitors must pay great attention to the classification set forth the schedule so as to determine the correct class in which to enter their cats. If there remains any doubt in the mind of the novice, then it is best to consult some reliable and well-known breeder, giving a full description of the cat you wish to show.

It is a grievous disappointment if through ignorance or carelessness a good specimen is labelled "Wrong class."

It is always stated in the schedules that the entries close on a particular date, and that after this none can or will be received. Experience proves, however, that this is often not a law of the Medes and Persians, for the date is frequently of an elastic nature, and therefore it is always worth while for an intending exhibitor to write requesting that, if possible, his entry may be received, although it is forwarded after the advertised time of closing. Many exhibitors are not aware that by paying an extra shilling they can generally secure a double pen for their cats. It is not usual for the secretary of a show to send a receipt for entries and fees, as the tallies and labels which are forwarded later serve as an acknowledgment for these. When by any chance labels, etc., are not received in time to be used by exhibitors, or they are lost or mislaid, then the hampers should be addressed to the secretary of the show, and a note of explanation enclosed. The entry can then be looked up, and the pen number discovered. If cats are entered in joint names, then it is desirable that the owners should let the secretary know to whom to send the labels and tallies, as if these are only forwarded a day or two before the show to the partner who does _not_ keep the cat, complications may arise. If litter classes are provided at a show, it is well for the intending exhibitor to send the whole litter, as the number of the family is taken into consideration in judging, and perhaps a large litter of six may take over a smaller litter of three, even though the quality of the trio is in advance of the larger family. As regards pairs of kittens, I would say select two kittens as near alike as possible in colour, size, and quality; they need not be of the same litter, but it is as a "pair" they will be judged, so if one exhibit is much inferior to its fellow then the value of the pair is seriously diminished. A defective eye or damaged tail will tell against a cat or kitten in the show pen, therefore it is useless to throw away entry fees upon these blemished, though perchance dearly loved, creatures.

[Illustration:

RICHMOND CAT SHOW: ARRANGEMENT OF TENTS.

(_Photo: Cassell & Company, Limited._)]

The question of ribbons to suit the colours of the various cats is one deserving of consideration. Many exhibitors make the mistake of using broad ribbons and making very big bows, but both long and short-haired cats present a neater appearance with narrow ribbons, and the bow should be stitched in the centre, so that it cannot come undone and thus give a dishevelled appearance to the puss. The metal tallies will hang more gracefully round the neck if a slip ring is run through the hole of the tally and then the ribbon is put through the ring. Cushions and hangings for the pens are not at all desirable, even if they are permitted. They collect germs and become offensive, and moreover it is much better that all exhibits should be placed on the same footing—namely, a bed of hay or straw.

If owners are unable to accompany their exhibits to the show, it is more than ever necessary that secure, comfortable, and safe travelling boxes or hampers should be used for the transit of the cats. It is not advisable, nor is it generally allowable, for more than one cat to be sent in a hamper to a show.

The question of hampers and travelling appliances has been dealt with in a previous chapter, but I would earnestly impress upon exhibitors not to send their cats away on journeys, long or short, in tumble-down hampers and unsafe packing cases. Whether

hampers or boxes, I would here suggest that whichever is used let the fasteners be secure and yet easy to manipulate. Straps should be attached to the box or hamper, as in the confusion and hurry of show work these, if left loose, may get mislaid. The labels should be so arranged that they may be conveniently turned over for the return journey, where, on the reverse side, ought to be the owner's name and full address. It is most important that these should be distinctly written. I recommend all exhibitors to insure their cats when sending them to a show. The charge is 3d. for every £1, and having paid our money we take our chance, which is perhaps a less hazardous one than if this precaution had been neglected.

The arrangements, or rather want of arrangements, as regards the transit of live stock on our railways leave much to be desired, and therefore it behoves fanciers and exhibitors who value their cats for their own sakes and for their intrinsic worth, to do all in their power to mitigate the discomforts of a journey and the risks that must necessarily attend the conveyance of live stock by rail. Some fanciers make it a rule never to exhibit unless they themselves can take and bring back their cats, and though this necessarily entails a great deal of trouble and some expense, yet there is an immense satisfaction in feeling our pets are under our own supervision. There is also an advantage in penning your own cats, and if you arm yourself with a brush and comb you are able to give some finishing touches to pussy's toilet previous to the judges' inspection and awards. Let me recommend a metal comb, and a brush such as is used for Yorkshire terriers, which has long penetrating bristles, but is neither too hard nor too soft.

Disqualification of cats or kittens at shows may arise from various causes. First, if the cat has not been registered, or if it can be proved that the animal has not been in the possession of the exhibitor for fourteen days before the show, or if a wrong pedigree has been given, or the date of birth of a kitten is incorrect. Any attempt at "faking" will disqualify an exhibit, and in some cases the too free use of powder on white and silver cats is a disqualification in the eyes of some judges. Exhibitors have been known to dye the chins of tabby cats and treat white spots on self-coloured cats in the same manner. Such "faking," as it is popularly called, is always risky, as well as a most undesirable operation, and if resorted to ought not to be passed over by a judge who might detect the artifice and yet lack the moral courage to expose the offender. Let me warn exhibitors against the evil practice of over feeding their cats at shows. It is so much better for a cat to starve for two days than to overload its stomach with the plentiful supplies brought by an over-anxious exhibitor. The sanitary arrangements at present existing at cat shows do not allow of such a course, and if one meal of raw meat and plenty of fresh water is supplied by the show authorities pussy will fare much better than being stuffed with a variety of dainties brought in paper bags.

[Illustration:

MRS. GREGORY'S "SKELLINGTHORPE PATRICK."

(_Photo: W. J. Smith, Lincoln._)]

Whilst the inmates of your cattery are attending shows it is a good opportunity to give an extra cleansing and airing to their houses, and on their return be careful to destroy the hay or straw contained in the hampers or boxes, and thoroughly disinfect these, leaving them out in the open air for a day or two before packing them away. It is generally advisable to give a slight aperient to grown cats after they come back from a show, for it often happens that these cleanly creatures refuse to make use of the scanty accommodation provided for them in the show pens, and thus complications may arise unless attention is paid to their wants on their return. If many cats are kept, and some are sent to a show, on no account allow these to mix with your other animals on their return. It is a wise precaution to keep them apart for a few days, more especially if you have young kittens to consider.

The prize cards should be returned in the hampers when sent back to exhibitors. If these are soiled or broken on their arrival, a request to the secretary asking for fresh ones will probably be attended to.

Every member of a cat club and exhibitor at a show has a right to lodge a complaint with the secretary and committee of the club under whose rules the show is held, if an injustice has been done to an exhibit in the opinion of the exhibitor. According to the rules a deposit has to be paid, which can be reclaimed unless the complaint is considered "frivolous."

Show promoters cannot afford to give their money away without some return or provisional stipulation, and therefore fanciers must not complain if when a class does not fill it is either amalgamated or only half the advertised prize money is given. This latter plan is by far the more satisfactory. There has probably never been a show of any live stock held where complete satisfaction has been given; but, generally speaking, "grumbling" is a most mistaken and pernicious habit, and exhibitors should strive to become good losers. If they cannot learn this lesson, then the remedy remains in their own hands, and they had better keep their cats at home rather than run the risk of being disappointed themselves and of causing unpleasantness to others. If a judgment is obviously

wrong, then the triumph is with the best cat, and we should take our defeat in a sportsmanlike manner.

[Illustration:

"INQUIRY."

(_Photo: Mrs. S. F. Clarke._)]

In July, 1902, a cat section in connection with the annual dog show was held in the Old Deer Park, Richmond. This proved a great success, and entries numbered over three hundred. A few words in description of this show may be appropriate here, especially in view of the photographs (specially taken) which illustrate this chapter.

Its chief features were the twenty-five entries in the litter classes and the ring class for neuters only. Objection is often made to litter classes, and yet these are certainly the most attractive. I think that double pens should be provided, and special food ought to be supplied for the little ones. It stands to reason that very young kittens cannot be fed like the grown cats, and it is only natural that if big pieces of meat are thrust into the pen for the mother the hungry little creatures will make a rush for it. They bolt down the hard lumps, and these remain undigested in their tender little stomachs. It is not to be wondered at if gastritis, inflammation, and other distressing ailments supervene. It is much better to let the mother do without her usual meat rations and content herself with good, nourishing baby food, such as Mellin's or Ridge's, rather than run the risk of providing her with such which will injure her little kittens. With ordinary supervision no evil consequences should ensue from the introduction of litter classes, especially at a one day show. It is not, however, advisable to have litter classes at shows held during the winter months. But in perfect, warm weather no fatalities will be reported. Certainly the mothers with their families prove a great attraction, and as woollen balls, attached from the top of the pens, are provided for the amusement of the kittens, they delight themselves and their audience with their playful frolics.

The ring class for neuters _only_ was an innovation and proved very successful, and although some of these pet pussies declined to show themselves off to the best advantage, yet they did not "go" for each other as is sometimes the case when the males are within measurable distance of each other. The illustration given is from a photo specially taken for this work, and shows the judges deliberating on the respective merits of the neuter cats. On this occasion a famous Blue Persian owned by Madame Portier carried off the honours. He behaved very well on the lead, and his grand shape and wonderful coat made him an easy first.

Another illustration shows the judges at work awarding the special prizes, which in many cases have to be decided conjointly. Miss Frances Simpson and Mr. C. A. House are comparing notes and determining which of the first prize kittens is deserving of the special for the best in the show. On this occasion Mrs. Bennet, a well-known breeder of Blue Persians, was awarded the coveted prize.

A general view of one of the rows of pens is given, but on this particular occasion no covering was supplied for the benching, and, therefore, the aspect of the show pens leaves much to be desired. The travelling baskets being placed under the pens, these should be hidden from the public gaze in order to give a neat and tidy appearance to the show. The best material for this purpose is red baize. The custom of allowing exhibitors to pen their own cats enables them to give their pussies a final brush up before they are subjected to the critical examination of the judge. Our illustration represents Mrs. Peter Brown, a well-known breeder of Blue Persians, attending to the toilet of her beautiful "Bunch," who on this occasion repeated her successes at the Botanic Gardens, and carried off the highest honours in the Blue Female Persian class (_see_ page 73). And now to pass on to another portion of our subject.

JUDGING.

A standard of points for all long and short-haired cats was drawn up by a sub-committee of the Cat Club, of which I was a member; but since specialist clubs have come into existence, having each their own list of points, nothing much has been seen or heard of the Cat Club's standard. It is just as well to have some definite lines upon which fanciers and exhibitors may base their ideas, and so aim at, if they cannot attain to, the height of perfection set forth in these standards. They are really not meant for judges, because I venture to assert that a judge is no judge if he requires anything besides his own personal conviction, experience, and common sense when called upon to decide the various points in the different breeds. A good judge of old china will not search for the mark to know whether the specimen is Chelsea or Worcester. He will tell you "it is marked all over"—that is, he knows a good bit of stuff, even if it should not have the gold anchor of Chelsea or the square mark of Worcester ware. So it is with a good all-round cat. It appeals at once to the eye of the connoisseur, just as a worthless specimen is at once put out of the ranks of winners.

[Illustration:

RICHMOND CAT SHOW: JUDGES AT WORK.

(_Photo: Cassell & Company, Limited._)]

It is the greatest error not to have thorough confidence in oneself when undertaking to judge cats, or, in fact, in judging any animal, or any thing. No one should undertake to judge if they wish to seek the counsel of others. They must have the courage of their _own_ convictions, and, although some amount of training may be required, I think that judges are born, not made; and people who have not a keen power of observation and a faculty of coming rapidly to a fixed conclusion can never hope to become satisfactory or competent judges. There are many cat fanciers on whose judgment of a cat I should implicitly rely, and who know a good specimen when they see it, but if placed before a row of twenty or thirty cats of a breed they seem to lose their heads and get hopelessly confused, and then the reporter says, "We could not follow the awards." There is no doubt that judges of cats are severely handicapped. Firstly, cats are such terribly timid, shrinking animals that when dragged out of their pens with great difficulty—for the doors are most inconveniently small—they often struggle so violently that, for fear of hurting the animal or of its escaping, the judge will swiftly restore it to its resting place without having obtained much satisfaction from his cursory examination. Unless judging pens are provided, there is really no chance of making fair comparisons between two cats which may appear of almost equal merit. How is a judge to decide on the form of limbs and general build of a cat when holding it in his arms or seeing it huddled up at the back of its pen?

An agitation is now on foot for having cats judged in a ring, and, no doubt, in time this will be the order of the day at our shows; but fanciers will have to train up their cats in the way they should go—namely, when quite young they must be accustomed to a lead and also be constantly brought out amongst strangers. As an example, I would refer to the starting gate recently introduced into this country on the racecourse. It was no use to attempt it for the old stagers, but trainers soon accustomed the two-year-olds to the innovation, and I believe many, if not all, the objectors are now converted to the new system of starting racehorses.

[Illustration:

TYPE OF CAGE AT THE RICHMOND CAT SHOW.

(_Photo: Cassell & Company, Limited._)]

In judging a class, I first go round and mark the absent cats; then I note down those that could not under any circumstances take a prize. If there is a large class—say, of twenty to thirty specimens—I mark off all poor and seedy-looking cats until the number is reduced to about eight or ten; then I begin to search for the winners. At this point I take out each specimen, and, if no judging pen is provided, I get someone to assist me, and by bringing out two cats at a time I can make comparisons and note down any remarks in my book for further reference. It often happens that one particular cat will stand out prominently from all the rest in a class, and then there is no difficulty about the first award. It is always well to give a "reserve" and to distribute—but not too freely—the V.H.C., H.C., and C. cards. It does not do to make these too cheap, and scatter them all over the class. V.H.C. might be awarded to a cat in splendid coat, but which failed in head and eyes; H.C. to another specimen with hardly any coat and poor head, but correct in eye; and C. to a promising youngster without any serious fault, only with no striking point of merit. A good judge must thus weigh the pros and cons and have a reason to give himself or anyone else for each degree of merit, from first prize to the humble C. And here I would mention that there is a nice and a very nasty way for an exhibitor to question a judge's award. To be attacked suddenly with the query, "Why have you not given my cat a prize?" is quite enough to make a judge retire into his shell and refuse any explanation; but if asked to kindly give a reason why a certain animal has failed to win, and to explain why one specimen, apparently a fine cat, should be lower than another, I am sure any judge would gladly give the inquirer the benefit of his larger experience and the reason for his awards. It is a mistake for a judge to distribute the full complement of prizes in a class when and where the exhibits are not possessing of sufficient merit. A first prize cat should be a good specimen of its kind, and it is much better to withhold this award than to give it to a poor representative of his breed. It also reflects discredit on a judge, for an exhibitor wishing to boast of his honours may publish that his "Tommy Atkins" took first under so-and-so, when perhaps there were only two cats in the class. It is quite legitimate for a judge to ask permission of the show authorities to award an extra prize in a large class with several fine specimens; and if he has withheld others in a poor and badly filled class then there is no extra burden put on to the funds of the club. A great deal should be left to the discretion of the judge, and in the matter of special prizes, if one is offered for, say, the best long-haired white cat, and only one or two specimens are on show, and these are neither of them good types of this breed, then the judge should be empowered to withhold the prize. Such a course may be an unpopular one, but I am sure it is the

correct and fairest one, for it is a farce to award first prize and specials to an inferior animal just because he happens to be without other competitors. Anyone who has judged the large classes of blues and silvers which now appear at our principal shows will bear me out in my suggestion that such classes, numbering perhaps thirty and more exhibits, should be subdivided according to age. Such an arrangement would be welcomed by judge and exhibitor alike. At the Crystal Palace Show in 1901 the blue kittens numbered thirty-nine in the class, male and female, the age limit being three to eight months. How could a judge be expected to satisfactorily award three prizes in such a huge class? And I know that many superb specimens on this occasion had to be content with a V.H.C. card, which it would have gone to my heart as a judge to place on their pen.

[Illustration:

MR. C. A. HOUSE,

EDITOR OF "FUR AND FEATHER."

(_Photo: A. & G. Taylor._)]

[Illustration:

MR. T. B. MASON.

(_Photo: C. L. Eastlake, Leeds._)]

If there is a prize offered for the best cat in the show, the judge or judges have not to consider which is their favourite breed or which is the most fashionable colour, but just which cat is the best possible type, which specimen is the nearest perfection, and which is exhibited in the best all-round show condition. In long-haired classes the length and quality of coat and fulness of ruff go a long way towards a high place in the awards, and, as I have before remarked, condition is a most important factor in the judges' estimation. In the self-coloured classes of blues and blacks a judge should make diligent search for white spots on throat or stomach. Formerly cats thus blemished were relegated to the "any other" class, but it has been wisely decided by both clubs that cats with white spots should be judged in their own classes, and that this defect should count as a point or points against them. This is as it should be, for to place self-coloured cats in an "any other colour" class seems absurd. They are black and blue cats in spite of a few white hairs, and should be judged as such. They may never aspire to a first prize, at any rate at a large show; but surely a really fine black or blue cat, with correct eyes, grand head, and good shape, even with the unfortunate spot, should and ought to score over a poor specimen with green eyes and long nose. In the tabby classes a judge will first consider the ground-work and markings, and to these premier points special attention should be given, as there is a tendency to breed tabby cats which are barred only on heads and legs, the body markings being blurred and indistinct. It is not unlikely that in due time the "any other colour" class will no longer form part of the classification at our large shows. Formerly this used to be the largest class of any, but nowadays the entries are becoming small and beautifully less. It is not worth while for a fancier to keep these specimens—they do not fetch any price, they are not valuable as breeders, and it is quite a toss-up whether they can win in such a mixed company. I remember the time when blues were entered in the "any other colour" class, and when blue tabbies were more numerous than silvers or blues. It is really a most difficult task for a judge to give his awards at a local show where all sorts and conditions of cats are placed in the one class. Such an arrangement is good for neither man nor beast. And then, again, at our large shows it behoves a judge to be very level-headed to cope with the numerous brace, team, and novice classes, for one cat may be entered in all these, besides being in the open cat and kitten class; and woe betide the unfortunate judge who makes a slip, for the wrath of the exhibitor and the sarcasm of the reporter will be poured out upon him. No doubt it is a grave mistake to reverse one's own awards, and yet judges are but mortal, and "to err is human." It is hard when cat fanciers take to judging the judges and their judgments. A judge may be absolutely ignorant of the owners of the cats, and thus utterly unbiased; yet there will not be wanting those who will pick holes in their characters, and see in their awards clear proof of personal spite and party favour. The intense suspiciousness of some fanciers and the readiness with which they impute low motives to others is greatly to be deplored.

[Illustration:

THE TOILET.

MRS. PETER BROWN AND HER PRIZE CAT.

(_Photo: Cassell & Company, Limited._)]

I will here quote from an article by Mr. C. A. House, the well-known editor and judge of live stock. Under the heading of "The Judging of Cats," Mr. House says:—"All my awards are based on the idea that each breed possesses a distinctive feature, and that distinctive feature must be the one to which most consideration is given. After the chief features come others, such as shape, coat, colour, etc., and the premier awards should be given to cats possessing the best all-round properties.... Selfs, above all things, should be pure in colour. For instance, a blue should be blue, and a black, black. Yet a little rustiness of colour should not be allowed to outweigh a host of other good properties. Colour, however, is hard to breed rich and pure, and should at all times be more highly valued than size, or even coat. The same with markings. Only those who have tried to breed markings know how difficult it is to get them anything approaching perfection. Nothing is more fleeting than marking, and nothing more tantalising to the breeder. Summing up the matter, my own opinion is, and has been for years, that the cat fancy has been hindered and hampered by judges judging the exhibits because they belong to so-and-so, or had won so-and-so under so-and-so.... I was much amused at one incident at Westminster where a big champion had suffered defeat. The fair owner was heckling the judge, and he in reply to her remarks made this answer: 'It makes no difference to me had the cat belonged to the Queen herself; I should then have done the same. I don't judge cats on what they have previously won or because they belong to any particular person. I judge them on their form at the time, and it makes no difference to me if a cat has won fifty firsts or none at all.' This reply was more than the exhibitor had bargained for, but all honest-minded fanciers must acknowledge the judge was right. What is sadly needed in the cat fancy to-day is more of this sturdy, unflinching determination to judge cats and not their owners. Cat exhibitors have much to learn yet, and the sooner the morale of the judging arena is raised the more healthy will the fancy become and the more quickly will it advance."

[Illustration:

BLUE PERSIAN KITTENS.

(_Photo: Mrs. S. F. Clarke._)]

Another of our well-known judges, Mr. T. B. Mason, writing on the same subject, says:—"In my judging engagements I have very often come across exhibits with good-coloured eyes, but not the correct shape. A small eye, however good the colour may be, will give the cat a disagreeable, sour expression. With this shape of eye we generally see a narrow, long face, which should keep any exhibit out of the prize list in good competitions. Let it, however, be clearly understood, I do not want eyes to have undue weight in the general conditions of cat judging; but they are important, and as such ought to have due and careful attention at the hands of breeders and judges alike. Two things in the judging of short-hairs weigh heavily with me, namely, pale colours and light-marked heads and white lips. These defects, in my opinion, ought to put out of the money those that possess them in good competition. I perfectly agree with Mr. House about the standards. They are useful both to the breeder and judge; but for the judge to take the standards and try to judge by them at any show would be foolish indeed. All judges are expected to know the varieties they are called upon to judge, and to have the faculty to weigh up the good points and defects of the specimens before them, and place them accordingly."

[Illustration:

KITS WITH A TASTE FOR FLOWERS.

(_Photo: Mrs. S. F. Clarke._)]

[Illustration:

TWO KITTENS BRED BY MISS WILLIAMS.

(_Photo: H. Jenkins, Lowestoft._)]

MANAGEMENT OF SHOWS.

Now to turn our attention to the management of shows, and upon this question I feel I am fairly competent to give an opinion, as I have acted as show manager and as show secretary to some of our largest exhibitions in London and at Brighton. The office is indeed no sinecure, and very few fanciers, exhibitors, or visitors have any idea of the enormous amount of forethought required, to say nothing of physical and secretarial labours, to make a big show run smoothly. The responsibility also is great, for a conscientious manager feels he has valuable live stock in his temporary possession, of which he has, so to speak, to render up account. There are many mixed shows held throughout the country where a cat section is given, and it is to be regretted that in

most, if not all cases, the poor pussies are badly provided for and generally go to the wall. At a dog and cat show everything goes to the dogs! Secretaries wishing to promote successful cat sections at their mixed shows should secure some well-qualified person to have entire control of this department. It is certainly true that, of all live stock, cats require the most consideration and supervision, and yet to the masculine mind of a show secretary it would appear that the cats can look after themselves. There is no doubt that the first step towards making a show successful is to engage the services of a competent, energetic, and painstaking manager and secretary. It is also very desirable to appoint a really good working show committee, the members of which should each undertake some particular duty in connection with the show. For instance, one member might superintend the feeding, another could be responsible for obtaining promises of special prizes, another devote him- or herself to verifying the prize tickets placed on the pens, and so on. A system of advertising a show must be decided upon by the show committee, and notices sent to the various journals which are circulated amongst fanciers. The class and prize tickets must be ordered in good time either by the secretary of the club or the manager of the show.

The best time of the year for a show as regards the appearance of Persian cats is in December or January. Then, if ever, these particular cats should be in the best show condition. As regards kittens, the early summer or autumn is the best period, as spring kittens will then be ready to make their bow to the public. It is much to be regretted that the two principal shows of the National Cat Club—namely, the Botanic Gardens and the Crystal Palace Shows—should be held respectively in June and October, when Persian cats are in poor coat.

Quite three months before the date of the show a managing secretary will start work. Catalogues of previous shows must be collected together, in order to ascertain the names and addresses of likely exhibitors.

Special prizes are now a great feature at all cat shows, and a good deal of extra work is entailed by writing to obtain promises of these for the various breeds. If possible, it is well to appoint someone who is in touch with those who are likely to become donors, and to hand over this department. I would advise anyone undertaking this branch of the show to have a book, and to head each page with the respective classes of long and short-haired breeds, and then when a special is received—say, for the best black Persian cat—to place this on the page set apart for specials for this particular breed. Keep a separate list for kittens, and decline to accept specials given in the form of stud visits or for cats bred from such and such a sire; these savour too much of self-advertisement. There are so many specialist societies nowadays, and as these provide their own specials the show executive is considerably relieved of the duty of obtaining prizes. Of course, there are always a certain number of challenge cups, medals, and specials given by the club holding the show, and care should be taken to distribute these fairly amongst the various classes. It is usual and advisable to limit the competition of the majority of these special prizes to the members of the club. I do not approve of a special prize being offered for the best cat in the show, as it is almost impossible for the judges to arrive at a satisfactory decision, and considerable heartburnings are generally the result of such a competition. A very useful mode of assisting a show is by guaranteeing classes; and I would suggest yet another plan, namely, to subscribe so much towards the expenses of the show. These are necessarily heavy, and it has been stated that no cat show can ever be made a paying affair.

As regards the specialist societies, I think it seems the correct thing that the club intending to hold the show should instruct its secretary to write to the secretary of each specialist society to ask if he is willing to support the show by prizes or by guaranteeing classes, and to name the latest date for receiving particulars of the support to be given. The specialist societies have their own judges, and it is only natural when they are offering handsome prizes that a claim should be made for first-class judging in the interests of the breed. It is therefore essential, as matters at present stand, for one of the judges from the list of the specialist club to be selected to give awards in the classes connected with the society. It is important to obtain as full a list as possible of special prizes from societies and outside donors in good time for insertion in the schedule, as a tempting list will ensure a better entry. In the schedule the exhibition rules of the club should be printed, and in addition there should be a list of arrangements in a prominent position setting forth details as to the opening and closing of the show, the time up to which exhibits are received, the earliest hour at which they may be removed, and the prices of admission. The names of the judges, with their respective classes, should be clearly set forth, and it should be mentioned whether classes will or will not be amalgamated or cancelled. A few advertisements of stud cats and trade notices should be obtained, as this means grist to the mill and helps to pay for the printing of the schedules and catalogues.

[Illustration:

RICHMOND CAT SHOW: THE RING CLASS.

(_Photo: Cassell & Company, Limited._)]

The question of classification is an all-important one, and needs the consideration of a careful show committee, well versed in the ways of cats and of fanciers. A list of the classification used by one or two big cat clubs has been given. Of course, at smaller shows it is often impossible to give separate classes for several breeds or to divide the sexes; but my remarks in this chapter will refer to the customs and arrangements of large shows, such as those held by the National Cat Club at the Crystal Palace, and the Cat Club at Westminster. I do not think it is good policy on the part of a show committee or management to amalgamate classes. It is much better to advertise in schedules that when entries are fewer than, say, four or five, then the judges are empowered to withhold any of the prizes; or, again, in the case of a very small class, half prize money might be awarded.

[Illustration:

"MINDING SHOP."

(_Photo: C. Reid, Wishaw._)]

Having decided on the classification, and given as liberal and attractive a one as is possible and practicable, it is well to consider the number of schedules likely to be required, and then start addressing the wrappers. In each schedule must be inserted two or three entry and registration forms. The entry forms, with fees, are returned to the secretary, and the registration forms to the person who keeps the register of the club holding the show. And here I would remark on the mistake it is to have two registers for cats. It is very confusing for exhibitors, and a double expense, as the National Cat Club and the Cat Club each charge a shilling. Then, again, as the National Cat Club has recently passed a rule disqualifying all cats exhibited at Cat Club shows, the confusion is worse confounded. Some fanciers having large catteries divide their exhibits and send to both National Cat Club and Cat Club shows; but this new registration rule falls heavily on cat fanciers who are keen to exhibit their specimens and anxious for the pleasure of obtaining prizes, and desire to profit by showing their stud cats or having an opportunity of disposing of their stock. The National Cat Club shows since the passing of this rule have suffered considerably, both from lack of entries and by the absence of some of the fine champion cats that, having been exhibited at the Cat Club show in January, were thus debarred from appearing at the Botanic Gardens and Crystal Palace shows. How much simpler and better it would be if both clubs could and would agree to have _one_ register kept by an independent person, not necessarily a catty individual, and that the fees should form the salary of such a person. A small fee might be charged when reference was desired by fanciers as to the pedigree of any cats. If the secretary of a show happens to be acquainted with the members of the cat fancy, he will be able to use his discretion as to the number of entry and registration forms needed. In some cases, where he is sending to a well-known breeder and possessor of a large cattery, more numerous forms will be required. Schedules should be sent out quite a clear month in advance, and the entries should close about ten days before the date of the show. The secretary will have a book in which he will note down each entry as it is received, placing it under the correct class heading, and, of course, these can only be numbered up when entries close. The entry forms should be filed and kept for reference. Then comes the work of arranging and writing the labels, and placing these with the tallies, entrance tickets, and removal orders in envelopes and addressing them to the exhibitors. These should be posted four clear days before the show.

During this time the secretary will be able to compile the catalogue for the printer, and arrange to have an instalment of copies the night before the opening day of the show, also to draw up the judges' books. Letters should be written to the judges and veterinary surgeons acquainting them with the hour at which they are desired to present themselves at the hall, and a complimentary pass ticket should be enclosed. A pass should also be sent to the representatives of the Press, to the veterinary surgeon, and to those who may be giving their services as stewards. Distant exhibitors will write requesting catalogues to be forwarded to them, and a list should be kept. A secretary will do well to provide himself with strong cord, scissors, brown paper, writing materials, labels, telegraph forms, stamps, and other useful articles.

[Illustration:

"THIEVES."

(_Photo: Mrs. S. F. Clarke._)]

In these days of specialist clubs it is necessary for the secretary to have a list of members of each society supporting the show, as the prizes being confined to members the judge will have to refer to the secretary's office for information before making his awards.

The day before the show will be fully occupied in superintending the arrangement and putting up of the benching and pens. A conveniently sized glass case should be ordered for the special prizes, and this must be placed in a prominent position. The prizes should all be distinctly labelled with the donor's name and the breed of cat for which each is offered. The case should be one which locks up, and then it is not necessary to have any supervision of the contents. It is best for some two members of the show committee to undertake the arrangement in the case of the special prizes. Two men should be engaged to take the tickets and money at the entrance gate, and in the sales office a clerk will be required to receive purchase money and give receipts. At a large show it is necessary to employ four or six stewards to collect the judges' slips as they complete each class, and take them to those in the office appointed to write out the tickets. These same stewards should also undertake to place them on the pens. And here let me say how much better it would be if some arrangement could be made for the prize tickets to be fixed in a rack at the top of the pen, instead of being thrust between the wires, where a large number almost hide the cat, and frequently they are torn down by the inmates of the pen.

[Illustration:

MISS SIMPSON'S "CAMBYSES."

(_Photo: Gunn & Stewart, Richmond._)]

A good manager will have all in order well before the hour when the cats are received, and if the veterinary engaged is in attendance the cats can be examined and, when passed, placed at once in their proper pens. It is very important to entrust the work of penning to those who are used to handling cats, and no better men can be found than those employed by Messrs. Spratt, who, as everyone knows, are the universal providers at cat shows, as at every other live stock exhibition. It is a question whether hay or straw is best for bedding. I incline towards the latter if it is the fine wheaten straw, as hay, if it becomes at all damp, will stick to the long-coated cats. I also prefer dry earth at the back of the pens to sawdust, for the same reason. I trust we may ere long be able to provide something better in the way of a cat pen than those at present in use. The doors should open the full height of the cage and two thirds of the width, so that the cat can be more easily taken out.

[Illustration:

MRS. DRURY'S BROWN TABBY, "PERIWIG."

(_Photo: Kerby & Son, Ipswich._)]

There is no doubt that, considering the peculiar nature of cats, some more adequate arrangement should be made in the sanitary accommodation. The earth scattered at the back of the pen amongst the bedding is not all that could be desired. What we want is a false bottom, and an earth pan or tray sunk in it about two inches deep, on the plan of the bird cage, so that it can be drawn out and fresh earth supplied, and replaced. Greater care should be paid as regards the security of the fastenings of the pens, and the wires of some of them are too wide apart, so that young kittens can easily make an exit. It is well known that cats have extraordinary powers of escaping whenever and wherever escape is possible.

I disapprove as strongly as do the cats of any disinfectant being sprinkled or placed _inside_ the pens. Each pen must, of course, bear a number; but instead of the different classes being numbered, it is much better to have them named, and the large placards fixed high about the pens by means of split sticks of Japanese bamboo. Thus anyone seeking the blue or the brown tabby class will have no difficulty in locating it, even without a catalogue.

It is very important that all exhibits should be examined by a qualified veterinary surgeon before being penned, and if a cat is seriously ill the owner should be at once communicated with and the specimen returned. If it is a doubtful case, perhaps a running eye or high temperature, then the cat should be placed apart in a properly arranged, and if possible warmed, hospital room to be again examined. Remember it is always better to disappoint one exhibitor by refusing his cat, than to disgust everybody by bringing their carefully trained and dearly loved pets into contact with disease. It is necessary to appoint an official to check off each exhibit as it is passed, and in the event of pronounced illness or some other objectionable feature to make a note of this for future reference.

[Illustration:

A LITTER OF BLUES.

(_Photo: E. Landor, Ealing._)]

As regards the feeding of exhibits, I am in favour of raw beef or cooked meat cut into small pieces or else put through a mincing machine, and water to drink. For many reasons it is not desirable to provide milk; it is apt to turn sour, and it certainly more easily collects germs of disease, and so may prove a fruitful source of evil.

The Cat Club started the idea of having china saucers instead of the usual tins, and these are decidedly better in every way. A one-day show is no doubt best for the cats, but for the exhibitors and the executive a two-days show is really preferable. If the exhibits are allowed to be penned up till eleven o'clock on the morning of the show, the judging ought to be got through and the tickets placed on the pens in two hours with a competent staff, and the show opened at one or 1.30.

A smart secretary will arrange with his printer to have a list of awards printed with the utmost speed directly after the class judging is finished. This can either be given in the catalogues themselves or a separate sheet inserted in the catalogues. A large board ought to be hung in a conspicuous and convenient position, and the list of class winners and the winners of special prizes entered on it. This is better than having the slips pinned upon a board. They are often very indistinctly written, and are apt to get torn down. Let the closing hour on the first night be eight or nine o'clock, when the hall should be cleared and the pens covered over. I consider one good feed of raw meat ought to suffice during the day, with fresh water continually supplied. The hour for opening on the second day may be ten o'clock, and before then the pens ought to be cleaned out, fresh straw given where needed, and disinfectant sprinkled up and down the passages between the rows of pens—not in them. Careful attention to these points will ensure the show being free from disagreeable odours by the time the public are admitted. It is a wise plan to arrange and announce that the show closes, say, at five p.m. on the second day, so that exhibitors can, in many cases, get home with their cats the same night. It is unreasonable to expect to be allowed to depart before the time fixed, even though in some cases half an hour would save a train. As regards a one-day show, it is almost impossible for a secretary and manager to get through the necessary work and to open in anything like time. There must be a scramble, and for the exhibitors to be obliged to present themselves and their cats at some unearthly hour in the morning is very trying and most inconvenient. Then a two-days show is, of course, an advantage as regards the entrance money. The Cat Club used to have a stringent rule against exhibitors penning their own cats, but at the Westminster Show this rule was amended, and cats could be penned by their owners or representatives on the night before the show, but not in the morning. No evil result followed this concession on the part of the authorities, and therefore I trust this very natural desire on the part of the exhibitors to see their precious pussies safely into their temporary quarters may always be permitted at Cat Club shows.

In order to facilitate the work of the judges, it is well to have their books carefully and clearly arranged, and this especially applies to the list of special awards. I instituted a plan at Westminster Show, in 1901, which gave great satisfaction, but which entailed a lot of extra work for the secretary. I am sure, however, this special arrangement lightened the labours of the judges, and hastened the appearance of the special prize cards on the pens. I had separate books for the special awards, and carefully cut out of the schedules the prizes pertaining to each judge. Thus, if Mr. A. had black, white, and blue long-haired classes, every challenge medal and special offered for these cats I arranged in order on one side of the page, with the numbering as it appeared with them in the schedule. So in the left-hand page would be, say, "Special No. 10, for best long-haired black," and on the right-hand page "Awarded to No. ....," leaving a blank for the judge to fill in the number of the winner. Any prizes that had to be awarded in conjunction with other judges, such as for best long-haired cat in the show, I made a note of to this effect. Let me add that I gummed the printed portions relating to the prizes, cut from the schedule, into the judging books, so the judges needed neither schedule nor catalogue to refer to. In preparing judges' books it is very helpful to place male and female (M. and F.) after each catalogue number in the mixed kitten classes, to avoid reference for the special awards; and this should also be done in the catalogue itself, as very often the name of the kitten does not indicate the sex, and would-be purchasers are obliged to make inquiries.

I am always an advocate for having selling classes for cats and kittens at shows, where the price should be limited to £5 5s. in the long-haired classes, and £3 3s. in the short-haired classes. It would be an assistance if someone who understood cats, and was also a good salesman or saleswoman, undertook to preside over the selling classes. The 10 per cent. commission deducted by the show authorities is a material help, and often a little pressure and persuasion, combined with useful information, will decide a wavering purchaser. A class I should like to see introduced into our shows is one for kittens bred by exhibitors. I am of opinion that more encouragement should be given to fanciers to keep the best of their litters for exhibition. Lady Marcus Beresford had the happy inspiration of starting breeders' cups for competition at Cat Club shows, and special prizes are often given for the best kitten bred by exhibitors. But these are tiresome awards for a judge to make; he is obliged to make inquiries from someone with a

catalogue, and even this reference will not always suffice. It is always pleasant to win prizes, but an additional pride would naturally be felt if, in a large class of kittens bred by well-known exhibitors, the son or daughter of our own breeding should be awarded first and special.

[Illustration:

JUDGING IN THE RING AT THE CRYSTAL PALACE.

(_Photo: Russell & Sons, Crystal Palace._)]

With respect to a ring class, which is often held at some of the National Cat Club shows, I cannot say that it is very interesting to see a collection of toms, females, and neuters, long- and short-haired, being dragged along by their anxious owners, whilst the puzzled judges try hard to decide which of the motley and mixed assembly is most worthy of honours. I think that for a ring class neuters alone should be eligible, or at any rate until we have trained our young cats to behave properly on a lead. There need be no necessity for the neuters to be entered and penned in the show, but they could be charged a higher fee for the ring class; and I believe that many owners of neuters would not object to their precious pets being on exhibition for ten or twenty minutes, led by themselves into the ring, but who will not let them be cramped up in a pen for two days. Neuters are always at a disadvantage in the show pen—they are generally too large and too lazy to be properly seen, and a ring class for these specimens would be a very attractive feature at our cat shows. A row of chairs should be placed round, and sixpence a seat charged. It is quite absurd to mix up the sexes, and dangerous to allow tom cats to come within fighting distance of each other. At a recent show great excitement was caused in the ring by the sudden attack of one famous stud cat on another, and it was lucky that nothing worse than a torn and bleeding ear was the result of this onslaught. Another class I should like to see at some of our large shows, and certainly at the summer N.C.C. Show, is a class for stud cats, which should be judged quite irrespective of coat, and special attention directed to form of limb, size of head, and massive build in awarding the prizes. This might not be an attractive class, but it would be an instructive one, and give the veterans a chance of proving of what stuff they are made. A young untried male will often take all the honours in his class, and the stud cat of a busy season is forced to take a back place, probably on account of services rendered. Anyhow, this idea might be carried out as regards the two largest classes—namely, those for silver and blue Persians. In former days there used to be classes at some of the shows in which the cats were judged by weight, but these have wisely been done away with.

[Illustration:

MISS KIRKPATRICK'S BLUE KITTENS.

(_Photo: E. Landor, Ealing._)]

The question of open judging at cat shows has frequently been discussed in catty circles, and several fanciers have given their opinions on this subject. Mrs. Neate, a well-known fancier, writes thus in _Fur and Feather_:—"It would indeed be a step in the right direction if cat shows were run on (as far as possible) the same lines as dog shows. Much of the absurd mystery that at present envelops our cat shows would vanish if exhibitors were permitted to be present during the judging, and I feel sure that the majority of cat fanciers would not be so wanting in etiquette and good taste as to hinder the judges or any of the officials in discharge of their onerous duties." No doubt there is much truth in these remarks; but, at the same time, I do not think fanciers take sufficiently into consideration the very timid, shrinking nature of the cat when they advocate open judging. It is often most difficult for a judge to properly examine a cat, even when he or she is quietly going round giving the awards; it would be still more trying to man and beast if a collection of strangers were pressing forward on all sides.

What I consider is more practical than open judging for cats is that some arrangement should be made so that judges may be enabled to compare the points of the various exhibits, and for this purpose I consider that judging pens on movable tables should be provided at all shows, as were adopted by the Cat Club at Westminster. By these means the work of the judges would be much simplified, and the cats more satisfactorily and quickly judged.

Supposing a special prize or medal is offered for the best cat in the show, then I think it is interesting and instructive to have the first prize-winning cats placed, if possible, in pens, and to arrange for the award to be given in public during the show by the judges in conjunction with each other. Such a plan was adopted at the last Manchester Cat Show, and much satisfaction was expressed at this innovation.

Having given some suggestions as to the classification, I would again refer to points of management in shows. At the closing hour on the second day the hall should be cleared, and only exhibitors or their representatives allowed to remain. An efficient staff of attendants should at once set to work to assist in packing up the cats belonging to those exhibitors who intend taking them away. After these have all left, then the manager should direct his attention towards those exhibits that should be started by the night mails. The catalogue must be consulted, and a good way is to mark with a cross on the pen tickets those cats that must be packed up; and, having previously ordered the railway vans at a certain time, the precious packages should be sent off as speedily as possible. Those exhibits left over till the following morning should be fed again and started at daybreak.

[Illustration:

"ROSE OF PERSIA."

(_Photo: E. Landor, Ealing._)]

There is a sense of immense relief when the last hamper has been fastened down and seen off the premises. And here let me say how much exhibitors can contribute towards the speedy and safe despatch of their pets, if only they will provide substantial and well-appointed travelling baskets or boxes. Amidst all the hurry and confusion of packing up an immense amount of extra trouble is given by having to lace up a hamper with string, or nail down a box that has no other means of being made secure! I speak from experience, and therefore I plead for more consideration to be extended to the show manager and his assistants, and, above all, to the poor pussies themselves.

At every show that is held there are a number of exhibitors who try the patience and courtesy of the manager or secretary, or both, by requesting to be allowed to remove their cats before the advertised time. Of course, it is only natural that those fanciers residing at a distance should wish to make tracks home and catch early trains for their own comfort and convenience and the welfare of their pussies. But, looking at the matter from a secretary's and a visitor's point of view, it is certainly hard that perhaps some of the best prize cats should be absent from their pen whilst the public are paying their money at the gate; but, having made a rule, it is best to stick to it, and no cat should be taken away till the fixed hour under any pretext whatever, unless a veterinary certificate of illness is obtained.

It is always open to the management to advertise an earlier hour for the removal of exhibits on payment of a certain sum, but this should be made a substantial fine, especially in the case of a prize-winner. A lower figure might be named for other exhibits. As regards cats or kittens purchased at the show, it is certainly an inducement and incentive to buyers if there is a rule that these exhibits may be removed at any time.

According to the rules of the two leading clubs a certain fixed time must elapse before the prizes are sent out. In some cases this is a most uncertain and unfixed time, and many complaints have been made through the cat papers of the long drawn out period between the prize being won and the prize being received. No doubt, immediate distribution of prizes after the show would lead to complications, for objections might be lodged within the given time allowed by the rules, and such objections would have to be brought before the committee of the club; therefore it is obvious that successful competitors must allow, say, a month to elapse before showing signs of impatience. It is then the manager's business to send the money awards, and the secretary of the club is generally accountable for the distribution of the "specials," which certainly call for a special acknowledgment from the recipient to the donor of these prizes.

As regards the financial aspect of a cat show, the first important point is to make the entries pay for themselves—that is, supposing your prize money in each class is £1, 10s., and 5s., then you need twelve entries at 3s. to carry you through. And here let me remark that, considering the character of our first-class shows and the value of the special prizes offered, I am inclined to think that entry fees are too low, and that they should be more in accordance with the fees charged at dog shows. It is always advisable to make a difference between members of the club holding the show and outsiders. Thus, if 5s. is the entry fee for members, then 6s. or 7s. 6d. might be charged to non-members. New recruits to a club are often gained by this arrangement. The usual commission on sales is 10 per cent., and then there is the gate money, which somehow is generally disappointing, for truly the outside public are not partial to cats, nor attracted to exhibitions of the feline race. I have always contended that exhibitors themselves ought to be charged an entrance fee—say, half-price admission on presentation of their exhibitor's pass, which in many cases would only be sixpence, yet one or two hundred of these small coins would materially assist the exchequer; and surely no cat fancier would grumble at this tax on their resources when they consider how much trouble and expense is entailed in providing them with a favourable opportunity of exhibiting their pets, and with a possibility of winning golden guineas and silver trophies.

Another plan is to advertise in schedules that exhibitors of more than, say, two entries would be allowed a free pass. Fanciers will be tempted to send additional cats, and thus swell the entries, in order to secure their free admission ticket. I do not think it would be a bad plan to have a "Contribution Column" on the entry forms for members' and exhibitors' voluntary donations towards the expenses of a show which, if well managed, is worthy of the utmost support from the cat-loving community.

"Every mickle makes a muckle," and it should be the earnest desire of each individual member of a club to do something, however small, towards keeping a balance on the right side of their treasurer's accounts.

BUYING AND SELLING.

I believe that a Bow Street magistrate once asserted that anyone owning a stud dog or selling a dog was, in the point of law, a dealer. I do not know if the same decision would apply in the cat world. Anyhow, there are few fanciers who do not desire at some time or other to dispose of their cats and kits; and, again, there are many who keep stud cats, yet cannot be considered dealers in that sense of the term. The best way to set about trying to sell our surplus stock is to advertise in the cat papers, in which case it is advisable to fully and fairly describe our animals and to name the price required. If profit is to be considered, it is not advisable to keep kittens more than eight weeks. Very soon after this period they begin to lose their fluffiness and grow leggy in appearance. There is also the risk of illness and death. It is better, therefore, to be willing to accept a moderate sum for kittens at eight weeks old rather than to keep them to see how they turn out. It is a clear case of "a bird in the hand is worth two in the bush."

I have always thought that there is a good opening for any enterprising person well versed in cat lore and cat fanciers to start an agency in London, where cats and kittens might be sent on approval, for would-be purchasers to call and interview them. There might be a system of messengers who would meet cats and see them off at London stations. In connection with such a cat agency a register might be kept of cats for sale or cats wanted and arrangements made as at the Army and Navy Stores for having a certain number of animals on view. These could be boarded at so much per week, and commission charged on the sale.

A list of names and addresses of those willing to receive cats as boarders would be very useful, and many ladies who do not choose to advertise could and would, I am sure, avail themselves of the means of letting fanciers know they could undertake the charge of pets during their owners' absence from home. Many and frequent are the letters I receive on this subject, especially as the summer vacation approaches.

A day and hour for the visit of an experienced veterinary might be arranged, so that country fanciers could send or bring their sick cats for advice. All sorts of cat appliances might be on sale. It would be convenient to have a writing-room for the use of fanciers, where correspondence on catty matters could be carried on. Perhaps a tearoom could be added, and bedrooms, if space was available, for fanciers coming up to attend London shows. Anyhow, a list of suitable rooms might be kept which could be personally recommended.

THE BLUE PERSIAN CAT SOCIETY PEDIGREE FORM.

Breed and Sex———————————— Breeder————————————

Colour———————————————— Date of Birth————————————

Name of Cat———————————— ==========
PARENTS. GRAND-PARENTS. GREAT GRAND-PARENTS. GREAT GREAT GRAND-PARENTS. ————————————
———

Sire. { { { _ex_ { {—— { { { _ex_
{—— { { {
_ex_ { {—— { { { _ex_ ————————————
———

—— Dam. { { { _ex_ { {—— { { { _ex_
{—— { { {
_ex_ { {—— { { { _ex_ ————————————
———

—— Prizes Won, Remarks, &c. ————————————————

These Forms, at 8d. per dozen, can be obtained on application to Miss F. SIMPSON, Hon. Sec., 9, Leonard Place, Kensington, W.

In these days, when competition is so keen and occupation so difficult to obtain, the idea of starting a cat agency should commend itself to some who, being in touch with members of the cat fancy, and wishing for lucrative employment, might embark on this novel undertaking. Needless to say, it would be most desirable to have the cat agency in a central part of London, and in close proximity, if possible, to some of the main railway stations. I think that, if only as a means of assisting fanciers in the purchase and disposal of their cats and kittens, this idea of an agency might be successfully worked. Many breeders become very disheartened at the inability to find purchasers for their kittens. A complaint was recently made by a lady living in the Isle of Wight. She writes: "No one seems to care for breeding in this island, and people are not willing to give more than about five shillings for pedigree kittens." No doubt fanciers living in the country and away from any catty centre have but little opportunity of finding a sale for their surplus stock. I would suggest photography as one means of making known the perfections of their pussies. A start in the right direction has been made by Mr. Landor, of Ealing, whose clever pictures of kittens are so well known. He is willing to take portraits of pretty, fluffy kits and good cats on special terms, provided he retains the copyright of such photographs. It is always handy to have a good photograph to send by post when endeavouring to dispose of our pets, and by such means fanciers may be spared the trouble and risk of sending their valuable kittens on approval.

[Illustration:

"MISCHIEF."

(_Photo: Mrs. S. F. Clarke._)]

Naturally, for unknown cat fanciers it is more difficult to effect sales through advertisement, and in their case it is necessary to offer to send on approval at buyer's risk and cost; and if an application is made from an entire stranger, then the purchase money should be deposited in the hands of some reliable and independent third person. Some fanciers entirely decline to send their cats on approval, and then it is very requisite to enter fully into particulars, and, if possible, to send a photograph. It is best to give the faults and failings as well as the good points, so that disappointment and disagreement may not follow between the purchaser and seller. Buyers should endeavour to learn something about the person from whom they purchase their cats; and it as well to ask not only for age and full pedigree, but whether the cat has been exhibited, and if it has taken any honours, and at which shows. It sometimes happens that valuable animals may be picked up for low prices at shows; but there is always a risk, and this is especially the case with young kittens, who more easily contract any disease. In buying a cat or kitten it is always advisable to make inquiries as to the way in which it has been fed, so as to continue the same regimen for at least a few days. The pedigree of a cat or kitten should be sent at the time of purchase, and it is much easier to fill this in on a properly drawn out form, and certainly it is pleasanter to receive the particulars thus intelligently written out. I give a copy of the forms I drew out for the use of blue Persian members, but these can, of course, be used for cats of any breed.

[Illustration:

OUR PLAY-ROOM.

(_From a Painting by Madame Ronner._)]

Here let me quote from an article in that excellent American paper, _The Cat Journal_, headed "Unreasonable Buyers." The writer says:—"One of the most difficult things with which the cat seller has to contend is the unreasonable buyer. There are buyers who, finding a cat to suit them, pay the price and are satisfied. There is, however, another class that it is best to let alone. They are never satisfied, and blame the seller for everything that happens either on the road or after the kitten is received, and many of them also think if they are sharp they will be able to buy a $100 kitten for $10 or $15, and when they get such a kitten and they discover that it is not worth $100, they are disgusted, and have a lot to say about unfair dealing, etc. If a kitten that has been a pet is taken from its surroundings, and sent on a long journey, the rattle and the unusual conditions of such a trip places her in a state of nervous terror, so that she very rarely shows off to good advantage in her new home. The purchaser, if a true cat lover, will appreciate all the trouble of poor little pussy, and give her the tenderest treatment and coax her to make the best of her new surroundings. It is a very rare thing for a kitten to come from the box after a long journey looking just as the new owner expected. Tired, homesick, and frightened, she will not eat, and is altogether a pitiable looking object. It is always advisable to put a new arrival in a room by herself, with a comfortable bed and conveniences, entirely away from the rest of the cats and kittens, and allow her to become acquainted with the members of the family gradually. Do not allow other cats to come bothering around till the new member of the family is entirely acquainted with its surroundings. Especially be very cautious in introducing two male cats.

"Sellers must be very cautious in sending out their stock, and buyers must not expect too much. Give the new member of the family a little time to know things before you write your letter of complaint. Be sure you are not expecting too much for the price you paid."

The question has often been asked, "Can cats be made to pay?" and, naturally, novices in the fancy wish to know the best way in which to make a good start.

Here I would say how much may be done by well-known and influential members of any fancy if they will give themselves a little trouble in helping the novice, who, after all, is the backbone, so to speak, of every fancy, and hence it is very essential that beginners should start on the right lines and with reliable, and therefore profitable, stock. Speaking from experience in the cat fancy, I can say that several persons have come into the ranks and gone out of it again, in many cases through sheer disgust because of the deceptions practised, and of which they, as novices, have been made the victims. I hold that if beginners are to be retained as members of a fancy, they should be treated kindly and liberally by the experienced fancier, especially when it is a question of purchasing stock. It is much to be lamented that novices are frequently treated in a reverse manner, and fanciers (so-called) seize upon an opportunity of getting rid of superfluous and often inferior specimens to those who are unable to discover good from bad in the cats offered to them.

At the same time, it is a pleasing fact that there are many true fanciers in the feline world who, having made their names as breeders, prize-winners, and perhaps judges, put themselves out to give valuable advice, and often spare no pains in endeavouring to obtain good stock for the novice at reasonable prices.

Another question often asked is, "Does showing pay?" In answer to this query, I give an extract from the pen of the clever weekly correspondent of _Fur and Feather_, "Zaida," who says:—"To those who keep their cats for pleasure, who really love them and can afford to despise the small 'takings' available, keep your cats at home and do not show. Expense does not count with this class of exhibitor, but risk to the welfare of their best-beloved pussies undoubtedly does. To those who are trying to make money by their cats, we would urge: harden your hearts, learn how to show, where to show, and when to show; and recognise the expense, risk, and trouble involved as part of the unavoidable outlay which is to bring in a certain return. Undoubtedly, a show is a heavy expense, and will always leave you out of pocket. Even if you conduct it on the most selfish terms—the 'give-nothing' and 'take-all-you-can' system—you will be exceptionally lucky if you clear your expenses. You cannot expect to sell your kittens well if you do not exhibit.

"If you possess a stud cat, he must be seen and known before you can hope to have a demand for his services. Your own eye must be continually trained by comparison of your own stock with the prize specimens of others. In short, if you wish to make money, you must spend money. On the other hand, never exhibit except at first-rate shows, and never be tempted to show an animal out of condition. If you can afford to buy animals already well known in the show world, cats of renown, for whose offspring there will always be a keen demand, you may possibly abstain from exhibition. This plan, however, involves a very large initial outlay. Then, again, the happy people who have won their laurels, whose names are always associated with first-rate animals of a particular breed, they, indeed, can afford to rest in peace, and show no more. Other people will buy their kittens, and do their exhibiting for them, and also do that mournful nursing and burying that too often follows a show. Undoubtedly, it is fascinating to show successfully; but, on the whole, we think the most enjoyable shows are those where one goes to look at other people's exhibits and leave one's own at home."

A few words as to the stud fees and arrangements for visiting queens will not here be out of place. The usual fee for the services of a stud cat is fixed at £1 1s., but some fanciers are willing to accept less, especially if their cat is not a well-known prize-winner. A higher charge is often made if the railway journey has to be followed by a cab fare, or if the owner, having a valuable stud cat, does not wish to encourage many visitors. The carriage of the queen should always be defrayed by the sender, and if a telegram and return insurance is desired, then these sums expended should be refunded to the owner of the stud cat. It is desirable to announce the despatch or intended despatch of a queen, as it may not be convenient to receive her. The usual time to keep a visitor is from three to six days, and then the owner of the stud cat should give notice of the return. In case the first visit proves unsuccessful a second visit is usually allowed by courtesy without any extra payment, but this must not be taken as a matter of course, and it is best for the owner of the queen to ask permission to send again. If through a mistake in the time of sending a cat apparently fails to mate during two visits, it can only be by the kindness of the stud cat's owner that a third visit is permitted for the one fee. If, however, the queen has been known to have mated on each occasion, a third visit gratis cannot be expected even if there is no result. A fee once paid for a visit is not returnable. It is sometimes a matter of arrangement between fanciers to have the choice of a kitten instead of the mating fee, but this transaction does not commend itself unless the parties are on very friendly terms. A clear understanding should be arrived at on all occasions between the sender and the receiver, and thus any after unpleasantness may

be avoided. It is catty etiquette to forward the fee when sending the queen; or, at latest, immediately on her return. A label for the return journey should be fixed inside the lid of the hamper. This is a saving of trouble to the owner of the stud, and is also a means of identification.

[Illustration:

MR. F. W. WESTERN, THE SECRETARY OF THE SANDY CLUB SHOW.

(_Photo: Kingham, Bedford._)]

In selecting a young kitten for purchase out of a litter, take note of the size of head and width between the ears. In self-coloured kits look out for white spots, and avoid those with long tails. Fanciers should strive to resist the temptation of buying too many cats and kittens of different breeds. To the novice and the beginner I would say, Buy two or three good specimens, carefully selected; these will be worth quantities of doubtful ones, which, as a matter of fact, have, as a rule, no value at all. Seize every opportunity which comes across your path of seeing and examining well-bred, prize-winning cats, and attending shows. The cleverest fancier and most successful breeder can improve himself by observation and education.

Do not be offended if you are told by those who have had a larger and longer experience in the fancy, and who are really experts, that you have made a mistake in any purchase. If you resent their criticisms, you may, and probably will, accumulate much rubbish as a monument of your own conceit. A great deal may be learnt from books, but more from observation. Above all, do not, when you have acquired some knowledge, form too high an estimate of your own powers and of your own cats; a true fancier is always ready—nay, anxious—to learn, well recognising that ignorance alone claims to be omniscient.

LOCAL SHOWS.

As an example of the ever-increasing interest shown in cat sections at local shows, the following account, kindly supplied to me by Mr. F. W. Western, the secretary, will be of interest:—

[Illustration:

OFFICIALS OF THE N.C.C.C.

(_Photo: Mrs. G. H. Walker._)]

"Sandy Show has long since outgrown in size and importance the title it bears, viz. 'The Exhibition of the Sandy and District Floral and Horticultural Society.' The first schedule, issued in 1869, catered for plants, flowers, fruit, vegetables, poultry, and cage birds. In 1880 pigeons were introduced, and in 1883 rabbits were added. Later, in 1899, dogs put in an appearance with four classes. It was not, however, until 1894 that our friend 'pussy,' in whom we are especially interested, made her _debut_ at Sandy, and as we look at the schedule for that year we are driven to the conclusion that none but a philosopher could have drawn up such a classification for our pets. The trouble which we now frequently experience at a cat show of being 'wrong classed' could not well arise on that happy day in August 1894, when eight catteries were represented in the one and only class, viz. 'Any variety, any age, male or female.' But if our pets made a modest bow to the public in that year, they have lived to be proud of their position. In the succeeding year three classes were provided, bringing together 31 cats. From this date the cat classes have shown substantial improvement. The year 1900 found Sandy with five classes and 41 entries. By this time the cat fancy throughout the country had come into prominence; clubs had been established, and specialist societies were springing into existence. With a leap forward the cat section of the 1901 show numbered 20 classes. This was far too bold a bid for popularity to be lightly esteemed. The support was obtained of the Cat Club, the Silver Society (to-day the Silver and Smoke Persian Cat Society), the Short-haired Cat Society, and the Siamese Club.

"Generous aid was given by many individual lovers of cats, and fifty special prizes, in addition to the class prize money, were offered. The show was attended with success, both as regards the number (about 150) and the quality of the exhibits. From a public point of view, moreover, the result was most gratifying.

"The cat tent was crowded throughout the day, and this section was acknowledged on every hand to have been one of the best features of the show.

"With such success attending their first earnest venture in cats, it is not surprising to find that the committee resolved still further to increase the classification. In August 1902, therefore, 32 classes were arranged, of which 21 were guaranteed. Special prizes numbered 85, and the cat section had the support of all the specialist societies.

"With such attractions the splendid entry of 1901 was eclipsed, and at the very worst time of the year for cats as many as 266 entries were made. Long-haired cats were decidedly well represented, and in the blue kitten class 21 specimens were penned. In the short-haired classes some noted winners appeared.

"Ring classes were provided, and proved a great attraction to the public. The local classes were proof that Mrs. F. W. Western has succeeded in interesting some of her friends in the hobby, and the specimens to which the honours fell would have done well in the keenest competition."

Mention was made in the list of clubs on a previous page of the Northern Counties Cat Club, which was founded in 1900. The committee decided on holding a one-day kitten show in September of that year, and the judges selected were Miss D. Champion, Miss Frances Simpson, Mr. T. B. Mason, and Mr. L. P. Astley. Entries came up well, numbering 154, and this novel undertaking was in every way a great success. The Northern Counties Cat Club kitten show is now an annual fixture, and on October 1st of 1902 a really splendid exhibition of promising youngsters was held at Bellevue, Manchester. Twenty-two classes were arranged, and over fifty specials offered. Entries were twenty in excess of the previous year, and would have been still higher in number had not sickness prevented several well-known silver breeders from exhibiting. The litter class numbered 17, and these, with the splendid blue classes, were the chief glory of the show. There were 18 pairs of blue kittens and 40 entries in single blue kittens, and it was most noticeable how few of these specimens failed in eyes. There were rows of gleaming orange orbs that rejoiced the heart of the Hon. Sec. of the Blue Persian Cat Society.

The kitten show of 1902 may fairly be classed as another success for the Northern Club.

A similar show for cats and kittens is held annually in December in Manchester by this enterprising club. I am indebted to Mrs. G. H. Walker for the group of officials and members of the Northern Club. The photo was taken by Mrs. Walker at the Manchester kitten show of 1902.

In connection with the dog show of the Ladies' Kennel Association, an exhibition of cats is now held annually at Harrogate under the rules and patronage of the National Cat Club. The first venture in this popular and fashionable water resort was made by Mrs. Stennard Robinson in 1901, when entries came in splendidly; but rain descended most disastrously, and seriously interfered with the success of the show and the attendance of visitors. In 1902 the weather proved most favourable, but the cat section suffered considerably as regards numbers of exhibits in consequence of the date clashing with that of the Sandy Show, held also on August 28th. On this occasion the Hon. Mrs. McLaren Morrison was advertised as judge, but owing to ill-health her place was taken by Mrs. Stennard Robinson, and Mr. J. B. Townend, of the National Cat Club, undertook the management. The Midland Counties Cat Club held its first show in Birmingham. The classification was on a liberal scale, and several of the classes were guaranteed. Several of the specialist clubs supported this first venture of the Midland Counties Cat Club. A new departure in the matter of shows may shortly be attempted, and a scheme has been submitted to the cat world by the Hon. Sec. of the Silver and Smoke Persian Cat Society, that the specialist societies should combine and hold a show in the West of England. Each society is to be asked to bear a part in the expenses, and secretaries will probably hold a meeting to consider the best ways and means of carrying out such an undertaking. It is not intended that such a show should be in any opposition to those held by the parent clubs, and registration in either of these clubs will be enforced; but, to quote the words of a well-known fancier and supporter of the specialist societies, "It is simply a way of escape from the enforced division of interests, and a means for permitting the cats of all club persuasions to meet on equal ground. As matters now stand, open competition is a thing of the past, and the sooner it becomes a possibility again the better for the cat fancy. On this ground, therefore, we think all unbiased minds will accept with pleasure the scheme submitted to the public by the secretary of the S.S.P.C.S."

[Illustration:

SANDY STEALING THE MILK.

THE PROPERTY OF MISS HARPER.

(_Photo: B. Tugwell, Haywards Heath._)]

The Scottish Cat Club, which has Lady Marcus Beresford for its President, holds its annual show during the winter months, and its exhibition follows closely on that of the Midland Counties.

Under the list of winter shows mention may be made of the following, where, in connection with other live stock, cats play a more or less important part:—Peterborough, Sheffield, Hounslow, Kendal, Bedford, Caterham, Hinckley, Hamilton, Doncaster, Yarmouth, Stratford-on-Avon, Bristol, Haverfordwest, Stockton, Cheltenham, Taunton, Epsom, Hexham, Larkhall, Stirling.

In this list I have made no mention of the great championship show of the National Cat Club, held annually at the Crystal Palace in October, to which the whole of cat creation looks forward with awe and longing. This is one of the greatest events in the cat world, and is always eagerly looked forward to by fanciers in all parts of the British Isles. In the schedule for the exhibition in 1902 no fewer than 216 special prizes were offered. Many of these were given by the following specialist clubs, who generously supported this annual fixture:—The Blue Persian Cat Society, the Silver and Smoke Persian Cat Society, the Chinchilla Cat Club, the Orange, Cream and Tortoiseshell Society, the Siamese Cat Club, the Manx Cat Club, and the British Cat Club.

The names of the judges acting on this occasion were as follow:—Mrs. Greenwood, Miss Forestier-Walker, Miss G. Jay, Miss Cochran, Miss F. Simpson, Mr. Louis Wain, Mr. Sam Woodiwiss, Mr. C. A. House, and Mr. Jung.

In our latter-day shows the work of the judges is considerably augmented by the numerous specials that have to be awarded amongst the winners in the well-filled classes, and as regards the Crystal Palace show of 1902, the patience and skill of the judges making these awards were taxed to the uttermost.

[Illustration:

SILVER CATS BELONGING TO MRS. CLARK, OF ASHBRITTLE.]

The Cat Club's show has been held for three years in succession at St. Stephen's Hall, Westminster Aquarium, about the beginning of January, and it is at this season that the really finest exhibition of Persian cats is witnessed, for at no other time are long-haired cats in such grand coat and good condition as in the middle of winter.

It is no wonder, therefore, with so many shows held throughout the length and breadth of the land, that the cult of the cat is becoming more and more widely known and appreciated, and that the fancy is really assuming such proportions that there can be no doubt of its permanent position amongst us.

CHAPTER VI. THE "POINTS" OF A CAT.

Before entering upon the distinctive breeds of cats, of which I propose to treat fully in the ensuing chapters, I would draw attention to the accompanying diagram of a cat, and will proceed to point out the general contour of the animal, whether long or short-haired.

[Illustration: [THE "POINTS" OF A CAT.]]

Having given a table of reference, I will take the points of the cat as arranged in order:—

No. 1, Ears: These should be small, and rounded at the tops, carried somewhat forward, and not wide open at the base. In the Persian varieties especially the inner surface should be hidden by a growth of fur extending from the face, termed ear tufts. It is a beauty in the cat to have the ears set well apart, giving an appearance of greater width to the head. The outer portion of the ears should be evenly covered with soft, short, downy fur.

No. 2, Eyes: These ought to be round, large, and full. A small, beady eye is a great disfigurement in a cat. The eyes should be set straight in the head, not slanting like those of a Chinese. In the Persian varieties a fringe of overhanging fur greatly improves and softens the expression. The colour varies in different breeds, but in green, orange, or blue eyes, purity and depth of colour should prevail. Very often an orange eye is spoilt by an inner rim of green, and a blue eye is weakened by a paler shade of blue, giving the appearance of an opal.

No. 3, Skull: Should be broad, with width between the eyes and ears.

No. 4, Cheeks: Well developed.

No. 5, Face and nose: These should be short; if the contrary, a "snipey" appearance is given to the cat, which quite spoils the expression.

No. 6, Chest: Should be full and broad.

No. 7, Neck: Short and full.

Nos. 8 and 9, Shoulder and fore arm: These call for no special remarks; but in male cats especially firm and massive limbs are most desirable.

No. 10, Paw: A large, broad paw, with short but not stumpy feet. In the Persian varieties the tufts are an additional beauty.

Nos. 11 and 12, Body and back: There is a diversity of opinion as to whether a cat should be long in the body or of cobby build. I incline to the latter as regards beauty of form, but I am of opinion that female cats with long bodies are the best breeders. All cats should be low in the legs.

No. 13, Tail or brush: In both breeds this should be short rather than long, and in the Persian varieties broad and spreading. The tail should be carried almost on a level with the body, and slightly curving upwards towards the end. A too-tapering tail is a defect.

Nos. 14, 15, and 16 call for no further remark beyond the desirability of symmetry in form.

The foregoing list of points in a cat may be of some service to novices in the fancy, but it is necessary to add that, as in all animals, condition is a very important factor. A cat may be perfect in all points, and yet if in either the long- or short-haired varieties the coat lacks softness of texture, and in Persians the fur is matted or draggled, such specimens cannot expect to find favour in the eyes of a critical judge, or even an ordinary lover of cats. In short-haired breeds there is an unmistakable gloss on the coat of a cat that is in good health. A spiky appearance of the fur always denotes poor condition, and greatly detracts from the charms and chances of our pets or show cats. A great deal depends in keen competition upon condition. It turns the scale in a vast majority of instances. Therefore, as great attention should be paid to this point as to those set forth in the list I have given.

A small yet distinctive feature in a cat is the whiskers, and these vary in colour, according to the breed. They should be strong and yet sensitive, and curving slightly inwards. It is supposed to be a sign of strength if a cat's whiskers attain a great length.

[Illustration:

(_Photo: C. Reid, Wishaw._)]

[Illustration:

A BLUE PERSIAN BELONGING TO MRS. WELLS.

(_Photo: Ward, Hounslow._)]

CHAPTER VII. LONG-HAIRED OR PERSIAN CATS.

In classing all long-haired cats as Persians I may be wrong, but the distinctions, apparently with hardly any difference, between Angoras and Persians are of so fine a nature that I must be pardoned if I ignore the class of cat commonly called Angora, which seems gradually to have disappeared from our midst. Certainly, at our large shows there is no special classification given for Angoras, and in response to many inquiries from animal fanciers I have never been able to obtain any definite information as to the difference between a Persian and an Angora cat. Mr. Harrison Weir, in his book on cats, states that the Angora differs somewhat from the Persian in that the head is rather smaller and ears larger, fur more silky with a tendency to woolliness.

It is, however, my intention to confine my division of cats to long-haired or Persian cats, and short-haired or English and foreign cats. In both these breeds there are "self-coloured," "broken-coloured," and "any other coloured" varieties.

In the foregoing references to the diagram of the cat I have touched upon the points of the animal, which are practically the same as regards the form of body and limb in both long- and short-haired breeds of cats.

In comparing the dispositions of these two breeds, I think it is generally allowed that Persian cats are not so amiable, or so reliable in their temper, as the short-haired varieties. I am inclined to think, however, that they are more intelligent, and have a greater

instinctive desire to make themselves at home in their surroundings. They are apparently as keen hunters of prey as the short-haired cats. When we come to the question of stamina and general health, I certainly think the Persian must, so to speak, "go to the wall."

It is a common belief that, in human beings, if the hair grows long and thick it is a sign of great strength and a good constitution; but as regards cats the longer the coat the weaker the animal. This I have specially noticed in Persian kittens, and have remarked that little mites with unusually long fur are the most difficult to rear, and suffer from extreme delicacy. Perhaps in-breeding amongst Persian varieties has been more carried on than with the short-haired breeds, which are allowed a greater freedom of choice, and therefore are the result of natural selection.

Apart from the question of health and strength, Persian cats require a great deal more care and attention on account of the long fur. In the spring Persian cats begin to shed their coats, and this process continues through the summer months, and it is not till about October that the new fur begins to grow again. Persian cats may be considered in their finest condition during the months of December and January. It is a wise provision of Nature that during the coldest months these somewhat delicate cats should have their warmest clothing. It has often been a matter of surprise that cat shows should ever be held in the summer, when long-haired pussies present a most unkempt and moth-eaten appearance. In this condition they are not likely to win converts to the cult of the cat; but from an educational point of view these unclothed specimens give the judge an opportunity of displaying his ability, for it needs a really capable judge, with experience, knowledge, and good common-sense, to allow for absence of coat, and to place the awards accordingly. Under summer skies shape and bone will have their innings, whereas a grand winter coat may hide a multitude of sins that even the eagle eye of the most astute judge may fail to discover.

At the same time, for a breed of cats called "long-haired" the coat ought to demand the greatest consideration; for what is the good of the most perfect shape in a Persian cat, if it is exhibited out of coat and almost like an English short-hair in a class set apart for long-haired specimens? No doubt many breeders of Persians have been led through disappointment to join the ranks of short-hair breeders, for it is indeed very vexatious and tantalising, after having entered a grand-coated cat a month before a show, to find your precious pet persistently scratching out her fluffy frill and shedding the chief glory of her breed before the eventful day when you had hoped to reap golden awards.

[Illustration:

"GENTIAN," OWNED BY LADY MARCUS BERESFORD.

(_Photo: E. Landor, Ealing._)]

As regards Persian kittens, the change of coat takes place between the ages of three and six months. In some cases long-haired kittens will cast their fur to such an extent as to present the appearance of an uneven short-haired specimen, whereas in others the shedding process is so gradual that the transition stage from a kitten to a cat is hardly more discernible in the long- than in the short-haired breeds. Any severe illness may cause the fur to come out of Persian cats at any season of the year, and the growth of the new coat will be retarded by poor condition of the skin. In both long- and short-haired cats, as in other animals, the teeth are the chief guide in deciding the age, and a kitten may be said to become a cat after six months, when the adult dental process is completed, and the second set of teeth has become established. And here I would quote from Mr. John Jennings' interesting book on "Domestic or Fancy Cats" in support of my twofold classification: "Of the many varieties or breeds of the cat with which we are now familiar, it must be remembered that, however crossed, selected, re-crossed, domesticated, or what not, we have but two breeds on which the superstructure of what is known to-day as the 'classification of varieties' has been reared—viz. the long-hair or Eastern cat, and the short-hair or European. The term 'breed' is even here used advisedly, for whatever the outer covering or coat, colour, or length of fur, the contour of each and all is practically the same.

[Illustration:

MRS. HERRING'S "CHAMPION JIMMY."

(_Photo: W. Morice, Lewisham High Road._)]

"Nor is this confined to mere outline. Take the skull, for example, which measured in the usual manner with shot, making due allowance for difference in size, is not only similar in the different varieties of either long- or short-hair, but even in the wild cat the anatomy is similar, the slight variation being in a great measure explained by its different conditions of life and diet, and is in unison

with the fact of how even the ordinary domestic cat will undergo a change in taking up a semi-wild, outdoor existence."

At the present time there is no doubt that long-haired cats are the more popular, and, judging by the entries at our large shows, the numbers may be taken as four to one. A slight reaction has set in since short-haired societies have been formed, but the fascination for fluffy pets and pretty pussies will, I think, always predominate, for the less attractive points of the English domestic cat do not appeal so strongly to the heart and the eye of the general public.

It may be remarked by the readers of "The Book of the Cat" that very few pictures of short-haired cats are reproduced; and it is just because the long-haired pussies are so much more attractive that they are brought into greater prominence in this work. It is more difficult to obtain nice photographs of short-haired cats, probably because the owners of these less expensive pets do not think it is worth while to spend their money or to go to any trouble over having a good picture taken. As regards the coloured plates appearing in this work, care has been taken to instruct the artists to bring out as prominently as possible the special points of the cats, long- and short-haired. It is the first time that coloured plates of the different kinds of cats have been attempted; and it is hoped that, as types of each breed, these will prove useful to fanciers and instructive to the cat-loving public.

[Illustration:

THE HON. MRS. McLAREN MORRISON'S CATTERY AT KEPWICK.]

CHAPTER VIII. SOME NOTABLE CATTERIES.

Before entering upon a description of the various breeds, it may be interesting to my readers to give a short account, with illustrations (photographs for which have been specially taken for this chapter), of the catteries of some well-known fanciers who have not confined themselves to any special breed or variety.

Lady Decies' catteries, at her pretty summer residence at Birchington-on-Sea, are indeed most perfect in their arrangements, and every detail for the comfort and well-being of the inmates is considered. The stud cats have separate single houses, with good-sized wired-in runs, and luxurious and cosy sleeping apartments in the rear.

The main cattery is in a sheltered portion of the grounds, and will accommodate a large number of cats. The runs are arranged with boxes, benches, chairs, and ladders, and the sleeping places, built of brick, are most comfortably fitted up. By a system of wooden blinds the strong sea breezes and the bright rays of the summer sun can be regulated. There are side blinds and top blinds. The floors of the spacious catteries are wood, covered with cork carpet, and they are raised about a foot from the ground, so that there is a free current of air passing under the boards, thus securing absolute freedom from any damp.

In the house there are three rooms set apart by Lady Decies for her pussies. In two of these the queen mothers have their families, and the other is used as the cats' kitchen. The beds for the cats are specially designed by Lady Decies. The walls of the cats' rooms are adorned with pictures by Louis Wain, and there is a display of prize cards won by Lady Decies' famous cats. "Zaida," so well known as the winning silver female, is the privileged occupant of Lady Decies' boudoir, and here the aristocratic little lady makes herself at home on the soft cushions and couches.

The famous "Lord Southampton" is now in the possession of Lady Decies, and resides in one of the up-to-date catteries at Beresford Lodge. He was purchased at a very high price. Since his change of ownership he has not frequently appeared in public, but in the past he was a noted winner. It is, however, as a silver sire that he attained his success and made his name. It is well-nigh impossible to mention his numerous winning children. His name in a pedigree is a safe guarantee for quality and colour.

The two Siamese cats have warm quarters in the stable cottage.

Lady Decies' pets comprise both long- and short-haired cats. Among the latter "Xenophon" is generally considered as the best specimen of a brown tabby, and has a long prize-winning record. A woman and a boy are kept to attend to the wants of these aristocratic animals.

The Bishopsgate cattery may be said to have won a worldwide renown, and those who have been privileged to visit the ideal residence of Lady Marcus Beresford will agree with me that it is impossible to give any idea either by photography or description of the delightful dwelling places set apart for the pussies belonging to this true lover and fancier of the feline race.

There is the cat cottage, where the attendant has her rooms, and where the other apartments are especially fitted up for the cats. Here the Siamese have their quarters, and the sun streams in at the windows, which face due south. Opposite to the cottage, as may be seen in the illustration, are some of the cat houses, and in the centre is the kitchen. The cat attendant stands at the door, and some of the pussies are having their midday meal. The celebrated "Blue Boy II." occupies a house, and in the background is a grass run, securely wired in, which is used as a playground for the pussies. In the hot summer weather this is shaded by the lovely spreading beech trees of Windsor Park.

The stud cats' houses are splendidly arranged with sleeping places and nice large runs. The space in the centre in front of these runs is used as an exercise ground for the females and kittens. The garden-house cattery is, indeed, an ideal one, being a bower of roses in the summer-time, and in winter an ivy-clad retreat. This house is divided into two apartments, and these are generally used for the queen mothers and their families. On the shelves along the windows the pussies sit and sun themselves.

Truly the lives of inmates of the Bishopsgate catteries are spent in peace and plenty, and when their little span of life is over they find a resting place under the shadow of the grand old trees, and a little white tombstone with a loving inscription marks the spot of pussy's last long sleep.

Lady Marcus Beresford has had almost every breed of cat under the sun at her catteries, but of recent years she has specially taken up silvers, blues, and Siamese, and a grand specimen of each of these varieties is in the stud at Bishopsgate. Amongst some of the celebrated cats owned by Lady Marcus Beresford I may mention "Lifeguard," a grand orange of massive build; "Tachin" and "Cambodia," two imported Siamese with perfect points; "Cora," a tortoiseshell-and-white of great beauty, and "Kismet," a brown tabby of exquisite shape, both imported; and "Cossy," a smoke that has found a home in America. At the present time three of the most notable inmates of the Bishopsgate cattery, representing blues, silvers, and Siamese, are "Blue Boy II.," "Beetle," and "King of Siam."

[Illustration:

BISHOPSGATE, GENERAL VIEW.]

[Illustration:

CATS' EXERCISE GROUND.]

[Illustration:

THE STUD CATS' HOUSES.]

[Illustration:

CAT COTTAGE AND KITCHEN.]

SCENES AT "BISHOPSGATE."

(_Photos: Cassell & Company, Limited._)

One of the largest catteries in Scotland, where the fancy grows apace, is owned by Mrs. Mackenzie Stewart, of Seagate House, Irvine. Mrs. Stewart has possessed several notable cats of different breeds. Her blue stud cat "Ronald" has made himself a name in the south of England as well as in the north. Mrs. Stewart has had silvers, creams, brown tabbies, and is now the owner of the celebrated black stud cat "Dick Fawe," who has sired many winning kittens. The severe weather of this part of Scotland seems to suit these Persian cats, for a healthier, hardier set of pussies one could not wish to see than those disporting themselves in the pleasantly situated catteries of Seagate House. Mrs. Mackenzie Stewart is a most enthusiastic fancier, and often takes the long journey down South to bring her pets to the London shows. She has acted as judge in Scotland and England, and a contingent from the Seagate cattery is generally to be seen and admired at most of our large shows.

[Illustration:

A SLEEPING BOX IN LADY DECIES' CATTERY.

(_Photo: Cassell & Company, Limited._)]

To old fanciers and exhibitors the name of Mrs. H. Warner is familiar. It was as Mrs. Warner, in 1889, that the Hon. Mrs. McLaren Morrison first exhibited a black cat called "Imp" at the Crystal Palace Show; and as black cats are said to bring luck, this puss took a first, and, thus encouraged, his owner commenced her "catty" career. In the following year, I note, by the catalogue, that Mrs. H. Warner had fourteen entries, and amongst these were two imported cats and the celebrated black Persian "Satan," who departed this life in 1902. As late as 1897 this superb fellow, with glorious orange eyes, won everything he could (in spite of his age) at the Crystal Palace. There remains a worthy son of this worthy sire at the Kepwick cattery, named "Lucifer."

[Illustration:

LADY DECIES VISITING HER PETS.

(_Photo: Cassell & Company, Limited._)]

It was in 1890 that Mrs. McLaren Morrison, then Mrs. H. Warner, made her name as an exhibitor of white Persians; for no less than six of this breed put in an appearance, and gained prizes at Sydenham. Mrs. McLaren Morrison writes:

"I have always been lucky with black cats, both long- and short-haired; but I especially love white Persians, and, in fact, at one time I owned a 'white cattery.' I may say I still have some good specimens—namely, 'Musefer,' 'Queen of the Pearls,' and 'Lily.' I love the imported cats, and always get them when I can. I have nine now at Kepwick. One of these hails from Patagonia and one from Afghanistan. My cattery at one time was twice again as full as now; but my losses have been great, and I have reduced the numbers so that I may give more attention to the young stock.

"It is only recently I have really gone in for orange Persians, encouraged by the wins of 'Puck' at the Botanical. I love this beautiful variety, but consider the queens of this breed very delicate. I have owned some fine blues at different times, and purchased for £25 a beautiful fellow, bred from 'Beauty Boy,' at the Crystal Palace many years ago; but, alas! he came home only to die. Foremost amongst my blues ranked my late Champion 'Monarch,' who held the Beresford Cup. Of late years I have taken up silvers. My first Chinchilla was Champion 'Nizam,' ancestor of such cats as 'St. Anthony' and 'Ameer.' I bought 'Nizam' at the Crystal Palace in the early days of silvers, and he only took second prize, because, I was assured, he was 'too light' for first. I have a few Russians. I am most devoted to my pussies, and have tried to persevere in breeding good stock in the face of very great difficulties. I do not much care about running the risk of showing, but a true fancier likes to support all well-arranged cat shows."

[Illustration:

MRS. MACKENZIE STEWART'S CATTERY.]

Mrs. Collingwood, of Leighton Buzzard, is a most ardent lover of cats, but it is only of recent years that she has been before the public as a fancier and exhibitor. During this time, however, many have been the honours showered on the lucky inmates of the Bossington cattery.

Mrs. Collingwood has great difficulty, so she tells me, in keeping her number of cats down to about thirty! She likes these to be equally divided between long- and short-haired pussies; so there are all sorts and varieties. Blues have been great favourites, and Mrs. Collingwood is on the Blue Persian Cat Society Committee. "Royal Bobs," a big, massive blue male, has done a lot of winning. He was bred by the Princess Victoria of Schleswig-Holstein. His sister "Jill" also inhabits one of the twelve cat houses distributed over five acres of the Bossington grounds. These smaller houses are mostly on wheels. The larger houses are kept for females and their families, and sometimes a corner of the hay-loft is set apart for a nursing mother. The male cats have their liberty during the morning, and then the females enjoy their afternoons out. Mrs. Collingwood does not keep a stud cat, but there are neuter pets that have their run about the house, and have their meals in a corner of the dining-room. Mrs. Collingwood intends going in strongly for smokes in the future; and although possessed of extremely good short-haired cats, this ambitious fancier is desirous of breeding a perfect silver tabby and a likewise equally perfect orange tabby. "James" is a beautiful specimen of a silver tabby, and during this year alone has won eight first prizes. At Altrincham he had the honour of claiming championship and silver medal for the best cat in the show, beating all the long-haired cats that generally carry off this coveted prize; and at the Crystal Palace he was the admired of all admirers, with a number of prize tickets covering his pen. I know many cat-loving people, but I do not think I have ever seen greater devotion shown to the feline race than is displayed at Bossington. Mrs. Collingwood is ever ready to support cat shows by entries, by guaranteeing classes, and by giving handsome prizes. Her cats are always shown in the pink of condition, and it is seldom they appear in the pens unless their devoted mistress is in attendance. Mrs. Collingwood kindly had the accompanying photographs specially taken for this chapter.

Perhaps no name is better known in the cat world than that of Mrs. Herring, of Lestock House, Lee, who has for nearly twenty years been a prominent fancier and breeder of both long- and short-haired cats. Mrs. Herring is a member of the National Cat Club Committee, and also belongs to several of the specialist clubs, and is a member of the Cat Club and the Northern Counties Cat Club. At all the principal shows this enthusiastic lady is a prominent figure, and in the quantity and quality of her exhibits she generally leads the way.

[Illustration:

THE IMITATION TREE, MRS. CLARKE'S CATTERY.

(_Photo: Mrs. S. F. Clarke._)]

At some of our large shows Mrs. Herring has entered from 25 to 30 cats; and I have known and seen these arrive with their mistress in a large omnibus or van. It is no light undertaking to prepare such a number of pussies for show, and then to convey them carefully to the place of exhibition.

Mrs. Herring started with a short-haired silver tabby called "Chin," and then turned her attention to long-haired brown tabbies; and although every variety of cat, both long- and short-haired, may be said to have existed from time to time in the Lestock catteries, yet it is with tabbies perhaps that Mrs. Herring has chiefly made her name and fame. Champion "Jimmy" was a superb specimen of a well-marked silver tabby, and he carried everything before him in the show pen. He passed away in 1900, and I do not think we shall see his like again.

Amongst many celebrities in the feline world which have been born or bred, or have found their habitation at the Lestock cattery, I may mention "King Saul," the noted tortoiseshell tom who still holds a unique position at our shows, and won the Coronation Cup at the Botanical show. "King Alfred," a long-haired silver tabby, and "King David," a massive blue, are also well-known winners of the present day. Mrs. Herring bred some sensational silver tabby long-haired kittens, and two of these—"The Duchess" and "Princess Lestock"—were exhibited respectively at the Westminster and Crystal Palace shows, and both were speedily claimed at the high catalogue price. "Floriana," a huge, handsome long-haired brown tabby, who formerly belonged to Mrs. Herring, has recently found a home in America. Siamese and Russian cats have not been strangers to this cattery, where sometimes the number of inmates has been over forty! Within the last few years Mrs. Herring has had to reduce her stock, owing to the complaints of neighbours, who showed no sympathy with the feline race, and some excellent, well-arranged cat houses had to be removed, as they somewhat encroached on a neighbouring garden wall. It must have been a trying time, and the weeding-out process a most difficult one, for such a really warm-hearted and devoted fancier as Mrs. Herring, whose pussies are all pets, and who personally supervises her cattery at Lestock House.

[Illustration:

MRS. CLARKE'S CATTERY.

(_Photo: Mrs. S. F. Clarke._)]

It is not given to all, particularly in large towns, to have at their disposal such an amount of waste space as their more fortunate brethren of the country. I have therefore asked Mrs. S. F. Clarke, whose cat photographs have been a delight to all our readers, to tell us how she manages in her town residence at Louth. Here are her notes.

BREEDING BLUE PERSIANS IN LIMITED SPACE.

"The successful breeding of blue Persian cats in a space so limited that a grass run or green trees are things to be desired rather than attained, requires nice judgment and great care. The space at my command for cat keeping and breeding purposes is only a back yard, some 14 yards long by 6 yards wide. This very limited space is further curtailed, on one side, by my husband's laboratory; while the cattery and its covered run cut off another strip at the end, of 7 yards by 2 yards, reducing the ground available for open air exercise and run to a patch about 18 feet by 12 feet, and a flagged portion some 21 feet by 6 feet.

"The space between the front of the laboratory and the flagged path being occupied by a small independent house and covered run, is very useful either for isolation or as a separate home for growing kittens. The boundary wall is supported by 4-foot wire netting supported by 3-foot iron stanchions, thus allowing a free edge at the top of about 12 inches to be bent _inwards_ and left _loose_. This I find a sufficient safeguard against my own cats getting out or strange cats getting in—a very important matter at all

times, but especially so at certain periods, if breeds are to be kept pure and pussy not allowed to make her own arrangements.

[Illustration:

THE HON. MRS. McLAREN MORRISON.

(_Photo: Esmé Collings, Hove._)]

"If I were asked for the very best design for building, fitting up, and furnishing a small cattery, I fear I could only answer that requirements differ so in individual cases that it is impossible to draw a hard-and-fast line that will meet all circumstances. Here is a photo of my own (p. 107). It is the outcome of my personal experience, and answers my requirements fairly well. It is a lean-to structure, about 7 yards long by 2 yards wide. The back and one end is formed by the north and west boundary walls, while the east end joins the dwelling-house, thus giving it a south aspect and complete shelter from north and east winds. It is divided into two unequal portions, the smaller (east) portion, 6 feet by 6 feet, forming the cat house proper; the longer portion is the covered run. The front of the house is built of 1-inch wood, with a lining of wood leaving an air space of about 3 inches between the outer and inner surface of the front and dividing partition. The roof is of corrugated iron, with a ceiling of wood about 4 inches below. This arrangement of double walls and roof secures reasonable warmth in the winter, but not quite sufficient coolness for mothers and kittens during the height of the summer. So the roof is then covered with a large white sheet hooked to the wall about 12 inches above the roof and carried over a rail in front about the same height, and there securely fastened. This arrangement insures not only a reasonable temperature, but also a never-ending source of exercise and amusement for both cats and kittens, some gambolling above, while others hide beneath the sheet. An ordinary sun blind along the front completes the summer arrangements. The front of the covered run is closed in with inch mesh wire netting from ground to roof, fitted on the inside with removable shutters, 18 inches high, and, above these, removable window-sashes, closing in as desired. These are held in place with turn-buttons, so they are easily removed or replaced in a couple of minutes, a great convenience in wet or changeable weather, and proving very cosy in the winter. The run is fitted with shelves for the cats to lie upon, a table, sleeping boxes, earth pans, two chairs, and an artificial tree covered with cork, which is a source of great pleasure when the cats are confined by bad weather to the run. The open run consists, as before mentioned, of a space about 18 feet by 12 feet; this is covered with gravel (which in such limited space should be renewed at least once a year), with the exception of a strip some 18 inches wide by 6 feet long on the west side, and two small corners on the east side, _reserved for grass_. This grass reserve, which is most important for the keeping of Persian cats in good health, is renovated every spring with fresh lawn seed, and should either of the patches suffer unduly from special attentions from the pets, it is wired in so as to protect it until it recovers. By this plan my cats secure a supply of grass all the year round. In the centre of the gravel space I have another artificial tree (_see_ photo), about 8 feet high; it is as great a favourite as the one in the run, and as it is hung with a loose cord, a few ping-pong balls, etc., it is a never-ending source of fun and frolic. To supplement the ground space, I place ladders leading to the tops of the roofs of the outbuildings and cattery, which afford extra space for exercise and a charming, interesting, and envious outlook for the cats into my neighbour's garden. It is surprising how soon the kittens learn to climb up and enjoy the roofs.

"The sleeping house contains two wired-in runs going round two sides, about 2 feet by 12 feet long, containing nest-box, earth pan, etc. These are very useful for keeping a queen and litter of small kittens in. There are also two smaller wired-in runs, 2 feet by 6 feet, fitted like the larger ones, so that a cat may be shut up at any time if necessary. The queens sleep in the smaller runs in the winter. Beneath the runs a small cupboard is very useful for odds and ends of all kinds.

"In so limited a space cleanliness is of the utmost importance. The house and runs should be swept out, and the earth pans should be changed, washed, and disinfected _every day_. The question of supplying dust for the pans may prove a source of anxiety to the breeder confined to a limited space. In winter the dwelling-house fires supply about sufficient ashes daily; in summer I am compelled to fall back upon sawdust, which answers the purpose very well, only entailing a little extra litter in the runs and more grooming of the coats. Whatever the difficulty in this direction, it _must_ be overcome and the pans daily changed. The floors and shelves, both in cat house and covered run, should be washed with hot water containing some disinfectant at least once a week, and the wired-in runs for cats and kittens thoroughly done out with hot Sanitas distemper every time they are required for fresh occupants. All bedding should be changed at least once a week, and as little of it used as possible in summer. All plates, etc., used for food must be thoroughly washed after each meal.

"In a space such as I have described my cats have to be kept, for they are allowed into the dwelling-house by special invitation only; but they each receive this treat at least once during the day.

"As to the number of queens: _two_ or _three_ are ample where space is so limited. Where the fresh air run is a back yard, blues are the very best of all colours, as with a daily grooming they always look clean and presentable. In a space such as we are considering I would not on any account recommend the keeping of a stud cat. The want of necessary exercise would be cruelty to it; and the very limited surroundings unfair to those who might wish for his services.

"It is of imperative importance that the queens you commence with be of pure blue pedigree; if prize-winners so much the better, as their kittens will sell more readily.

[Illustration:

MRS. COLLINGWOOD AND "JAMES II."

(_Photo: Alice Hughes, Gower Street._)]

"When mating, be sure that your queen is in perfect health, and do not mate her too young—in my opinion twelve months is young enough, in the interest of mother and family. See that the stud cat chosen be also of the best possible strain. That he be a noted prize-winner is of less importance than that he should be able to produce _kittens that will win_. He must have size, bone, strength, soundness of colour, length of coat, and good eyes. These are indispensable requirements if good blues are to be produced. He should especially be strong in those points where your queen may be somewhat weak; thus if the queen be deficient in length of coat or frill, or in colour, shape, or boldness of eye, see that the selected stud cat excels in those points, and so, as far as possible, correct and balance the points required between the parents. One must not expect to find perfection in any one cat. By using care, judgment, and forethought in mating our pets, we shall go a good way towards establishing in our strain the points necessary to build up the perfect blue Persian.

"All my kittens have been born in a Japanese dress basket, with the lid standing on its side and the bottom half thrust into it cradlewise. The outside of the basket proper is trimmed with a flounce, which helps to keep out draughts; over the top is thrown a small cloth table-cover, which covers, at will, the whole or part of the opening, thus making the little one's house a pretty thing to look at. When any one of my queens is about to have a family I 'flee-flea' her, which I consider most essential for the future comfort of both mother and kittens; then I bring her into the house three or four days before the expected event. For the time being the expectant mother becomes the house cat. I let her find her own bed, which has already been prepared for her, by carefully closing all other places she might be likely otherwise to choose. When her time comes I stay with her during her trouble; but _never interfere_ unless it is absolutely necessary.

"A few encouraging words, and the fact that one is near, seems to give her comfort. If a queen shews much exhaustion, I give a little Brand's Essence with a few drops of brandy in a spoon; but if all goes smoothly I let well alone. There is no need to press food upon the mother; she will not require it until some time after the births are complete. A little warm milk or gruel offered between the births may sometimes prove a comfort; but many queens will not touch it. For about three weeks, that is to say until the little ones creep out of their beds, I keep the queen and her family in the dwelling-house with me, changing her bed every other day. After the first week I make it a rule to handle the kittens at least once a day, and if the queen has more than three to bring up I begin, at two weeks old, feeding them three times a day with a few _drops_ of warm sweetened milk from a spoon, increasing the quantity very gradually as they grow. I never wake the kittens to feed them—sleep is as necessary as food; but always arrange to feed them just after the little ones wake; they are then hungry, and that is the best time to assist and relieve the mother. It is surprising how soon the kits enjoy being fed and look out for the friendly spoon.

"As soon as the little ones can get out of their bed they must be introduced to a shallow tin filled with ashes or earth. I prefer ashes to sawdust for very little kittens, and I find at a month old they will regularly use it. This early lesson in cleanliness is invaluable, as later on, with reasonable care, they never forget it. When the kittens are from three weeks to a month old I remove them, with the mother (or foster-mother), to their own little run in the cattery, where I visit them three or four times a day. When they grow stronger, and as early as the weather will permit, they are introduced to the open-air run, the sunshine, and the other cats.

"I begin the grooming as early as possible, daily brushing the little things in their bed or on my lap; it improves the fur, and the more they are groomed the sooner they get to like and enjoy it. When grooming kittens two or three months old, I generally have three or four trying to get under the brush at the same time, endeavouring to push the favoured one out of the way. I am strongly of opinion that the frequent handling of kittens does not do them any harm, but does tend to improve their temper and increase their gentleness. When I have callers the kittens are invariably fetched, introduced to, and fondled by the visitors, so that they become

not the least afraid of strangers; as a result, when they go to new homes they come out of their basket without fear, making themselves immediately at home, much to the comfort of themselves and their new owners.

"The best time to dispose of kittens is at about eight weeks old. Breeders with limited space _must_ sell young and quickly, keeping only the one or two of the season they may either wish to show or turn into next year's brood queens. To get overcrowded is to court disease and disappointment, so sell early for the best price you can get; but sell you must, even if the price does not seem anything approaching the true value of the kittens. The first loss will be the known loss—most certainly far less than that involved in the risk of keeping one or two more kittens than your space should accommodate."

[Illustration:

A MORNING MEAL AT BOSSINGTON.

(_Photo: A. J. Anderson & Co., Luton._)]

[Illustration:

BLACK PERSIAN "JOHNNIE FAWE" OWNED BY DR. ROPER.

(_Photo: Lavender, Bromley._)]

CHAPTER IX. BLACK PERSIANS.

Never have these truly handsome cats received the amount of admiration and attention which they deserve. There are fewer breeders of black Persians than of any other variety, the two most noted fanciers being Dr. Roper and Mr. Robert Little. Both of these gentlemen have owned and exhibited very handsome specimens; Miss Kirkpatrick has also bred some lovely black kittens. The entries in the black classes at our shows are almost invariably the smallest; but as a specialist club for black-and-white Persians has been started, it is hoped more encouragement will be given to the breeders of these handsome self-coloured cats.

As in the other self-coloured cats, the chief point is absolute uniformity of colour throughout. It is fatal for a black cat to have a brown, rusty tinge; it should be a glossy jet black, betraying no bands or bars in the full light, and having no under-coat of a lighter shade, and, above all, no spot or tuft of white hairs on the throat. This latter is a very common fault amongst black cats, and it is one which takes away enormously from the value of the specimen, for either show or breeding purposes. In some other varieties of Persian cats two, or even three, colours for eyes are permissible; but a really good black cat must have the full round eyes of deep orange, and very attractive are these gleaming orbs, shining forth from their dense black surroundings. When black cats are changing their coats they often present a very rusty appearance, and newly born kittens are sometimes like balls of brown fluff. These, however, frequently grow up the very best-coloured blacks. This breed is very strong and healthy, and often grow into large, massive cats. A tortoiseshell female is a splendid mate for a black male, and some of the most noted blacks have been bred in this way. Two brown tabbies will generally produce one, if not more, good blacks in a litter.

Black cats have been found very useful to breeders of silver tabbies and smokes for this reason—that these two breeds require to have their markings and colourings intensified. That is, a silver tabby with dark grey markings is not a true type, and a smoke with an upper coat of cinder colour does not represent the true smoke. Therefore the introduction of a black cross is often a great advantage to these breeds. There is certainly not much demand for black kittens, and we never hear of very high prices being asked or given for these, or, indeed, for full-grown cats. But as "every dog has his day," so, perhaps, there is a good time coming for blacks; and certainly beginners in the fancy might do worse than to provide themselves with a thoroughly good black queen, for, anyhow, in exhibiting the chance of honours is very much greater than when competing in classes in which there are so many entries, as in the case of blues and silvers.

For very obvious reasons black cats are the very best animals for those living in London or near large towns. They can never present a dirty appearance, and, therefore, in this particular they will always score over the whites, creams, and silvers. To keep their coats glossy and bright black cats should be well brushed and groomed. They will repay for this care and attention. Our American cousins call self-coloured cats "solid," and as applied to blacks this is especially expressive, for a black should not have a suspicion of any other colour than a dense black. If, when the coat is blown apart, a shading of grey or blue is seen it is a great defect. The nose should be black, and the pads of the feet also.

[Illustration:

CHAMPION "MENELIK III." (AMERICAN).

THE PROPERTY OF MRS. BOND, WASHINGTON.]

I do not remember having seen or heard of an imported Persian black cat. In an article on imported cats in _Our Cats_ the writer (whose name is not given) says:—"White cats with blue eyes are not often to be obtained from abroad, neither are the blacks warranted to possess the amber eyes voted correct by up-to-date cattists. I know of a black queen straight from the land of cats and the palace of the Shah himself; it had the most glorious emerald eyes it is possible to imagine—as different from the ordinary run of green as flaming amber is from faded yellow. This cat, a Persian among Persians, had a coat as black as the proverbial jet—perfectly black throughout—long and straight, of fine, silky texture, but not giving one the impression of massiveness that is such a prominent, feature of the type of imported cat. Moderate in size, slightly built, with an expression so foreign that it amounted to weirdness, this cat could with a dash of imagination have been worked up into the incarnation of a spirit, a soothsayer, the veiled beauty of a harem, a witch, snake charmer—what you choose; but always remain something far apart from prosaic England, something tinged with romance and the picturesqueness of the mystical East. This black cat was undoubtedly a typical Persian."

As there is such a dearth of good black cats in England, it is a pity some enterprising breeder does not try to import a really splendid specimen, which might bring luck to himself and the fancy.

In looking back to the old catalogues of Crystal Palace shows, I find the same scarcity of blacks exhibited as at the present day. In 1886 the black male class is marked "no entry," and in 1889 Mrs. H. Warner (now the Hon. Mrs. McLaren Morrison) makes the sole and only entry of "Imp" in the black class. It was in the following year, however, that this same well-known lady fancier exhibited "Satan," a black that was never beaten whilst it lived. It was the most remarkable of unapproachable excellence I can remember—a veritable triton among minnows.

In many of the accounts of our largest shows I remark such paragraphs as these: "Good blacks with orange eyes were conspicuous by their absence." Or again: "The black classes, as usual, were poorly filled." It is, therefore, high time that this beautiful breed should receive more attention at the hands of fanciers, and that not only beginners but those who are well known in the cat world should take up blacks, and, as the expression goes, "run them for all they are worth." At present Dr. Roper's and Mr. R. Little's black Persians have it all their own way. Mrs. Lenty Collins frequently has a look in with her wonderful big-eyed "Forest Beauty," and Mrs. Crowther, in the North, is faithful to this her favourite breed of cats; but we want some more dusky beauties to swell the ranks of black Persians.

As everyone knows, a vast deal of superstition is connected with a black cat. This is what Harrison Weir has to say on the subject:—"It is often said, 'What's in a name?' The object, whatever it is, by any other would be the same; and yet there is much in a name. But this is not the question at issue, which is that of colour. Why should a _black_ cat be thought so widely different from all others by the foolish, unthinking, and ignorant? Why, simply on account of its colour being black, should it have ascribed to it a numberless variety of bad omens, besides having certain necromantic power? In Germany, for instance, black cats are kept away from children as omens of evil; and if a black cat appeared in the room of one lying ill, it was said to portend death. To meet a black cat in the twilight was held unlucky. In the 'good old times' a black cat was generally the only colour that was favoured by men reported to be wizards, and black cats were said to be the constant companions of witches; and in such horror and detestation were they then held that when the unfortunate creatures were ill-treated, drowned, or even burned, very frequently, we are told, their cats suffered martyrdom at the same time. It is possible that one of the reasons for such wild, savage superstition may have arisen from the fact of the larger amount of electricity to be found by friction in the coat of the black cat than of any other; experiments prove there is but very little either in that of the white or the red tabby cat. Be this as it may, still the fact remains that, for some reason or other, the black cat is held by the prejudiced ignorant as an animal most foul and detestable, and wonderful stories are related of their actions in the dead of the night during thunderstorms. Yet, as far as I can discover, there appears little difference either of temper or habit in the black cat distinct from that of any other colour, though it is maintained by many even to this day that black cats are far more vicious and spiteful, and of higher courage, and this last I admit. Still, when a black cat is enraged and its coat and tail are well 'set up,' its form distended, its round, bright, orange eye all aglow with anger, it certainly presents to even the most impartial observer, to say the least of it, a most 'uncanny' appearance. But, for all this, their admirers are by no means few; and, to my thinking, a jet-black cat, fine and glossy in fur and elegantly formed, certainly has its attractions."

But although black cats are supposed to be harbingers of evil under some conditions, yet in others they are credited with miraculous healing powers. In Cornwall, sore eyes in children are said to be cured by passing the tail of a black cat nine times over the part affected; and in some parts of the country the presence in the house of a black cat is both an antidote and a cure for epilepsy.

[Illustration:

KITTEN BRED BY MISS KIRKPATRICK.

(_Photo: E. Landor, Ealing._)]

I think that most cat fanciers are inclined to believe in the possible luck that a stray black cat may bring them, and perhaps be more inclined to take in a stranger of this particular breed than one of another colour.

There is an old Scotch proverb that says:

"Whenever the cat o' the house is black, The lasses o' lovers will have no lack."

The celebrated "Fawe" strain of black Persians is well known in the fancy. Dr. Roper has sent me some notes on his famous prize-winning cats, together with some useful information regarding the breed with which his name has become associated:—

"For many years black Persians were a most popular breed; but, like fashions, for the time being other colours, I regret to see, are obtaining more notice from fanciers. For years I plodded away to breed what I considered a perfect black Persian; at last my labours were crowned with success. What can equal a richly coloured, heavily coated, deep orange-eyed black?

"In breeding blacks, like any other colour, it is essential you should procure the best of stock, and be prepared to give a fair sum for such, otherwise you are almost sure to be disappointed in your results, and, maybe, retire as a fancier of this colour and try some other; but you will meet with the same fate if you hold the same views as to expense. A black Persian should be perfect in colour, with absence of white hairs, cobby in shape, short in leg, tail bushy and not too long, eyes large and deep orange, a good broad head, ears short with tufts and well set apart, short face, coat long and silky.

"Having stated the points, I will now give my experience of breeding.

[Illustration:

MRS. LITTLE'S BLACK PERSIAN "COLLEEN."

(_Photo: D. Nottle, Beckenham._)]

"In my opinion, it is most important the sire should be a black, and one of his parents a black, whatever colour the queen is. I have had greatest success in breeding from a black sire and a tortoiseshell queen. Through this cross you may get either blacks or tortoiseshells. As an instance I quote 'Johnnie Fawe' (black) and Champion 'Dainty Diana' (tortoiseshell). From these I have bred many good blacks, amongst them 'Dick Fawe,' 'Lady Victoria,' and other good ones; also good tortoiseshells, three of them having taken championships. Blacks may also be bred from a black and a blue, or two blacks—in this case, cross the sire with one of his progeny, which I have found very successful. I admit there are other ways of breeding blacks, but in my experience the three ways I have suggested have proved to be the most satisfactory.

"In breeding, to be sure of success so far as the eyes are concerned, if possible it is better that both parents should have orange eyes, the deeper the better; but it is most essential the sire should have good orange eyes. Notwithstanding the queen's eyes being light amber, by crossing with a good orange-eyed sire the kittens are very likely to have good-coloured eyes, but not _vice versâ_. As an instance, I once purchased a very handsome black queen, perfect in all points with the exception of the eyes, which were very light amber. I mated her to 'Dick Fawe,' who had the deepest orange eyes I have yet seen in a black; the kittens developed orange eyes. I have mated in the opposite way, and the result has been unsatisfactory so far as the eyes have been concerned, and if breeding for show the colour of the eyes is most important. The late Mr. Welburn, a well-known judge, once said in one of his reviews of blacks at a large show (I think it was the Crystal Palace), 'I scarcely think that eyes alone should carry an award, yet it is always best to uphold the desired properties so hard to obtain.'

[Illustration:

THE CAROL SINGERS.

(_Photo: E. Landor, Ealing._)]

"Having bred a litter of black kittens, it is unwise to make up your mind what colour they are going to be until they have attained the age of six months. I remember once giving away a kitten at three months old which I called iron grey and thought would or could never be black. Six months after I saw my friend, who thanked me very much for the lovely black kitten. Two months after seeing him I saw the cat: there were no white hairs, and the colour was a perfect black. This last Richmond show I showed a black kitten, aged seven months; it took a first, a second, and a special. At three months old I thought it was going to be a smoke. It was claimed by the Hon. Mrs. McLaren Morrison. I have a kitten now, aged three months, perfectly bronze in colour and a grey frill. I have no doubt at seven months old it will be a perfect black. I have given these illustrations in order that those who are thinking of going in for blacks should not give up all hope of the kittens becoming black until the age I have stated.

"I breed my kittens from January to July, and find they do much better in the catteries, all of mine being separate; and I find Spratt's movable runs most useful. In showing blocks they should be brushed and rubbed with a Selvyt cloth daily one month previously and kept free of matted hair. The application of Brilliantine or American Bay Rum in small quantity brushed on gives a perfect gloss to their coats."

[Illustration:

BLACK-AND-WHITE PERSIAN CATS.]

CHAPTER X. WHITE PERSIANS.

A great change has taken place of late years in the quantity and quality of these beautiful cats, for whereas formerly blue eyes were considered quite a rarity, now it is seldom we see any yellow-eyed white cats exhibited at our principal shows. The most perfect type of a white Persian is assuredly to be found amongst the imported cats; there is a certain beauty of form and silkiness of fur which is not possessed by the specimens bred in this country. They are also generally distinguished by unusually long coats, round heads, tiny ears, and wonderful toe tufts.

[Illustration:

"JUNGFRAU," SIRE AND GRANDSIRE OF MANY AMERICAN WINNERS.

(_Photo: W. F. Arnold, Oak Park, Ill._)]

One of the most lovely white imported cats was exhibited by Lady Marcus Beresford at the Westminster Cat Club Show in 1900. The best judges declared that there was not a fault to find with "Nourmahal," but her career was a short one. These imported cats are often of a rather savage disposition, and, although they can be sweet-tempered enough with human beings, they are extremely fiery with their fellows. There are two points peculiar to white cats—they are frequently stone deaf, and they very often have odd-coloured eyes. Certainly the deafness is a drawback, and in selecting a white cat care should be taken to ascertain if the specimen is possessed of sound hearing. Needless to say, there are many ways of arriving at the solution of what is really a mysterious dispensation of Providence, for why should one particular breed of the feline race be so constantly minus this useful sense? Then, again, as regards the quaint arrangement of different-coloured eyes. One might not be so surprised if the eyes of white cats were sometimes pink, for their noses are pink, and the cushions of their feet, and, as in human beings, we might expect to have albinos amongst cats, namely white with pink eyes; but Harrison Weir states he has never seen pinkeyed whites, although it has been asserted that they exist. This peculiarity, however, of odd eyes seems only to be found in white cats, the two colours being blue and yellow. Occasionally white cats have wonderful seagreen eyes; and, although these are decidedly very uncommon, no colour is so completely in accord with the purity of the coat as eyes of heavenly blue. The tone should be not so much of a sapphire as of the deep forget-me-not blue. One of the drawbacks to white Persians is the difficulty of keeping them in spotlessly clean condition. This is absolutely impossible if they are living in or near a town, and certainly a white cat soiled is a white cat spoiled.

As regards the mating of blue-eyed white cats, I have been told by experienced breeders of this variety that kittens with blue eyes are just as frequently bred from odd-eyed parents, or, at least, when one of the parents has different-coloured eyes. It is easy to tell whether the baby blue eyes are likely to retain their colour or turn yellow. If at about three weeks or a month old the blue becomes

tinted with green, then surely but sadly may we make up our minds that these kittens have not a distinguished career before them, for they will see and be seen with yellow eyes. It is a pity to try mating white cats with any other variety, as broken-coloured cats will probably be the result. It frequently happens that white kittens, when quite young, have smudges of grey on their heads; these gradually disappear. In America white cats seem prime favourites, and the demand exceeds the supply for importation of white Persians with blue eyes. At the last Beresford Cat Club Show the entries in the white classes were very large. The classification included and provided for golden and blue-eyed whites, and these were subdivided according to sex, and all the classes were well filled. Mrs. Clinton Locke's "Lord Gwynne" is a noted white stud cat on the other side of the water, as is also Mrs. Colbourn's "Paris."

The devotees of the white cat in our own country are not many in number. I may mention Mrs. Finnie Young and Miss Hunt, who are perhaps the most successful breeders of whites in Scotland; and in the south we have Mrs. Pettit, whose tribe of blue-eyed whites I had recently the pleasure of seeing. No more lovely specimens could be imagined, and I counted more than a dozen long-coated, full-grown, bonnie blue-eyed beauties, walking about in the woods surrounding Mrs. Pettit's dwelling place near St. Leonards-on-Sea. The illustration shows Mrs. Pettit surrounded by eight of her pretty white pussies. Mrs. Westlake, Mrs. Nott, Miss White Atkins, and Miss Kerswill are all successful and enthusiastic breeders of white Persians.

[Illustration:

MRS. McLAREN's WHITE PERSIAN "LADYSMITH."

(_Photo: C. Reid Wishaw._)]

Several well-known fanciers keep one white cat amongst their flock. I may mention the Hon. Mrs. McLaren Morrison, the owner of "Musafer," a famous imported puss, and Lady Decies, the former possessor of "Powder Puff," who has recently been presented to H.H. Princess Victoria of Schleswig-Holstein. There is always a keen demand for white kittens, either as pretty pets or, if with correct coloured eyes, for breeding purposes, and, doubtless, when more encouragement is given to this beautiful variety, there will be an increase of fanciers of the white cat, whose praises have been sung in fairy tales, nursery rhymes, and by novelists who have a weakness for describing interiors with a beautiful white Persian cat reclining on the hearthrug.

[Illustration:

MRS. PETTIT WITH HER WHITE PERSIANS.

(_Photo: Cassell & Company, Limited._)]

I am indebted for the following notes on white Persians to Miss M. Hunt, whose beautiful white cat "Crystal" appeared on an earlier page, and by an unfortunate mistake was stated to be the property of Mrs. Finnie Young:—

"The blue-eyed white Persian is, I consider, one of the most interesting to breed, and, in my experience, no more delicate or difficult to rear than any other Persian.

"I have had them now for nearly four years, and, I think I may say, with a good deal of success. I bought 'Crystal' in 1898, when four months old, and she certainly has been a good investment. Out of the sixteen white kittens she has had, ten of them have been blue-eyed.

"The very best kitten I owned was never exhibited; he went to Mrs. Champion, who considered him the best and healthiest kitten for his age she had ever seen. Unfortunately, he died suddenly shortly after she had him. He was by Champion 'White Friar' _ex_ 'Crystal,' and was one of the same litter as 'Jovial Monk,' which did so much winning for Miss Ward, who purchased him from me at the Crystal Palace, where he took first. 'Crystal' herself has only once been beaten by a white cat, and that had not even blue eyes; but she was in splendid coat, and 'Crystal' was quite out of coat. Most judges are agreed, I think, that 'Crystal' is the best blue-eyed white female in the country.

"The colour of the eyes of white kits can be told much earlier than in any other colour; some I can tell as soon as they are open, others I am not quite sure of till they are about a fortnight old. The eyes are generally bright blue from the beginning, without a shade of kitten grey in them. I do not think that both parents having blue eyes makes much difference to the number of blue-eyed kits in the litter. If one parent is blue-eyed and the other odd-eyed the result is often just as good. I know of a green-eyed queen which had a litter of three by Champion 'White Friar'—all were blue-eyed.

"As to deafness, I cannot account for it at all, as it often appears, though both parents have perfect hearing."

"Since Mrs. Finnie Young and I purchased 'White Friar' in 1900, whites have become much more plentiful in Scotland, and the competition is now very keen indeed up North. 'White Friar' has had a very successful career since he came into our hands, both as sire and on the show bench, and can still hold his own against all comers. He has won sixteen first prizes since 1900, besides championships and numerous specials."

Mrs. Champion, whose name is well known in "catty" circles, and who has now left these shores for America, did a great deal to establish a thoroughly good strain of white blue-eyed Persians. Her celebrated "White Friar" (now in the possession of Mrs. Finnie Young and Miss Hunt) is justly considered the finest male specimen in the fancy. Certainly he could only have been beaten by his son "White Tsar," bred by Mrs. Champion from her "White Witch." This cat, which assuredly would have had a notable career, was sold by Mrs. Champion for £20 to Mrs. Colbourn, in America. He arrived in poor condition and died shortly afterwards. I remember seeing an absolutely perfect white Persian kitten at Mrs. Champion's. It was by "White Friar" ex "Crystal." He had startling deep blue eyes, tiny ears, and broad, round head, and at nine weeks old his coat measured nearly three inches across. Alas! though healthy and strong, this proved too perfect a specimen for this world, and "Crystal Friar" succumbed to the epidemic of gastritis then raging amongst our feline pets. Referring back to celebrated white Persian cats of the past, I well recollect the marvellous size and splendid coat of Mrs. Lee's "Masher," who took the cat world by storm when exhibited at the Crystal Palace in 1890. This enthusiastic fancier paid £21 for "Masher," whose show career was shortened by an accident. This cat was remarkable in those days, if only for his grand blue eyes.

[Illustration:

"CRYSTAL."

THE PROPERTY OF MISS M. HUNT.

(_Photo: C. Reid, Wishaw._)]

The well-known breeder and judge Mr. A. A. Clarke, whose name is more closely connected with blue Persians, once owned a famous female called "Miss Whitey." I remember that this really remarkable cat was exhibited in 1887 at the Crystal Palace, and again in the following year, when at four years old she took first prize and silver medal in a strong class of nine females. It seems to me that these cats, as I recollect them, appeared half as large again as the present-day champion winning whites; but whether this was in consequence of more profuse coat or a generally bigger build of animal I cannot at this distance of time pretend to determine.

Amongst the well-known prize-winners and stud white Persian cats of the present day I may mention Miss White Atkin's massive-limbed "White Knight," whose broad skull is especially remarkable in a show pen, and commends itself to the notice of the judge. Miss Harper's "Blue-eyed Wanderer" has great quality and lovely texture of coat. He was in truth a wanderer in the streets of a London suburb, and, although labelled "breeder and pedigree unknown," he has almost always held his own in the white classes at our largest shows. Mrs. Westlake, Mrs. Pettit, Mrs. Finnie, and Miss Hunt are all possessed of imported white cats, which have proved worthy ancestors of many prize-winning kittens. There have not been any very notable female white cats exhibited since the appearance of Lady Marcus Beresford's "Nourmahal," with the exception of Miss M. Hunt's "Crystal" and Mrs. Pettit's most lovely "Piquante Pearl," bred by her from her stud cat "King of the Pearls" and "Beautiful Pearl." This cat is as near perfection as possible, and has carried off highest honours whenever exhibited. Mrs. Pettit began breeding white Persians in 1896, and has kept faithful to this breed ever since. This enthusiastic breeder always accompanies her exhibits, and her precious Pearls are never seen at the smaller mixed shows. I have always heard that white kittens are difficult to rear, and Mrs. Pettit, who should be well qualified to give her testimony on this point, says: "Without a doubt blue-eyed white Persians are the most delicate cats in existence." A well-known authority on cats, writing to one of the cat papers, says: "What a change has taken place in our white classes, long- and short-haired! A few years ago white cats with green or yellow eyes frequently were prize-winners, and a blue-eyed white was looked upon as a rarity. Now blue eyes have it all their own way, and judges are becoming more and more exacting as to the depth of tone and quality of the blue tint. If we could obtain a white Persian with the glorious eye of the Siamese, it would be a treasure indeed."

A gentleman who has lived for ten years in Assam says that he never saw in that part of India any long-haired cats except blue-eyed whites. He also gives an amusing account of the usual way of obtaining a cat of this variety for a pet. It is as

follows:—"You give instructions to a native, who offers to procure you one at a certain price, but gives you no idea where or how he means to procure it. In about a week's time he appears with the cat and claims the money. Things progress favourably with your new possession for a time, but suddenly and unaccountably your puss disappears. You are calling on some friend or acquaintance, and, to your surprise and astonishment, there on the armchair lies, curled up, your cat! Thus it will be seen that the wily native makes a small income out of one cat, by stealing or enticing it away from the original purchaser and calmly re-selling it to one of the neighbours."

Mrs. Clinton Locke, the president of the Beresford Cat Club, has owned some beautiful white Persians which she has imported from time to time. This lady writes thus to _Our Cats_:—"The first white Persian I ever owned was brought to me many years ago from Persia by a distinguished traveller, and its eyes were amber, showing that the white cats brought from their native land have not always blue eyes. The descendants of this cat, mated to both amber and blue-eyed cats, have thrown blue eyes. Two odd-eyed cats have also given blue-eyed kittens; but a pair of blue-eyed cats has by no means always thrown blue eyes with every kitten in the litter."

[Illustration:

"WHITE BUTTERFLY."

THE PROPERTY OF MISS WHITE ATKINS.

(_Photo: E. E. Lipputt, Leamington._)]

One of our most persistent and consistent breeders and fanciers of white Persians is Mrs. Westlake, and therefore I am glad to be able to put forward a few of her experiences as to the peculiarities of the breed.

Mrs. Westlake, writing from Camden Town, says:—

"My acquaintance with white Persian cats began some years ago, when I imported a white female as a pet. I was so delighted with her that, although for a London resident white cats would seem the least desirable, I decided to import two blue-eyed whites for breeding purposes. It was a litter from these two cats that tempted me to take up exhibiting. This litter consisted of _all_ blue-eyed kittens, the tone of the blue being exceptionally deep. Since then I have, of course, often had a different tale to tell, and odd-eyed kittens have sometimes predominated. This curious freak of nature connected with white cats seems unaccountable. The two colours are generally yellow and blue, but I have seen green and blue. I have also remarked on the very brilliant tone of the one blue eye.

"There is a popular belief that almost all blue-eyed cats are deaf. All I can say is that I have never had a blue-eyed white that was deaf. I have, however, often come across those that were stone deaf, and others with defective hearing. Again an unaccountable freak.

"White Persian cats have been declared to be the most difficult to breed and delicate to rear. My opinion is that the delicacy is much more in their coats than their constitutions; that is, of course, in comparison with other foreign varieties, none of which are as hardy as the British.

[Illustration:

IMPORTED BLUE-EYED TOM, "MUSAFER."

(_Photo: V. R. Clarke, Thirsk._)]

"A few remarks as to the cleansing of white cats may be useful. As a dweller in London, I need scarcely say that unless I occasionally gave personal attention to my pussies they would not always be in the show condition that I would desire. Some fanciers wash their white Persians, but I have come to the conclusion that this treatment tends to coarsen the soft silkiness of the fur; and therefore, for this reason, and also because there is a risk of cats catching cold, especially in winter, I advocate dry cleaning, and suggest the use of Pears' white precipitated fuller's earth. One plan is to place the cat on a large sheet or towel, mix a little ammonia in warm water, dip your hands in this, and pass them over and over the fur, letting it become thoroughly moistened but not wet. Then well sprinkle the coat with the powder, and by keeping the animal in front of the fire the fur will soon become quite dry. Then rub with a soft towel, and finally brush thoroughly with a clean and not too hard brush. Your efforts will be rewarded with success, and though puss may be considerably bored during the process, she will not resent it so much as a tubbing. I find that

white females are far more diligent as regards their toilet than the males, who seem always to have more of the Eastern languor and indolence in their nature. I have remarked—and no doubt it is more noticeable in the white breed—that as soon as young kittens are beyond their mother's control they exhibit a marked antipathy to keeping their coats in anything like decent condition. Sometimes they will make a feeble attempt at washing themselves; but something will excite their attention, and off they will go, or perhaps in sheer fatigue will fall asleep during the toilet. Thus white kittens will very soon present a most unkempt appearance, and the poor mother gazes sadly at them as though the cares of a family were too much for her, and she no longer wishes to own what was once her pride and joy—a spotless litter!

"It has been stated that white cats are wanting in expression, probably because of the lack of markings to give character to the face; but breeders of whites will nevertheless agree with me that they have even greater force of expression, not being assisted by any markings. I have found white cats to be most affectionate, and very conservative in their tastes. I have owned some white Persians with light seagreen eyes, and although these are not correct, yet I must say they were strikingly beautiful and very uncommon. I have been offered high prices by Americans and others for my imported white female, but my 'blue-eyed darling' will, I think, end her days with her devoted mistress in dear, dirty, old London."

CHAPTER XI. BLUE PERSIANS.

A famous publisher once gave the following advice to a young author: "Never take it for granted that your readers have any previous knowledge of your subject, but credit them with ordinary intelligence." To all feline fanciers the heading of this chapter is a familiar household term, but to novices in the cat world and to outsiders the term "blue" as applied to a cat may sound rather absurd. Truth to tell, the name is misleading, and yet the same is used in describing certain breeds of domestic animals, such as dogs, rabbits, etc. There is also a fur much used for trimmings of ladies' jackets, etc., called blue fox, and this is very much akin to the colour and texture of the fur of the blue Persian cat, which, however, varies in tone from a dark slate to a pale lilac-blue.

[Illustration:

JACK AND

(_Photo: H. Warschkarski, St. Leonards-on-Sea._)]

It is over twenty years ago since I exhibited the first "blues" at the Crystal Palace Cat Show, and they created quite a sensation, for no one seemed to have seen any cats of this peculiar shade before. Some called them grey or lilac, and others London smoke or slate colour. One of my pair of blue kittens was quickly claimed at catalogue price, and I brought in the other, fearing I should lose her also. She, in her turn, became the mother of many celebrated blues. In those early days of the fancy blue Persians were entered in the "any other variety" class, and most of the specimens exhibited were in reality blue tabbies. For some years this state of things continued; but Mr. A. A. Clarke, so well known as one of the pioneers of the National Cat Club, and as a breeder, exhibitor, and judge, agitated with other fanciers, myself amongst the number, to obtain a better classification for the self-coloured blues, and in 1889 the schedule at the Crystal Palace Show contained a class for "Blue—self-coloured without white." For some time this breed of cats was termed "self blues," in contradistinction to the many blues with tabby markings which were formerly so very common in the fancy.

In 1890 it was decided to divide the sexes in the blue cat classes, and let the kittens compete with black-and-white. The result was an entry of eight in each class, my famous "Beauty Boy" taking first in the male, and Mrs. H. B. Thompson's celebrated "Winks" first in the female division. At Brighton in the same year the "self-blue" class was adopted with success.

[Illustration:

JILL.

THE PROPERTY OF MISS BENNETT.

(_Photo: H. Warschkarski, St. Leonards-on-Sea._)]

The famous blue stud cats of that period were Mr. A. A. Clarke's "Turco," Miss Bray's "Glaucus," and my own "Beauty Boy." Amongst other exhibitors of blues about this time I may mention Mrs. Warner (now the Hon. Mrs. McLaren Morrison), Mrs. Vallance, Mrs. Wells, Mrs. Hunt, Mrs. H. B. Thompson, Mrs. Ellerton, and Miss F. Moore. In 1891 blues came very much to the fore, and the entries at the Crystal Palace numbered 15 males and 17 females. At Cruft's Show in the year 1894 a grand blue, called

"Wooloomooloo," was exhibited by Mrs. W. R. Hawkins, and this cat became one of the most famous of stud cats. Many of the finest blues of to-day are descended from this noted sire. Mrs. H. B. Thompson's "Don Juan" was for many years greatly in request as a stud cat, and many beautiful blues claim him as their ancestor.

A little later "Moko" became famous as the sire of a sensational kitten exhibited by Mr. C. W. Witt at the Westminster Show of 1900. "Moko" was sold at a high figure to Mrs. Barnett, and is now in the possession of Mrs. Singleton, of Yeovil. Mr. A. A. Clarke was considered the best judge of this variety, and at the Palace and Brighton he did much to encourage the breed by offering handsome special prizes in the blue classes.

It is true that the prize-winning cats of ten and fifteen years ago would have had but a poor chance in the present-day competitions, chiefly for the reason that cats of the past could look at a judge with bright green eyes and yet be awarded the highest honours. _Nous avons changé tout cela_, and now a blue cat without the much to-be-desired orange eyes fetches but a small price, and is at a great disadvantage in the show pen. An up-to-date judge may, however, be led into giving too great a prominence to this point and thus sacrifice soundness of colour, shape, and form. Then, again, I remember when a white spot on the throat of a blue Persian was not considered a serious defect; now a few straggling white hairs will cause anguish to the owner, and a judge will promptly put down the specimen for this blemish.

Blue cats with white spots used to be relegated to the "any other colour" class; but recently both the National Cat Club and the Cat Club have wisely decided that such cats should be judged in their own classes. However, I think that owners of these specimens would do well to keep them away from the show bench, where the competition in blues is now too keen to give any chance for defective cats to have a look in. I may mention that the nose of a blue Persian is a few shades darker than its fur, and the toe-pads yet a little darker.

As will be seen from the standard of points for blues, which will be found later on in this chapter, the highest marks are given for soundness of colour. There is a tendency to breed very light blues, and popular fancy favours this particular type. I am inclined, however, to prefer a good sound medium blue as being the best and safest for breeding purposes. The lovely pale blues are beautiful to look at, but are seldom absolutely sound in colour. Blues, whether dark or light, should be the same tint throughout, so that when the coat is blown apart the colour at the roots is the same as at the tips. A white under-coat is a serious blemish, and this often appears when silver blood may be traced in the ancestry of a blue cat. We have quite dropped the term of self-blue, and yet this well expresses the uniformity of colour which is so desirable. As tiny kittens blues frequently exhibit tabby markings; but fanciers need not worry over these apparent defects, for as the coat grows the bars and stripes are no longer visible.

It also sometimes happens that a kitten exhibits quite a light ruff, but this is generally shed with the second coat, and eventually disappears. There are some cats erroneously called blues by novices in the fancy, but which in reality are blue smokes. These have probably been bred from blues and smokes, and thus the type of each is seriously damaged. If it is desired to breed sound-coloured blues, then it is undesirable to cross them with any other colour save and except blacks. I have found good results from mating blues and blacks, more especially with a view to obtaining the deep amber eyes of the black Persians, which, for some reason or other, are generally larger, rounder, and deeper in colour than what we can produce in blues. Certainly all broken breeds and tabbies should be avoided when mating blues. I have heard of white cats being bred with blues to get a pale tint of blue; but white toes, chests, and spots have often been the results of such experiments. I have bred blue Persians ever since I took up the fancy, which is longer ago than I care to remember, and I have found them strong and hardy cats, requiring no special food, and enjoying the best of health without any cosseting or coddling. I do not consider that blues usually obtain any great size or weight, nor are they generally massive in build or profuse in coat.

[Illustration:

BLUE AND CREAM PERSIANS.

(_From a Painting by W. Luker, Jun._)]

Ten or fifteen years ago I used to have my blue kittens bespoken for about £5 each before they were born; but nowadays, when blues are so plentiful, one must be content with lower prices, and the average sum for a good blue kitten is three guineas. Still, I am sure that for beginners in the fancy, wishing to combine pleasure and profit, there is no better investment than a good sound blue queen with orange eyes. The demand for blue kittens is really larger than for youngsters of any other breed. They make superb pets, but it is to be regretted that blue neuters are generally spoilt with green eyes, doubtless for the reason that the possession of

good orange eyes tempts the owner or purchaser to reserve the specimen for stud or breeding purposes.

As one of the first breeders and exhibitors of blue Persians I feel I am in a position to speak with authority, and I am of opinion that no breed has made such rapid strides, either in improvements or popularity, as blues. In this statement I am supported by our best professional judge, Mr. T. B. Mason, who, writing to me on the subject, says: "I find ten good blues at the present time to one we came across two or three years ago. I am of opinion that in no colour of cats have we seen more distinct progress than we see in blue Persians." Such a statement, coming from our most able and ubiquitous judge, is a valuable one. Mr. Mason has had a large experience in cat judging during the last few years, and his duties take him north and south, east and west.

As regards the breeding of blues, I consider that to obtain the true sound colour blues should only be bred to blues.

I have often, however, observed that a kitten of unsound colour is to be found in litters bred from two sound-coloured blues; the kitten may have a white under-coat or be full of white hairs, or have a shaded ruff; but experienced breeders will soon discover that such blemishes are but temporary, and that the ugly duckling of a family may develop into the flower of the flock. It is, therefore, very interesting to make experiments and to keep an apparently worthless specimen to see what it turns into when the first months of infancy are passed and the kitten coat has been shed.

I have known a young blue of sound colour completely transformed in this particular by a severe illness. Her fur became a sort of pepper-and-salt mixture—a sprinkling of white and dark grey; but this same cat, contrary to the prophecy of an able judge, has again changed her coat, and is now a perfectly sound blue, even from tip to root. It was evident that her illness had affected her coat, and that when she regained her usual health she recovered her correct coat. As regards the eyes in blues, it is not possible to give any exact time for the change in colour from the baby blue to the dreaded green or hoped-for orange. This change takes place gradually, and sometimes the period extends till a kitten is almost a cat. There are many blue cats with what may be called indefinitely coloured eyes; that is, neither orange, nor yellow, nor green. This most unsatisfactory state of things may be generally accounted for by a circle of green round the pupil, which, according to the time of day, will be wide or narrow. Thus it is that cats with this defect are sometimes described with "good yellow eyes," and advertised as such, and then, when received by the purchaser, a glint of green is plainly visible in the inner circle. The perfect eye in a blue should be absolutely unshaded; and there are two distinct types of eyes, namely, the golden eye and the orange eye. The former resembles a golden coin in tint, and the latter has the dash of red which is to be seen in copper. Both these coloured eyes are correct, and much to be admired in blue Persians, and no doubt as time goes on we shall find it will be the rule and not the exception to see these perfect eyes amongst the blues of the future. It must, however, be borne in mind that in the point of eyes cats throw back, and two parents with good orange eyes may yet produce one or more kittens with pale eyes of yellow or greenish hue. Although I have dilated at length on the superiority of the orange eye in blues, I do not wish it to be thought that a weedy, boneless cat, even with eyes of deepest hue, would find favour in my sight; for in blues, as in all breeds of Persians, what we ought to seek after most earnestly are good massive limbs, plenty of bone, and broad skulls. There are too many Persian cats of hare-like proportions, and we really want some of the type of a good old English tabby introduced into the more aristocratic long-haired breeds.

[Illustration:

THE ARTIST.

(_Photo: Mrs. S. F. Clarke._)]

It will be interesting to up-to-date breeders of blues to hear what the veteran cat lover and fancier Harrison Weir had to say about them fifteen years ago. In his well-known book, "_Our Cats_," he thus alludes to the breed:—

"Blue in cats is one of the most extraordinary colours of any, for the reason that it is a mixture of black (which is no colour) and white (which is no colour), and this is the more curious because black mated with white generally produces either one colour or the other, or breaks black-and-white or white and black; the blue being, as it were, a weakened black or a withdrawal by white of some, if not all, of the brown or red, varying in tint according to the colour of the black from which it was bred, dark grey, or from weakness in the stamina of the litter. When once the colour or break from the black is acquired, it is then easy to go on multiplying the different shades and varieties of tint and tone, from the dark blue-black to the very light, almost white grey. If whole-coloured blues are in request, then parti-colours, such as white and black, or black and white, are best excluded."

Many of our leading cat fanciers "go in" exclusively for blues, and keep faithful to this one breed alone. I give a list of these, and trust I may be pardoned if I have left out the name of any enthusiastic breeder and lover of blues and blues alone: Mrs. Hill, Mrs.

Wells, Mrs. P. Hardy, Mrs. H. Ransome, Mrs. Bennet, Mrs. Mocatta, Mrs. S. F. Clarke (Louth), Mrs. Cartwright, Mrs. Gregory (Lincoln), Mrs. H. B. Thompson, Mrs. O'Brien Clarke, Miss Jay, Miss Bennet, Miss Messer, Miss Patterson, Miss Goddard, Rev. P. L. Cosway, Mrs. Swanson, Mrs. Curwen, Mrs. Duffin, Mrs. W. M. Hunt, Mrs. Slingsby, Mrs. Singleton, Miss Savery, Mrs. Eustace, Mrs. Hitchcock, Miss Hooper, Miss Violet Hunt, Miss Humfrey, Mrs. Kennaway, Mr. H. Maxwell, Mrs. Ponder, Miss Rigby, and Mr. C. W. Witt.

[Illustration:

BLUE KITTENS BRED BY MISS KIRKPATRICK.

(_Photo: E. Landor, Ealing._)]

There are, of course, a large number of fanciers who, amongst other breeds of cats, keep one or two blues, and several keep blues and silvers only. I think I may safely say that blue Persians have the largest number of admirers, and certain it is that at all our large shows the blue classes are the best filled. At the Cat Club Show held at Westminster in 1899 the number of entries in the blue female class was a record one—there were no less than 48, and the blue males mustered 42.

Seeing, therefore, how popular this breed had become, in April, 1901, I founded and started the Blue Persian Cat Society, a book of rules was drawn up, and the following ladies and gentlemen appointed as officials of the society:—

BLUE PERSIAN CAT SOCIETY.

Founded April 24th, 1901.

Presidents: Viscountess Maitland, Mrs. Maconochie, Miss Gertrude Jay.

Vice-Presidents: Viscountess Gort, Lady Danvers, the Hon. Mrs. Maclaren Morrison, Mrs. Collingwood, Mrs. W. M. Hunt, Miss Violet Hunt, Mrs. Clinton Locke, Mrs. Lionel Marks, Mrs. Herbert Ransome, Mrs. Mackenzie Stewart, Mrs. H. B. Thompson, Mrs. Woodcock, Sir H. Jerningham, K.C.M.G., Sir B. Simpson, K.C.M.G., Rev. P. L. Cosway, Frankfort Moore, Esq., R. Storks, Esq.

Committee: Mrs. Baldwin, Mrs. Russell Biggs, Mrs. Bishop, Mrs. P. Brown, Mrs. P. Hardy, Mrs. Collingwood, Mrs. H. L. Mocatta, Miss H. Patterson, Mr. Gambier Bolton.

Hon. Treasurer: Mr. Russell Biggs, 1, Garden Court, Temple.

Hon. Secretary: Miss F. Simpson, 9, Leonard Place, Kensington, W.

Judges: Lady Marcus Beresford, Mrs. P. Hardy, Mrs. W. M. Hunt, Miss G. Jay, Miss K. Sangster, Miss F. Simpson, Mr. C. A. House, Mr. T. B. Mason, Mr. F. Norris, Mrs. Mackenzie Stewart, Miss E. Goddard, and Miss Kirkpatrick.

[Illustration:

MRS. ROBINSON'S BLUE KITTENS.

(_Photo: J. Joyner, Cheltenham._)]

The chief objects of this society are as follow:—To promote the breeding and exhibiting of blue Persian cats; to define precisely, and to publish a description of, the true type of blue Persian cat, and to urge the adoption of such type on breeders, exhibitors, and judges, as the only recognised and unvarying standard by which blue Persian cats should be judged; the improvement of the classification, and, if necessary, the guaranteeing of classes for these cats at shows supported by the society; the selection of specialist judges to make the awards at such shows. The annual subscription to the Blue Persian Cat Society is five shillings, payable by each member on election. At the general meeting of the society, held in April, 1902, the number of members on the books was 183, and the honorary secretary reported that during the past year twelve cat shows had received the support of the society, and numerous handsome challenge prizes, badges, and specials had been offered for competition.

[Illustration:

MRS. WELLS' CATTERY.

(_Photo: Cassell & Company, Limited._)]

The following is the standard of points drawn up by the committee of the Blue Persian Cat Society and approved of by the members of the society:—

STANDARD OF POINTS FOR BLUE PERSIAN CAT.

Coat (30).—Any shade of blue allowable; sound and even in colour; free from markings, shadings, or any white hairs. Fur long, thick, and soft in texture. Frill full.

Head (25).—Broad and round, with width between the ears. Face and nose short. Ears small and tufted. Cheeks well developed.

Eyes (20).—Orange; large, round, and full.

Body (15).—Cobby, and low on the legs.

Tail (10).—Short and full, not tapering.

Members should not be deterred from showing their cats if they do not come up to the high standard set forth in the above definition.

It is true that very few, if any, blue Persians come up to the high standard here given, but still there is a very marked improvement in the breed during the last year or two. The number of green-eyed blues are steadily and surely decreasing, and the colour of the coat and size of head are points that have been carefully attended to. In reading the list of blue cats placed at stud in the columns of the cat papers we cannot help being impressed with the enormous strides made of recent years in this breed of cats alone. In a recent copy of _Our Cats_ I counted twenty-five stud advertisements of blues, and this does not nearly represent the entire number of blues used for stud purposes by fanciers. This breed of Persians has become very popular in America, and several fine cats have been exported, and have carried off the highest honours at the New York Cat shows, held under the auspices of the Beresford Cat Club.

Mrs. Clinton Locke, the president of the club, is an enthusiastic breeder and admirer of blues, and has possessed the finest specimens among American fanciers.

The names of two good "all-round" judges appear on the blue Persian list, namely, Mr. C. A. House and Mr. T. B. Mason, and exhibitors of this special breed—as, indeed, of any other—may feel quite sure that their precious pets will receive justice at the hands of these two careful adjudicators.

Mr. E. Welburn, also a blue Persian judge, was long known and respected in the fancy, and his death in 1902 was a great loss to the cat world. Two silver bowls have been subscribed for by his many admirers in memory of this upright judge, and these are competed for annually at the two largest shows of the National Cat Club and the Cat Club.

[Illustration:

"ROKELES KISSI."

BRED BY MRS. BENNET.

(_Photo: H. Warschkowski, St. Leonards-on-Sea._)]

Miss Jay and Miss Frances Simpson have frequently given their services as judges at some of the shows which have received the patronage of the Blue Persian Cat Society.

In conclusion, I would say that I am very hopeful of being able at some future time to hold a show for blue Persians, and by dividing and subdividing to give an attractive and liberal classification.

I have pleasure in giving a short account, with illustrations, of some of the catteries belonging to blue breeders.

Mrs. Wells, of Isleworth, was one of the first exhibitors of blue Persians, and has been faithful to this breed for many years. She has wonderfully well-planned catteries, and, having plenty of space at her command, the cats are able to enjoy lots of liberty in large wired-in runs, planted with shrubs, and with an abundance of grass. Mrs. Wells' blues are noted for their wonderfully fine coats. Her stud cat "Blue Noble" has sired many noted winners, and "My Honey," a lovely queen, has the deepest orange eyes I have ever

seen. Mrs. Wells takes the greatest interest in her cats, and each and all are pets; in fact, so great is the care and devotion bestowed upon them that Mrs. Wells is very seldom persuaded into exhibiting any of her beautiful blues, and never lets them attend any shows unless she herself is able to accompany them.

Mrs. Wells' cottage is situated in a most rural district of Isleworth, and one might fancy oneself miles and miles away from the busy haunts of men. At the time the photos illustrating these catteries were taken Mrs. Wells had eighteen blue kittens, besides several grown-up representatives of her favourite breed. At one time Mrs. Wells was bitten with the silver fever, and began to breed this variety; but the litters did not give satisfaction, and she determined to return to blues—with what success can be learnt from a visit to the gardens at Isleworth.

Miss Gertrude Jay started cats in 1891, and her name will always be connected with blues. Nothing has ever been exhibited to compare with her wonderful female "The Mighty Atom" as regards beauty and shape of head. This cat, now, alas! no more, swept the board wherever it was shown. Twice she carried off the highest honours for best cat in the show at the Crystal Palace. It is true that this grand specimen lacked the orange eyes, but no judge could pass over such a perfect type of cat, despite her one fault, and thus "The Mighty Atom" reigned supreme. "Trixie" and "Doris," two of Miss Jay's noted blues, have also both won specials for the best cat in the show at the Crystal Palace. Miss Jay is fortunate in having some descendants of these precious cats in the luxurious catteries at Holmwood (of which an illustration is given). Many lovely blues may be seen revelling in the well-appointed houses set apart at the end of the long terrace for their special use. Miss Jay about a year ago retired from the cat fancy, and withdrew her name from the two clubs; but she is still a vice-president of the Blue Persian Cat Society, and often acts as judge. Her name always draws a good entry, and, as a well-known fancier once remarked to me, "You can be sure of getting your money's worth when Miss Jay has the handling of the classes." The following few remarks from Miss Jay on her method of judging will be read with interest:—

"I fear my way of judging is unlike most other people's, because I do not judge by points unless it comes to a close fight between two cats. Of course, I consider shape and colour first, and then I mark all those unworthy to be in any prize list; next get to work with the remainder, and this I do, as I say, unlike most other judges, for I pick out the cat that I would soonest have given to me that day, with the object of showing it again at once. The point to be decided is the best cat _that_ day. It is no use beginning to think which cat will be the best in a month's time or which cat might have been best a month ago; it is there _that_ day—which is best? And, to my mind, if I award first to the cat I would rather have, with the one object of continuing to show it, _that_ surely must be the best cat in my opinion, and to that cat the first card goes. And so on through the class, only giving one V.H.C., one H.C., and one C., unless the class is a very large one. I know some judges who say commended cards are very cheap, and they please the exhibitors. True; but are you not pleasing them in a wrong way by making them think their cat is better than it is?"

[Illustration:

"SCARED."

TWO BLUES BELONGING TO LADY MARCUS BERESFORD.

(_Photo: Cassell & Company, Limited._)]

Mrs. Herbert Ransome is well known in the feline world as a successful breeder of blue Persians, and as the hard-working secretary of the Northern Counties Cat Club, and more recently as the editor of _Our Cats_. Her two blue stud cats, "Darius" and "Darius III.," have earned a great reputation, not only in the show pen, but as the sires of many lovely prize-winning kittens, notably "Orange Blossom of Thorpe," owned by Mrs. Slingsby, of Ouseburn, Yorkshire.

It is only of recent years that the name of Mrs. Paul Hardy has become known in the feline world as a breeder of blue Persians. Mrs. Hardy was a member of the Cat Club Committee, but on her removal to some distance from London she resigned her post. To her the Cat Club is indebted for a very beautiful design of a medal which, in silver and bronze, is competed for at the Westminster and other shows (_see_ illustration).

[Illustration:

CAST OF THE CAT CLUB MEDAL.

DESIGNED BY MRS. P. HARDY.]

Her first adventure into the domain of cat keeping was in the case of a very fine blue cat named "Juliet," whose first few litters were not a great success, so that sensible cat took matters into her own hands. She chose for her mate the raggedest black tom she could find, and though, of course, the results of this _mésalliance_ were not at all satisfactory from the show judge's point of view, in later years, when suitably mated, "Juliet" did not once throw back to a wrong-coloured kitten. I am not sure that I can follow Mrs. Hardy to the logical conclusion of her deductions from this fact, but I think it is worthy of notice by those extremists who hold the view that an incorrect mating in the first instance spoils a queen for the rest of her life.

It was at the Crystal Palace show of 1897 that Mrs. Hardy exhibited her first litter from her blue stud "Wooshoo," and she was then awarded a first, a special, and two or three silver medals. Another famous cat in Mrs. Hardy's establishment was a blue, named "Mark Antony," who met with success at several Scottish shows. Later he came under the notice of Mrs. Mackenzie Stewart, into whose hands he passed, and received a good deal of favour at the hands of the judges. From Mrs. Stewart he passed into the possession of the late Dr. Longwill, and was sire of the famous Crystal Palace winning female blue, "Dolly Gray," in 1902.

Mrs. Hardy's success has not been achieved without some set-backs, more particularly of recent years, since her cattery has been enlarged, and she has had to fight her way against disease and death. Her own account is so vivid that I quote it, so that fanciers in a like evil condition may fight for the lives of their pets to the last:—

"I was singularly free from illness of any kind amongst them, and I lived for some time happy in the belief that the Persian puss was in no wise different from her short-coated sister in the robust possession of nine lives; so I added cat unto cat, and bred for show; when swiftly Nemesis overtook me. I showed five full-grown cats at the first Westminster show, and twenty-four hours after the show was over my best blue queen, a young beauty whose proud owner I had been only for one brief month, died of acute pneumonia. A few days later influenza showed itself amongst the others, and all four were down with it.

"What a time I had, with the experiences of a ward-nurse! But I pulled them through, all but one young kitten of four months, in whom acute laryngitis developed, and so she had to be put to sleep.

[Illustration:

MISS G. JAY'S CATTERY.

(_Photo: W. Field, Putney._)]

"'Wooshoo' was given up by the vet., as he piled so many complications into his system one after the other, developing bronchitis, gastritis, and jaundice on the top of the original complaint. Poor fellow, for twenty-four hours he lay _unconscious_, but I kept his heart going by doses of _pure alcohol_ every two hours, while I fought the disease with hot fomentations, medicated steamings, and other proper remedies.

"For just _one month_ I had to hand-feed him, and then one afternoon it occurred to him he might try his minced oyster by himself, greatly to my joy and triumph; and when he feebly washed his face afterwards I felt like setting the church bells ringing!

"I am convinced, in serious cat illness, it is the _night nursing_ that does the trick and determines whether your patient is to live or die. It is somewhat of an effort, I admit, to have to arise two or three times in a night (nearly always in the bitter weather, when these epidemics occur), and, in my case, to be obliged to dress and go out of doors to the stableyard, with a dimly burning lantern.

"In every cat lover's career there must be some such saddening memories. Saddest when, after the efforts of the night, and you have left hopeful the morning will bring improvement, you return in the early dawn to note on entering a sign that causes your heart to beat heavily—_your patient's bed is empty_!

"You know what _that_ means, and look round. Yes, there in a corner, flat, stiff, and draggled, where he has crawled in the last uneasy seeking for air, is your poor pet, still for ever!"

Mrs. Hardy, in connection with illnesses, has some advice to offer as regards medicines which she has tested herself, and which I think will be of service to my readers:—

"While not intending to say anything authoritatively upon the subject of remedies for various cat ills, all of which will be most ably and exhaustively gone into by the writer of later chapters in this book, I might perhaps mention one or two things of which I have had personal experience, restoratives rather than drugs, which I now keep always at hand.

"One is a preparation of beef called 'Somatose.' It is sold in 1 oz. or 2 oz. tins, is in the form of a fine soluble powder, and has this advantage over certain beef essences—that it will keep good any length of time, and has not to be used up directly the tin is opened; while it is no more expensive, and a little will go a long way if used as directed.

"I make it by putting some _boiling_ water into a saucer, sprinkling about a teaspoonful on the water, and allowing it to dissolve slowly till cold, when it would look like weak tea. It is a most powerful restorative and stimulant, and given _cold_ in teaspoonful doses can be retained in the worst case of stomach irritation.

"A second good thing is Plasmon powder. I was recommended to try this by a cat lover, for a case of dyspeptic sickness of a chronic character. For delicate kittens it is most valuable, and I believe the very worst cases of diarrhœa or dysentery can be cured, and the patient saved to grow up strong and healthy, if a diet of Plasmon jelly, given cold, with alternate meals of Somatose, also given _cold_, be persevered with until the bowels are normal. Never give milk in _any_ form, either plain, boiled, or in puddings, to a cat that is suffering from looseness of the bowels. Another little hint I may be allowed, perhaps, to give: Don't wait for illness to come before you train your kittens to _take_ medicine from a spoon.

"I teach all my youngsters to drink easily from a spoon, beginning with something nice—sweetened milk or the like, going on to cold water and, when necessary, a drop or two of Salvo's Preventive in it. Then, when it becomes necessary for a real nasty dose, they are not in the least nervous of the spoon beforehand, and the dose is down and gone before they discover anything unusual. Never have I to wrap cloths round any of my cats, or get people to hold them by main force; but some cats will nearly turn themselves inside out when a spoon is held to their mouths! All the fault of early training. Badly brought up! You must be _very_ patient with a young kitten; never do anything in a _hurry_. When once you have gained a cat's confidence it will let you do anything to it."

[Illustration:

REV. P. L. COSWAY'S "IMPERIAL BLUE."

(_Photo: G. & J. Hall, Wakefield._)]

[Illustration:

"UN SAUT PÉRILLEUX."

(_From a Painting by Madame Ronner._)]

CHAPTER XII. SILVER OR CHINCHILLA PERSIANS.

[Illustration:

"JACK FROST."

BRED BY MRS. MIX, OLD FORT BATTERY, NEW YORK.

(_Photo: A. Lloyd, Amsterdam, N.Y._)]

Perhaps no breed or variety of cat has been so much thought about, talked about, and fought about in the fancy as the silver or chinchilla Persian. If blues are a new variety, then silvers are of still more recent origin. Years ago this cat did not exist—that is to say, we should not recognise the silver Persian of to-day as the silver of bygone times, for the simple reason that the only class of silver in the fancy formerly was the silver tabby. In those days there were self-coloured cats and tabby, or marked cats, and broken-coloured cats. Previous to the introduction of a Chinchilla class at the Crystal Palace in 1894, the class for silver tabbies included blue tabbies "with or without white," and it is curious to read in the old catalogues of the Crystal Palace shows the titles given to the various cats by the owners, some describing their cats as "chinchilla tabby," "light grey tabby," "silver grey," "silver chinchilla," "blue or silver striped." We may infer that these cats were either blue tabbies or silver tabbies, or something betwixt and between. I distinctly remember the large number of cats which in these enlightened days we should find it difficult indeed to classify. It is often said, "What's in a name?" But still, in trying to describe a particular breed of cat, it is as well to endeavour to find a term which expresses as nearly as possible both the colour and the appearance of the animal. There has been a great deal of discussion as to the correct name by which these delicately tinted Persians should be called.

The National Cat Club began by classifying them for the Crystal Palace show in 1894 as Chinchillas, and they have kept to this, although it is really a most misleading title, as the cats are quite unlike the fur which we know as chinchilla, this being dark at the roots and lighter towards the tips. Now, cats of this variety ought to be just the reverse.

It is difficult to give a correct idea of the real colour and appearance of these cats. The fur at the roots is a peculiar light silver, not white, as one might imagine, until some pure white is placed beside it, and this shades to a slightly darker tone—a sort of bluish lavender—to the tips of the coat. The Cat Club introduced the term "self silver," but this is suggestive of one colour only, without any shadings whatever. Another class, called "shaded silvers," was added; but then, again, tabby markings are not shadings. Formerly, blues used to be called "self blues," but this is entirely done away with, and now we never think of using this term, and speaking of them as blues we understand there should be the one and only colour.

Surely, then, the simplest term and the most descriptive of these beautiful cats is "silver," pure and simple, for whether dark or light they are all silvers, and so we should have blues and blue tabbies, orange and orange tabbies, silver and silver tabbies.

Then comes the question of what is nearest perfection in this variety of cat, which has come upon us of late years, evolved from the silver tabby and the blue. The ideal silver, to use the words of a well-known breeder of these cats, should be the palest conceivable edition of a smoke cat, with fur almost white at the roots and palish silver grey at the tips, and as free from markings as a smoke. I do not go the length of declaring that silvers cannot be too light, for I think that it is the delicate tips of silvery blue that lend such a charm and give such distinction to this variety. Without these delicate tippings a silver cat would look inartistic and insipid. There has been of late quite a rage amongst silver breeders to produce a totally unmarked specimen; but fanciers would do better to endeavour to obtain a light _shaded_ silver free from tabby markings with the broad head and massive limbs, which at present are qualities not often met with in this variety. I am quite aware this is a most difficult task, but we must remember that "all good things come hard," even in breeding cats, and if it were not so half the interest for fanciers would be gone.

[Illustration:

"THE ABSENT-MINDED BEGGAR."

OWNED BY MRS. NEILD.

(_Photo: E. Landor, Ealing._)]

[Illustration:

"STAR DUVALS."

SILVER PERSIAN OWNED AND BRED BY MISS MEESON.

(_Photo: F. Parsons, Southend-on-Sea._)]

Having, therefore, considered what a perfect silver cat ought to be, I will give a description of the type of cat generally bred and exhibited as a silver. I read the following account in one of our daily papers, evidently written by a non-admirer of these lovely cats: "The chinchillas are very fashionable, and very difficult to breed in perfection. They took their name from a supposed likeness the fur bears to that of the chinchilla. But the chinchilla cat, as at present in request, bears no resemblance to the little rodent. Most of the exhibits are of a dirty white, tinged with lavender, with a quantity of marks and stripes on the face, body, and paws." Now this is not a pleasing picture, and one that would be considered libellous by a silver breeder. It is, however, true that at present our silvers are too full of tabby markings, and in many cases the under-coat is not silvery white, but light grey or pale blue. There are many silver cats with dark spine lines and shaded sides, but they are heavily barred on the head and legs, and the tail is frequently almost black. It is a case of tabby blood which needs breeding out of the silvers, and which, no doubt, will be obliterated in time, so that two distinct types of silvers will only exist—the delicately tipped or shaded silvers, and the richly marked and barred silver tabbies. Just as in the case of the blue Persians it took a long while to eradicate the tabby markings which showed the existence of tabby blood, so amongst silvers the bar and stripes need to be carefully bred out, and we shall hope, in the good time coming, to have not _self_ silvers, but a very near approach to this—namely, a perfectly unmarked but yet not wholly unshaded silver cat.

[Illustration:

"OMAR."

THE PROPERTY OF MISS A. POLLARD

(_Copyright 1901—G. Hiller, Elizabeth, N.Y._)]

There is a greater delicacy amongst silver cats, and more difficulty in rearing the kittens, than in any other breed, and this may be accounted for by the immense amount of in-breeding that was carried on indiscriminately at the beginning of the rage for silver cats; also the desire to obtain lightness of colour caused breeders to lose sight of the grave disadvantages of loss of bone and stamina. Therefore it is that among the silver cats exhibited at our shows we seldom find massive limbs or broad heads or full cheeks. There is a tendency to hare-like proportions, and the faces have a pinched and snipey appearance, and noses are too long. However, great improvement is taking place, and with the numerous stud cats now at the disposal of fanciers, there ought to be no difficulty in making a suitable selection.

The question as to the correct colour of eyes for a chinchilla or silver cat is still a vexed question. In self-coloured cats the broad line is clearly laid down—blue eyes for whites, orange for blacks, and orange for blues; but when we come to the more nondescript cats—such as silver and smoke and tortoiseshell—there seems to be a wider margin given, and the line drawn is not so hard-and-fast. Still, I think it is always well to have some high standard of perfection in each breed, so that fanciers may breed up to it, and to my mind the bright emerald green eye is the ideal for a silver cat. I have seen very fine amber eyes which could not fail to attract admiration; but if these are admitted, then all sorts of eyes, not amber but wishy-washy yellow, will be the inevitable result. So many silver cats have eyes that may be described as neither one thing nor the other. Often one hears the remark, "Oh! but if you see So-and-so's eyes in the right light they are a lovely green." But viewed by the ordinary eye of a critical judge, they appear an uncertain yellow. Therefore it is best to set up a standard, and I think it is becoming an almost undisputed fact that silver cats of perfect type should have green eyes, and by green let it be understood that the deeper the tone the better will they accord or contrast with the pale silvery coat.

[Illustration:

THREE PRETTY SILVERS.

(_Photo: C. Reid, Wishaw._)]

I would here impress upon fanciers the great importance of striving to obtain the large, round, full eye, which gives such expression to a cat's face. How many of our silvers of to-day are spoiled by small, badly shaped or half-open eyes! I do not think sufficient importance is attached by our judges to this point of _size_ of eye. Many are carried away by the correctness of colour, and fail to deduct a sufficient number of points for a beady, badly shaped small eye.

Colour is fleeting, and with age our cats may lose the brilliancy of green or orange, but bold large eyes, placed well apart and not too deeply sunk, will be lasting points in favour of our pets.

There is one rather peculiar feature in the eyes of some silver cats. This is the dark rim which often encircles the eye. This rim decidedly enhances the beauty of the eye, and makes it look larger than it really is, and also throws up the colour. Light, almost white, ear tufts and toe tufts are adjuncts which go to make up a perfect silver cat. The nose is of a dull brick red, darkening slightly towards the edges.

Few Persian cats suffer so severely during the process of shedding their coats as silvers, and they present a most ragged appearance at this period of their existence. The lovely fluffy light silver under-coat almost disappears, and the top markings stand out very distinctly, so that a cat that in full feather would be considered a light, unmarked specimen will appear streaked and dark after the coat has been shed. As regards the silver kittens, it is a curious fact that these, when born, are often almost black—or, at any rate, generally very dark in colour, resembling smokes. It is seldom that a silver kitten is light at birth, but gradually the markings and shadings will lessen, and perhaps just the one mite that was looked upon as a bad black will blossom forth into the palest silver. In this respect, silver kits are most speculative, but in another they are cruelly disappointing, for a kitten at three months old may be a veritable thing of beauty, and ere it has reached the age of eight months, bars and stripes will have, so to speak, set in severely, and our unmarked specimen of a silver kit develops into a poorly marked tabby cat. I may say that if the kittens are going to be really pale silvers they will in the majority of cases have very pale faces and paws, with little or no marking, whilst the body will be fairly even dark grey—perhaps almost black. In a week or two a change takes place, as the under-coat begins to grow, and it will be noticed that the kittens become more even in colour, the contrast between their light face and dark backs will not be nearly so accentuated, and by the time they are nine or ten weeks old they will look almost unmarked. The reason

for this is that the dark fur they are born with is really only the extreme tips of the hair, and as their coats grow in length this shading becomes more dispersed.

And here I will allude to the so-called threefold classification which was part of the scheme of the Silver Society, founded by Mrs. Champion in 1900. At the inaugural meeting Mrs. Stennard Robinson took the chair. Voting papers had previously been distributed amongst the members, asking for their votes on the question of establishing three classes for silvers—namely, chinchillas, shaded silvers, and silver tabbies. The votes recorded were fifty-four in favour of the threefold classification, and nine against it. So this was carried by a large majority, and the question of points discussed and settled as follows:—

CHINCHILLAS.

As pale and unmarked silver as possible. Any brown or cream tinge to be considered a great drawback. Eyes to be green or orange. Value of points as follows:—

Head 20 Shape 15 Colour of coat 25 Coat and condition 20 Colour, shape, and expression of eyes 10 Brush 10 ——— Total 100

After much discussion, Lady Marcus Beresford moved, and Mrs. Champion seconded, the following definition of Shaded Silvers:—

SHADED SILVERS.

Colour: pale, clear silver, shaded on face, legs, and back, but having as few tabby markings as possible. Any brown or cream tinge a great drawback. Eyes green or orange. Value of points:—

Head 20 Colour of coat 25 Coat and condition 20 Colour, shape, and expression of eyes 10 Shape 15 Brush 10 ——— Total 100

[Illustration:

"SHAH OF PERSIA."

THE PROPERTY OF MRS. ANNINGSON.]

From this list it will be seen that for colour the highest points are given, and that eyes may be green or orange. But during the two years which have elapsed since the formation of the Silver Society, there has been a decided desire on the part of breeders for green eyes _only_, and certainly our best qualified silver judges are not partial to any other coloured eyes in this variety. In an article on the colour of eyes in silvers, "Zaida" of _Fur and Feather_ writes: "Eye colouring threatens to become a matter of fashion. Some eight years ago we received from a first-rate fancier and exhibitor a letter respecting a chinchilla cat, which later became a great prize-winner. 'It is useless,' wrote this lady, 'to think of exhibiting her on account of her green eyes.' What a change of opinion has marked the flight of eight years!"

It will be observed that, as regards the description of chinchillas and shaded silvers, there is a distinction and yet no very great difference, and herein lay the difficulty of retaining these two classes at our shows. The lightest silvers were deemed eligible for the chinchilla class, and then came the question for exhibitor and judge to draw the line between the two so-called varieties, and to decide what degree of paleness constituted a chinchilla and what amount of dark markings would relegate the specimen into the shaded silver class. The cat world became agitated, exhibitors were puzzled, and judges exasperated. There were letters to the cat papers on the "silver muddle." Show secretaries were worried with inquiries. I recollect a would-be exhibitor writing to me sending a piece of her silver cat's fur, and asking whether her puss should be in the chinchilla or shaded silver class; but even with her lengthy description and the sample before me, I dared not venture an opinion, and I used generally to reply to such letters by saying I did not know in which class to enter my own silver cat, and so I was going to keep him at home.

One correspondent, appealing through the columns of the papers, wrote: "Everyone knows a black or white or brown tabby, but how can we exhibitors discern between the number of shadings on our silver cats as to which class they belong? Do kindly air my grievance, and oblige."

It was quite pathetic to see the faces of disappointed exhibitors at the Westminster show of 1901, when several beautiful creatures who had travelled many a weary mile to be penned and admired were rewarded with a "Wrong Class" ticket only. They were either too light or too dark for the class in which their owners had entered them, and all hope of honour and glory and golden coins and silver cups vanished into thin air! At one show I recollect a cat was accounted by the judge a chinchilla _and_ a shaded silver, and

he came off very well with special prizes for both varieties. No doubt he really was either one or the other, or both!

[Illustration:

"FULMER ZAIDA."

SILVER, OWNED BY LADY DECIES.

(_Photo: E. Landor, Ealing._)]

It was no wonder, therefore, that a reaction set in, and exhibitors and judges felt alike that something must be done, and that, at any rate for a time, it would be better to have only the two classes for silvers and silver tabbies, and that specials might be given to encourage the lightest cats. The abolition of the threefold classification was therefore taken into consideration when the Silver Society was broken up by the departure of Mrs. Champion to America, and the Silver and Smoke Persian Cat Society came into existence, with Mr. H. V. James as Hon. Secretary.

The following are the objects of the Society:—

The title of this Society, which (under the name of The Silver Society) was founded in July, 1900, is "THE SILVER AND SMOKE PERSIAN CAT SOCIETY."

The objects of the Society are:—

1.— To improve the breeds of long-haired silver (or chinchilla), shaded silver, silver tabby, and smoke coloured cats and kittens, male, female, and neuter.

2.— To guarantee extra classes for these breeds at shows supported by the Society, when necessary.

3.— To offer prizes for the said breeds at shows supported by the Society.

4.— To hold shows independently, or in conjunction with other Societies or Clubs when it shall be deemed expedient by the members.

5.— To elect specialist judges to make the awards at shows supported by the Society.

6.— To establish and maintain a standard of points for the above-mentioned breeds.

It was in March, 1902, that voting papers on this burning question were sent out to members of the new society, with the following result: For the threefold classification, 20; against, 32. Therefore, by the wish of the majority, it was decided to give up the threefold classification _for the present_.

[Illustration:

"TROUBADOR."

SILVER, BRED BY MRS. E. N. BARKER.]

The Silver and Smoke Persian Cat Society is now in a most flourishing condition, with about 150 members. It is the fervent hope and earnest endeavour of each and all of the fanciers of silvers in the society to breed a perfectly unmarked specimen, and with perseverance we may in time puzzle the judge to decide which cat in a large class of lightly tinted silvers is the palest. We shall gradually but surely breed out the tabby markings if fanciers will, so to speak, nail the right colour to the mast and keep on striving to breed up to the perfect type.

To quote Mr. C. A. House: "What is wanted is for breeders to work on standard lines, and not push forward with such persistency their own pet particular whims. All that is required is for breeders to be determined to breed honestly and consistently for what the standard advocates, and leave severely alone all excesses and exaggerations. Let us have chinchillas free from markings by all means, but let us keep our shadings, our silver colour, remembering that pure silver is of a bluish tinge, and is not the whitey-brown article some would have us accept as the ideal in chinchilla cats." The same authority, writing on the threefold classification, says: "I have always maintained that the threefold classification in silvers was a mistake, and the majority of breeders, I am pleased to know, are coming round to that view. My opinion, when first enunciated, was not popular. With some it is not to-day. But many who

at one time could not see the force of my arguments now do so, and there is a more general feeling that the craze for self silvers is not conducive to the welfare of the silvers as a breed."

Amongst the well-known breeders, fanciers, and exhibitors of silvers in the present day, I may mention Lady Marcus Beresford, who owns some beautiful specimens of the celebrated "Lord Southampton" strain. A handsomer type of silver female cannot be met with than "Dimity," bred by Miss Cochran, and presented by her to Lady Marcus Beresford. Lady Decies is the proud possessor of the incomparable "Zaida," whose record of wins is a marvellous one. As all the cat world knows, "Zaida" is accounted the lightest and most unmarked specimen in the fancy. Mrs. W. R. Hawkins has bred some wonderfully good silvers, and was the owner of "Sweet Lavender," which has been acknowledged as one of the best of this breed that ever existed. The following are the principal silver breeders: The Hon. Mrs. McLaren Morrison, Mrs. G. H. Walker, Mrs. Neild, Mrs. Russell Biggs, Mrs. Wellbye, Mrs. Martin, Mrs. T. Drake, Mrs. Cubitt, Mrs. Marriott, Mrs. Balding, Mrs. Poole, Mrs. Ormerod, Mrs. Fawsett, Miss White Atkins, Miss Snell, Miss Horsman, Miss Dell, Miss Meeson, The Hon. Philip Wodehouse, Miss Chamberlayne.

During the last few years a very large number of silver cats have been placed at stud, but we may regard three cats as the founders of the breed or as the pillars of the silver strain—namely, "Silver Lambkin," "Lord Southampton," and "Lord Argent." To these worthy ancestors a very large proportion of the silvers of to-day can trace their lineage. But this noble trio is naturally being superseded by such stud cats as "Silver Starlight," "Tintagel," "Cambyses," "The Absent-minded Beggar," "Pathan of Dingley," "Jupiter Duvals," "St. Anthony," "Rob Roy of Arrandale," "The Silver Sultan," and many others. There is, therefore, now no excuse for in-breeding, which used to be carried on to a great extent when so limited a number of sires were forthcoming. To indiscriminate and injudicious in-breeding may be largely attributed the great delicacy amongst silver cats. There is no doubt that the number of fatalities among silver kittens is far in excess of that of any other breed. Then, again, the size of silver cats compares unfavourably with others, and they are wanting in muscle and bone. We do not want huge, coarse, heavy silvers, but breeders and judges sometimes show an utter disregard for size and strength, and the consequence is we see a number of ladylike looking studs that fail miserably in these very essential points.

Breeders should aim at the happy medium between the liliputian and the leviathan, but not be content unless their silver studs turn the scales at 10 lb. As regards the mating of silvers, a broad line to lay down is to avoid tabby markings. It is for this reason that smokes have been wisely selected by most breeders as the best cross for a silver. It is more than probable that in many cases some nondescript sort of kittens will be the result. These sort of light smokes are exceedingly pretty cats and make fascinating pets, but they are useless for breeding purposes or exhibiting. I have known of some handsome specimens that have wandered from class to class, only to be disqualified in each and either, and it was a case of, "When judges disagree, who shall decide?"

Several experiments have been tried of crossing a white Persian with a silver in order to get pale coloured kittens, but this appears seldom to succeed unless the whites have silver blood in them. Some breeders have tried blues with silvers, but there is the danger of introducing the grey blue under-coat which gives such a smudgy appearance to a silver and is suggestive of a badly coloured smoke. It does not at all follow that the mating of two light silvers will produce light-coloured and unmarked kittens, yet this cross and the smoke are the safest. It must be a work of time, as we have before said, to breed out the tabby markings of many generations.

The name of Mrs. Balding is as well known to breeders of silvers of the past as it is at the present day. In the past, however, it was as Miss Dorothy Gresham this enthusiastic fancier won her laurels. I well remember the sensation caused by the appearance in the show pen of the "Silver Lambkins" at the Crystal Palace in 1888. To breeders, exhibitors, and cat fanciers generally the following account of chinchillas from the earliest days, specially written for this book by Mrs. Balding, should be exceedingly interesting:—

"There is probably no variety of long-haired cat which has caused so much discussion, notwithstanding that, with the exception of the light-coloured reds, which have been designated 'creams,' the chinchilla is the cat which has most recently gained distinction as a separate variety. The notoriety which the chinchilla enjoys has been in great part brought about by the delicacy of its appearance and the difficulty that has been experienced in the production of a perfect specimen. Many cats are called chinchillas and are exhibited as such, often winning prizes, but very few indeed are of the pale silver tint, with bright emerald eyes, and with no bars or stripes on the legs or head.

[Illustration:

A PERFECT CHINCHILLA.

TWO VIEWS.

(_Photo: E. Landor, Ealing._)]

"The chief subjects that have been under discussion in connection with the chinchilla cat have been the colour of eyes and the shade of the coat; but, with regard to the former, I think it must be acknowledged that green is a more suitable accompaniment to silver than yellow or orange, and, as regards the latter, that silver, with dainty sheen evenly distributed, is more to be desired than a patchy grey, dull in hue and unattractive to the eye. As a matter of fact, these shaded grey specimens are in reality only ill-marked silver tabbies. They must, however, not be altogether despised, as they have been the steppingstones which have led to the creation of the chinchilla.

"It is something like twenty years ago that, amongst the competitors in the classes for long-haired tabbies at the Crystal Palace and other important shows, was occasionally to be seen an alien with the ground colour of the silver tabby, but with very few stripes on the body. These cats were evidently sports from the silver tabby, so much so that the class for that section was the only one open to them; and, although they invariably showed great quality, breeders were loth to exhibit them in the medley of different-coloured tabbies, where one of their chief beauties—the absence of stripes—became a disadvantage. Their only chance of distinction lay in putting in an appearance at provincial shows, where the authorities were sometimes to be induced to attach two cat classes to the rabbit division—one for long-haired of any colour, and the other for short-haired. In this indiscriminate assemblage, no colour having been stated, chinchillas when present wrought great havoc, although it cannot be denied that the judges of the day gave precedence to a well-marked silver tabby.

"Amongst these outcasts was a cat of striking beauty, whose like has not been seen again. This was 'Sylvie,' of unknown pedigree, owned by the late Mrs. Christopher, at whose death she became the property of the late Miss Saunders, of Peterborough. A beautiful portrait of this exquisite chinchilla is given in Mr. Harrison Weir's book 'Our Cats.' When judging at the Crystal Palace in 1886, this connoisseur and judge of worldwide repute awarded her first prize, medal, and special for the best long-haired cat, getting over the difficulty of her silvery, unmarked coat by calling her a very light blue tabby, though the puzzle was to find the tabby.

"Another chinchilla of the early 'eighties was Miss Florence Moore's 'Queenie,' who would, had chinchilla classes been provided at that time, have been loaded with championships and honours. In colour she was as light as any of our present-day celebrities, and might easily, from her freedom from markings, have earned the dubious compliment of the uninitiated so highly prized by owners of chinchillas of being mistaken for a grubby white. Miss Florence Moore, who later on had one of the best and largest catteries in the country, bred 'Queenie' from her 'Judy,' winner of many first prizes, a heavily marked silver tabby of Mrs. Brydges' noted breed, and 'Fez,' a light silver cat with indefinite stripes.

[Illustration:

MRS. BALDING'S "SILVER LAMBKIN."

(_Photo: E. Landor, Ealing._)]

"Mrs. Brydges can claim the distinction of having owned, something like half a century ago, some of the first long-haired cats ever imported into England. A coincidence worthy of note is that though there is no record of her having bred or possessed a chinchilla, two never-to-be-forgotten pairs of chinchilla kittens—Miss Florence Moore's 'Chloe' and 'Dinah,' winners of first and medal on three successive occasions at the Crystal Palace, Brighton, and Bexley, 1887 (they being the only chinchillas at any of these shows), and Miss Gresham's 'Silver Lambkins,' who swept the board in 1888, winning the specials at the Crystal Palace from forty-six pairs of other competitors of all colours—could in each case trace descent to the Cheltenham stock 'Chloe' and 'Dinah,' through the afore-mentioned 'Judy' and the 'Silver Lambkins,' through their sire 'Rahman,' also bred by Mrs. Brydges.

"Still more remarkable, these two couples of youthful prodigies were first cousins, on the other side of their pedigrees, the noted 'Fluffy II.' and 'Beauty' being bred by Mrs. Vallance.

"'Chinnie,' the Mother of chinchillas, is familiar in name to every breeder of this lovely variety, and the following letter, of the early 'eighties, relating to her birth and buying, will perhaps prove interesting to the up-to-date silver fancier. It is copied from the original in the possession of Mrs. Vallance. One guinea appears to have been a price to talk of in those days. Now, one would be tempted to hide the fact of such a small amount, and if a specimen were offered to us at this low figure we should certainly desire it to be

sent on approval.

THE VICARAGE, SANDAL MAYNER, NEAR WAKEFIELD, _October 14th, 1882_.

'_To_ Mrs. VALLANCE.

'MADAM,—The kitten I have to sell is quite pure bred. The mother I bought for £1 1s. when quite a kitten from prize parents. The father is one we bred partly from Mrs. Radford's breed and partly from a splendid tom cat that was found living wild at Babbicombe, and that we had in our possession for some months, but unfortunately he is lost again now—I am afraid permanently. I think this kitten promises to be very like the mother. She is very handsome and has good points—brush, ear tips, and so on—but I consider her rather small. But the kitten may be finer, as the father is a large cat. Miss Grant's are related to ours on the father's side, but Mrs. Radford's very distantly, if at all.

'I do not think these Angora kittens are delicate. We have never failed in rearing them. The more new milk they have, and the better feeding, the finer cats they are likely to make. We do not have much trouble in keeping ours at home, as we live some distance from the village. We always give ours their principal meal at 6 p.m., and keep them shut up in a hay-loft until next morning. If you have a box wherever the kitten lives, with sifted sand or cinders in it, kept in a corner, you will find that the best way to ensure habits of cleanliness. If I hear nothing from you to the contrary I will send the kitten on Wednesday morning, 19th, by the early train from Derby station; and if you are not satisfied with the kitten I am willing for it to be returned within a day or two, if the return journey is paid and I am let know beforehand when to expect it.

'I remain, yours truly, 'GRACE HURT.'

A letter redolent of lavender and old-world deliberation, but words of wisdom for all that. The reported delicacy of long-haired cats would trouble us less if we had more of the new milk and hay-loft system. Raw meat, raw eggs, new milk, fresh air, grass, and water are the sole ingredients required to rear the most valuable kitten.

"'Chinnie's' size is another interesting point. She grew to medium weight, but was remarkable for symmetry of form rather than bulk."

"Some of the loveliest chinchillas are small, but 'Nizam,' 'Tod Sloan,' 'Ameer,' 'Silver Lambkin,' 'Laddie,' 'Lord Argent,' 'Silver Mist,' 'Cherub,' and 'St. Anthony' stand out as being as large, or larger, than any cats of other colours, and the majority of them have also the purity of colour, broad heads, and short legs so often lacking in large cats. The legginess and want of quality which frequently accompanies size doubtless cause our leading judges to deem it of little account.

[Illustration:

MRS. BALDING'S "FLUFFIE TOD."]

"The name chosen by Mrs. Vallance for her new acquisition proves that even in those early days the term chinchilla was in vogue. 'Chinnie's' wins were third Maidstone, Sittingbourne, V.H.C. Oxford, Maidstone. Her charming little mate 'Fluffy I.,' a very pure silver with undecided tabby markings, also showed the quality of coat and cherub face for which their descendants have been unsurpassed. He was bred in 1883 by Miss Acland from imported cats, and won first and medal at Maidstone, Cheltenham, and Ealing, second Ryde, V.H.C. Crystal Palace, Oxford, and Lincoln. His career ended in 1886, when he disappeared. Tradition whispers he was destroyed in the village.

"In April, 1885, 'Chinnie' produced a litter by 'Fluffy I.,' two members of which—'Vezzoso' and 'Beauty'—have earned undying fame in the annals of chinchilla history. 'Vezzoso,' a marvel of lavender loveliness, in his one brief year of existence won first in the open class and silver medal for best in show Albert Palace, 1885, first Louth, Maidstone, second Frome, third Lincoln.

[Illustration:

"SEA FOAM."

THE PROPERTY OF MR. LAUGHTON.]

"In fatal 1886 'Vezzoso,' who belied his exquisite appearance by being very undomesticated, like his maternal grandfather the wild cat of Babbicombe, roamed to return no more. 'Lost in the woods' is his epitaph.

"An even more tragic fate befel 'Fluffy II.,' the 1886 son of 'Fluffy I.' and 'Chinnie,' who after winning first Crystal Palace, first and silver medal for best in show Brighton, second Albert Palace and Ealing, and siring the two before-mentioned kittens of the year, died in 1887 from the effects of an accident in which he was internally injured. Thus within little more than a year Mrs. Vallance lost three of the most promising young cats anyone could possess. At the time their owner scarcely realised their value, and allowed them absolute freedom, with such sad results.

"But undoubtedly the best result of the 'Fluffy' and 'Chinnie' alliance was 'Beauty,' from whom, as already stated, came the 'Silver Lambkins.' As a kitten she became the property of Miss Howe, of Bridgyate, near Bath, and later, by a breeding arrangement with the Miss Greshams (now Mrs. Bridgwater and Mrs. Balding), had three remarkable litters of chinchilla kittens, the first by 'Rahman,' who shortly afterwards strayed from home and was lost. This was the litter which produced four queens, including the two 'Silver Lambkins,' and which (with the exception of one renamed 'Mimi,' who went to America with her owner) all unfortunately died.

"The second of Bridgyate 'Beauty's' litters was by Mrs. Shearman's 'Champion Perso,' a magnificent light smoke with remarkable coat and wonderful mane, winner of a large number of first and special prizes. In this lot was a tom kitten destined to be a pillar of the chinchilla stud book, the 'Silver Lambkin,' named after his deceased half-sisters. The chief beauties of this remarkable cat are his size and muscular frame, the length and thickness of coat, and the enormous frill inherited from 'Champion Perso,' which spreads Elizabethan like round his shoulders and falls to his feet in front, a cascade of silvery white fluff several inches long. To 'Perso' may be traced in some degree 'Silver Lambkin's' success as the sire of unmarked cats, and to 'Beauty' their pale colour, green eyes, and perfect shape, which have won for her descendants by 'Lambkin' upwards of 150 first prizes.

"At the time 'Silver Lambkin' was bred there was no chinchilla stud cat, and no one had thought of trying to breed chinchillas, for whom, as before stated, there was no encouragement at shows or at home.

"The third litter which brought further fame to 'Beauty' was by 'Bonny Boy,' who in the early nineties was placed second in the class for silver tabbies at the Crystal Palace, but was considered by admirers of chinchillas to be the best cat in the whole show—an honour, however, which came to him a month later when at Brighton he was awarded the special for the most perfect specimen of the Persian breed in the exhibition; he had previously been claimed at Sydenham, by the Hon. Mrs. McLaren Morrison, at his catalogue price of £6 6s., and was afterwards renamed 'Nizam.'

"The only information that could be obtained about this beautiful cat was that he was exhibited by Mrs. Davies and that he came from Wales. Report suggested that he was imported, but there is no evidence of any chinchilla cat having been sent from abroad.

[Illustration:

MRS. WELLBYE'S "SILVER LOTUS."

(_Photo: E. Landor, Ealing._)]

"'Beauty's' litter by 'Nizam' consisted of one male and four females, two of which, as 'Twin and I'—so named because they were so exactly alike—won first prizes and medals wherever shown. Another was sold by me to Mrs. Martin, which, as 'Lambkin Queen,' was the foundation of the afterwards noted cattery at High Wycombe. 'Twin' eventually went to Mr. Lawton, who renamed her 'Queen of the Mist.' Mated with 'Silver Lambkin' she produced 'Sea Foam,' the first chinchilla to win a prize in a class solely confined to cats of the colour. There was an amusing coincidence about this win, inasmuch as after considerable trouble had been taken to get a separate class for chinchillas, the judge gave the first prize to a heavily marked silver tabby, thus totally ignoring the desired object. This occurred at the Crystal Palace in 1893 or 1894. The two first classes ever given for chinchillas were this one and that given at Cruft's first cat show at Westminster, held in March, 1894.

"The next that was heard of 'Twin' was that she had succumbed from the effects of swallowing a needle. 'I,' registered as 'I, Beauty's Daughter,' remained the whole of her lifetime at The Lodge, Penge, where, when paired with the pale blue 'Champion Bundle,' 'Southampton Duchess' was the result, the latter the mother of the 'Silver Lambkin's' most sensational son 'Champion Lord Southampton,' who was sold by Mrs. Greenwood for £60, when he became the property of Lady Decies, this being probably the highest price that has ever been given in England for a cat of any variety. 'Champion Lord Southampton,' who has been a very great winner, is remarkable for the lightness of colour and slight markings of his kittens, this being undoubtedly due to the strain of blue in his blood. Many beautiful cats own him as sire, notably Miss Leake's 'Seraph,' Mrs. Bluhm's 'Silver Sultan,' Mrs. Neild's 'Absent-minded Beggar,' Miss White Atkins' 'Tintagel,' Mrs. Tyrwhitt Drake's 'Musa,' Mrs. Rickett's 'Empress Josephine,' Mrs. Earwaker's 'Buxton Cloud,' Mrs. Geo. Walker's 'Woodheys Fitzroy,' Mrs. Barnes' 'Nourmahal,' winner of the Chinchilla Club

challenge for the best kitten, 1899, and a daughter of 'Champion Fulmer Zaida,' shown by Lady Decies at the Crystal Palace in 1901, also 'Green-eyed Monster.'

[Illustration:

MRS. WELLBYE'S SILVER "DOSSIE."

(_Photo: E. Landor, Ealing._)]

"Whilst speaking of 'Tintagel' it may be remembered that he sired a charming litter exhibited by Mrs. Poole, which were first at the National Cat Club show at the Crystal Palace, and one of which won as a single kitten at the Botanic Gardens in 1902.

"Other famous progeny of 'Silver Lambkin' are 'Silver Mist,' 'Watership Cæsar' (who won the gold medal at Boston, U.S.A., for the best cat in the show, 1902), 'Silver Tod Sloan,' 'Silver Owl,' Mrs. Bluhm's 'Silver Lily,' 'Silver Squire,' and 'Mowgli,' the last-named bred by Mrs. Dunderdale, but later the property of Mrs. Smyth, of Forest Hill, one of the most enthusiastic admirers of chinchillas, who has in her possession the stuffed figure of 'Beauty.'

"A chinchilla that gained a considerable notoriety was 'Sweet Lavender,' the property of Mr. Hawkins. This was a beautiful specimen, very light in colour. The latter was also a distinctive feature of the Hon. Mrs. McLaren Morrison's 'Ameer,' a son of 'Lambkin Queen,' who stands prominently forward as one of the most perfect of his kind. Mrs. Martin's 'St. Anthony,' whose name appears in the pedigrees of several winners, is a brother of 'Ameer.'

"As the sire of Lady Decies' 'Champion Fulmer Zaida,' the most lovely chinchilla female that has ever been seen, 'Silver Laddie,' who is now unfortunately gone to his happy hunting grounds, can claim to have been one of the most noted of sires, more particularly as he was also the father of many others of great value, prominent amongst which were Miss Horsman's 'Aramis,' Miss Snell's 'Starlight,' 'Silver Cherub,' 'Lady of Quality' (one of the most perfect chinchillas ever bred), 'Charterhouse Pixie' (the dam of 'Tod Sloan'), and numberless others.

"Not only as a chinchilla, but when competing with all breeds of cats, both long and short-haired, 'Champion Fulmer Zaida' has proved her excellence, and has on more than one occasion secured the cup at the Crystal Palace for the best cat in the whole show. She was bred by Mrs. Bluhm, one of the pioneers of chinchillas, and, it is stated, has now won 136 first and special prizes, and that Lord Decies has refused £90 for her.

"'Zaida' has also produced some first-class kittens, amongst which was Miss Stisted's 'Pearl,' the owner of the latter pretty queen being a most devoted admirer of the chinchilla and sparing no expense to further its interests.

"Mrs. Bluhm's strain of chinchillas are all very light in colour, and show great quality, which may also be said of those of Mrs. Wellbye, whose 'Silver Lotus' and 'Veronica,' daughters of 'Silver Squire' and 'Dossie,' did so much winning in their day.

"Miss Meeson has also shown considerable enthusiasm in her endeavour to reach the ideal, her best efforts having resulted in 'Jupiter Duvals,' of wide fame.

"Two clubs have been formed in connection with the chinchilla cat—one, the Silver Society, embraced other coloured cats besides the chinchilla, this eventually becoming the Silver and Smoke Persian Cat Society. It was owing to this club encouraging shaded, or marked, silver cats and orange eyes that the Chinchilla Club was formed by Mrs. Balding. This Club has the honour of having as patron H.S.H. Princess Victoria of Schleswig-Holstein, who owns and exhibits some beautiful chinchillas, and Lord Decies as vice-president.

"The Chinchilla Club gives its support and specials, besides guaranteeing classes at any show whose management apply. The conditions on which the specials are presented is that the cats to which they are awarded must be the property of members of the club, prize-winners in their respective classes, and registered cats.

"The club prizes usually consist of half a guinea in each class, and the more coveted Special of the club's badge for the best chinchilla of either sex. Badges were selected in place of the ubiquitous medal, because most of the dainty professional beauties very soon obtain a considerable number of the latter, and smart little badges were more appreciated.

"The club's present challenge trophy for chinchilla kittens is a solid silver model of 'Silver Lambkin,' offered by the hon. secretary for competition amongst its members; it is also open to members of the National Cat Club, in acknowledgment of the compliment paid

by the latter to the original in choosing his statuette to surmount their challenge cup. The little history of the origin of this special has never appeared in print before, and as I was not present at the committee meeting referred to, 'I tell the tale as 'twas told to me.' When the challenge cups of the National Cat Club were designed in 1897, it was decided that the beauty and interest attached to them should be enhanced by immortalising on each the most representative cat of the long-haired and short-haired varieties. For the latter the great 'Xenophon' was chosen without hesitation. Then came the more difficult task of deciding upon a recipient for the distinction from the long-haired ranks, which claim so much of the beauty and wealth of winnings of the cat world as to render the singling out of one a matter of consideration. To hasten the termination of the discussion Mrs. Stennard Robinson sent for a collection of cat photographs which had been left to her by the late Miss Portman, the well-known 'Rara Avis' of the _Lady's Pictorial_. Amongst these the hon. secretary of the N.C.C. pointed out one—with no name attached—as the most beautiful photograph of the lot. This was recognised by most of the committee as being 'Silver Lambkin,' so the honour fell to him.

[Illustration:

MRS. WELLBYE'S SILVER "VERONICA."

(_Photo: E. Landor, Ealing._)]

"By some error at the makers' the long-haired cat was placed on both challenge cups, and it was determined by the club that the superfluous model which had to be removed and replaced by 'Xenophon' should be mounted as a letter-weight and given as a challenge prize for kittens, to be won three times before becoming the property of the winner. After some keen competition, covering about half a dozen shows, Mrs. Martin won it outright in 1899, when it was replaced by the present exactly similar model.

"The endeavour of the Chinchilla Cat Club, of which all the leading breeders and most successful exhibitors are members, is to continue the work that has been done to improve chinchillas, and to produce a new variety the colour of the palest shade of the fur (dyed) known as 'blue fox,' or a very light shade of pigeon blue. Without doubt such a result can be obtained by careful selection and—'the little more.' Darwin's words on the subject of selection are attractive to all owners of live stock. He says: 'Improvement is by no means due to crossing different breeds. All the best breeders are strongly opposed to this practice, except sometimes amongst closely allied sub-breeds. And when a cross has been made, the closest selection is far more indispensable even than in ordinary cases. If selection consisted merely in separating some very distinct variety and breeding from it, the principle would be so obvious as to be hardly worth notice; but the importance consists in the great effect produced by the accumulation in one direction during successive generations of differences absolutely unappreciable by an uneducated eye. Not one man in a thousand has the accuracy of eye and judgment sufficient to become an eminent breeder.... Few would readily believe in the natural capacity and years of practice requisite to become even a skilful pigeon fancier.'

"The Chinchilla Cat Club is also prepared to encourage cats of new colours, which should now be not so very difficult to produce, considering the points that have been brought out in those varieties that were well known, the latter showing that it is possible to breed to a standard if judgment is used in the endeavour to do so. Some of us remember the time when a blue cat, either long or short-haired (now the largest classes), was a _rara avis_ when Mrs. Lee's 'Meo' was the only Siamese at the Crystal Palace show, smokes an equal oddity, blue eyes in a white cat a comparatively unnoticed point, and cream-coloured cats entirely unknown.

"The colour of the chinchilla has been bred in various ways. In bygone days, when chinchilla cats were flukes or freaks and few and far between, methods which would now be considered somewhat eccentric were resorted to by the first breeders of the colour. The useful tortoiseshell, from which black, red, cream, or tabby cats can be got, was pressed into the service, and, paired with a silver or light blue tabby not too clearly marked, would occasionally, amid the multi-coloured kittens for which tortoiseshells are proverbial, throw a medium chinchilla or light silver tabby, which with careful selection might, a generation or two later, develop into something approaching a good chinchilla.

"But it is, perhaps, more difficult to foretell with cats than any other animal what the result of pairing will be with anything like certainty. This particularly applies to the ordinary English cat, as it is impossible to guess at the mixture of different-coloured creatures which have preceded it, and any of which may influence the progeny of its descendants. A fancier who would produce any particular specimen must, amongst other gifts, be equipped with the patience of biblical celebrities and prepared to wait seven years, as one enthusiast actually did before arriving at the fulfilment of his desires in the shape of a well-marked tabby kitten.

[Illustration:

SOUTHERN CATTERY, SHOWING ENTRANCE TO INFIRMARY AND INDOOR CATTERY.]

[Illustration:

MRS. WALKER VISITING HER PETS.

TWO VIEWS OF WOODHEYS CATTERY.]

"With pedigree cats, of course, the chances of unexpected traits reappearing in their progeny are considerably lessened, and, given desirable connections on both sides of some years' standing, the personal attributes of a coming litter may be predicted more or less successfully. One of the loveliest of smokes—the correct black, with white under-coat, without the shadow of a stripe—was from a brown tabby queen, from brown tabby parents, and a chinchilla bred from a chinchilla dam and smoke sire. Again, a brown tabby with white paws, whose appearance did not suggest the bluest of blood, mated with the same chinchilla sire, produced in a litter three chinchillas and two faintly marked silver tabbies, which would nowadays have been styled 'shaded silvers' by followers of the dubious hue. Needless to say, these instances are not given to encourage the idea of breeding chinchillas from brown tabbies, but as illustrations that just as the results of pairing a cat with one of nondescript pedigree cannot be guessed, so in an animal carefully bred for generations so indelibly have the characteristics of the breed or variety been stamped upon it by past ancestors that it is practically impossible for them to become obliterated or submerged.

[Illustration:

"SILVER BLOSSOM."

OWNED BY MRS. WALKER. (_Photo: Findlow & Co., High Wycombe._)]

"Thus the type once fixed survives, though it be by the aid of the most incongruous connection, such as a brown tabby. Had the latter been the patrician bred from progenitors of her colours, and the chinchilla been the one of doubtful lineage, the result must, of course, have been reversed, and the kittens, in all probability, would have followed the brown tabby strain. If neither parent cat when of distinct varieties can boast a particularly dominant strain, the offspring naturally partakes of the peculiarities of both.

"Colour, in chinchillas, is the most important point. It should be of palest silver, lavender tint, and lighter—in fact, practically white—at the roots. There should be no dark blotches or stripes or brown tint on the back or about the nose. A rusty hue is, however, sometimes caused by the action of the sun or wind. As regards bars or stripes on head, these should be as few and light in colour as possible, with a view to breeding them out altogether in the future.

"The coat should be long and thick, of fine, soft texture, much thicker and longer round the neck, forming a decided frill and mane, the latter reaching well down the fore legs. It should also be longer on the hinder part of the thighs, forming _culotte_, and very bushy on the tail, which should be short and wide. The legs should be slightly feathered, with tufts of hair between the toes. There should also be tufts in the ears, which should be very small and set low.

"The head should be wide at the forehead and short in the muzzle, well filled up below the eyes, giving it a round appearance. The eyes large and luminous, in colour emerald green with black lids. Green and yellow mixture is permissible, but not so picturesque as the green; yellow in the eyes is not desirable. In shape the chinchilla should have a level back, and be only slightly long in the couplings. The legs should be short, with round paws, the latter well padded. When in full coat the hair should nearly reach the ground and the frill envelop the back of the head, making a very fascinating whole."

The following is the standard of points as drawn up by the Chinchilla Cat Club. It is also used in America as a basis for criticism:—

1. Colour of Coat.—Palest silver, lavender tint preferred, nearly white at roots. No dark stripes, blotches, or brown tint. Darker tips to the long-hairs give the coat an appearance of being lightly peppered with a darker shade. The whole appearance of the cat to be very pale 30 2. Coat.—Long and thick 20 3. Texture of Coat.—Fine and soft 10 4. Tufts of hair inside and round the ears and between the toes 10 5. Head.—Broad and round; forehead wide, ears small and set low, nose short 25 6. Shape.—Back level, not too short; legs short, paws round; brush short, wide, and carried low 20 7. Eyes.—Large, luminous, and green in colour (if green mixed with yellow, 5 points only allowed) 10

To breeders of silver Persian cats an article by Mrs. Neild will be valuable and instructive. Mrs. Neild has made, so to speak, a speciality of silvers, and owns two noted silver studs—the "Absent-minded Beggar" and "Lord Hampton." There are always some good silver queens, and very frequently some choice kits, disporting themselves in the well-arranged catteries at Hart Hill, Bowdon, where Mrs. Neild has a kennel of Borzois and a cattery of silvers.

This is what Mrs. Neild says regarding the breeding and rearing of silver Persian cats:—

"Perhaps of the many varieties Persian cats—and, indeed, they are a goodly number as they now appear on our show catalogues and schedules—the silvers may claim their owners to be the most sporting of cat breeders. Certainly, to breed successfully it is essential that one should possess the not too common virtues of unlimited patience and perseverance. Also experience is necessary.

"A common occurrence among even old hands is to assign a kitten—one of a new litter under inspection, as being of 'little good except as a pet'—'to be sold at a small sum to a good home,' and a few weeks later discover this same kitten to be the pick of the litter. In short, the old, old story of the ugly duckling incessantly repeats itself in our catteries, certainly in those devoted to silver cats. Therefore I suspect fanciers who have succeeded (all honour to the few!) and those who mean to succeed in breeding silver Persian cats of possessing a larger stock of patience and of having acquired a larger experience than their brothers and sisters whose love has turned towards the blue, black, or white pussies.

[Illustration:

"SILVER BLOSSOM'S" TWO BUDS.

(_Photo: Mrs. G. H. Walker._)]

"With these last three one may be tolerably sure—always taking for granted some knowledge—of fairly pure coat colour, and at a very early age the best kittens of the litter may be picked out—those having greatest breadth of skull, smallest ears, etc. But the silver litters are a veritable surprise packet, and remain so for an irritatingly long period. Personally, I have found that those kittens which, when born, have very pale—almost white—unbarred faces and fore legs are ultimately those which grow palest. I take no notice of the colour of the coat on the back, sides, hind legs, or tail, even if striped, as frequently happens, for all these markings generally vanish _if_—as I before said—the face and fore legs are unbarred. I must, however, own to one kitten who was born jet black. She was by Mrs. Champion's 'Lord Argent' and a shaded silver queen of my own breeding. When a month old I dubbed her a very bad smoke; at three months she was coatless—a most indecent little person, having shed her coat more completely than I had ever seen in cat or kitten. When, after a provokingly long period, she again consented to appear clothed, her dress was of palest silver, unadorned by any markings except a very faint smudge on her forehead and—which, alas, spoilt her for show—a darker tinge on her broken tail. How is it that to our _best_ some accident _always_ happens? So, as I could not exhibit her, I sold her to a delightful home in the North of England, and her enthusiastic owner wrote to me a few weeks since that her big babies by 'Lord Hampton' were as pale as the mother, who herself grew steadily of a fainter silver.

[Illustration:

"WILD TOM."

SILVER, BRED BY MRS. G. H. WALKER. (_Photo: Mrs. G. H. Walker._)]

"Unfortunately, silvers more than any other breed of cats lack bone, caused, of course, by the unavoidable in-breeding practised when this variety of cat was first introduced and so enthusiastically welcomed, and when but one or two fanciers owned a cat of such shade. Another article on this subject, by a lady who may really claim to have established this breed, will explain to the reader more than it is in my power or province to declare.

"To go back to the subject of our small silvers, in-bred to delicacy. We should now remember how many good sires, absolutely unrelated and within easy reach, are placed at our disposal. Therefore, surely there can be no possible excuse if in a comparatively short time we do not manage to own silvers big in bone and limb, and owning—ah! happy accompaniment—greater constitutional vigour.

"We are, I believe, too apt, if owning a pale queen, to mate her with the palest known stud, disregarding other very important considerations in the all-absorbing wish to breed the wonderful 'dirty white' king or queen of silvers. Sometimes this atom (verily so) of perfection does make its appearance, and is enthusiastically greeted. But what of the mite itself? A tiny, sickly scrap of a kitten, constantly ailing, refusing to grow or to weigh, except at a rate of less than half the average blue kitten of its own age. But extraordinary care keeps the mite alive until one day some chance draught or a maid's carelessness ends our careful nursing, and the poor owner of that 'lovely dirty white kit' at last realises that this other good-bye means it may be wiser to mate that same pale queen to the strongest, hardiest, biggest-boned stud possible to be found among our silver studs, even if he is rather barred.

"Now mark. From the result of this mating, keep the best of the female kittens and marry her—if possible, not before she is eighteen (at any rate, fifteen) months old—to a stud unrelated, sturdy, of undoubtedly splendid health, for preference paler than herself, and boasting grand head and the essential tiny ears and short nose. Then you may dream your dreams with a chance of their resulting in a golden reality.

"If breeders would but spend rather more thought when they select husbands for their pussies, they would be indeed repaid. I am not speaking, of course, to the fortunate few who have won their laurels, and of whom I would I might learn; although I rather suspect their secret of success is but the result of continual study, coupled with extreme care. Would not an enormous increase of size and weight soon become evident in the occupants of our catteries if, when a queen was about to be mated, her owner would first carefully study the list of points provided by the Silver and Smoke Persian Cat Society (previously quoted in this work), jotting down those good qualities to which she believes her queen may lay claim, and then selecting that sire possessing the points most wanting in her own cat—of course, never forgetting relationship? The old rule about in-breeding is 'once in, twice out,' as all old fanciers know; but where silver Persian cats are in question, I would most strongly urge that this adage be disregarded, and, as a rule, avoid in-breeding entirely until a stronger race of silver cats is established, cats with frames equal to those big blue beauties we see at our shows. I think that in a comparatively short time—of course, always avoiding tabby blood, breeding _chiefly_ for bone—our silver cats may be very different to those of to-day, those who own too fairylike limbs to be beautiful.

"A word about our famous sires—and, by the way, we may congratulate ourselves on having within reach so many beauties. Often I have letters asking for advice as to which stud such and such a queen shall visit; and, in addition to the above suggestions, I would remind the owner that length of journey should be taken into consideration, and the fact that if the chosen sire is extremely popular it may be that a better result may be gained if the queen is sent to one not so much in request, especially if the owner of the stud cat has not been warned before of the visit of your pussie. However, most owners of stud cats are extremely careful in limiting the number of visitors, and few object to keeping Sir Thomas free for a week beforehand if given due notice.

"Do let me urge all whom it may concern to keep Madame in close confinement for several days after her return home. Indeed, in the interest of the owner of both stud and queen this is of vast importance, and many a disappointment is due to this seemingly small neglect. Puss does not always return as one would wish, however great the care given her whilst away on her holiday, and may take her matrimonial affairs into her own paws with results most unsatisfactory to everyone but herself. When the kits arrive, do not—if you have reason to expect valuable kittens as a result of the mating—leave more than two or three with the mother (I am, of course, speaking of silver kittens) for reasons I shall directly state. By far the best plan is to procure (some time before the birth of both litters) a good big English cat as foster mother, one known to have brought up a previous litter—_not_ an old cat. The usual method of substituting her foster for her own babies is to take away the mother cat for a few minutes—of course, out of sight—and, removing one of her own kittens, rub the little silver baby with the hay of the nest and against the other kittens so that the strange smell—sense of all others so wonderfully developed in animals—may not raise suspicion in the foster mother. Then the next day remove one or two more.

"May I, at this point, plead that the little kittens taken from their mother for your benefit should not be drowned? If they must be sent along the silent road to the Quiet City, let it be done mercifully and by chloroform. Such wee things may rest easily in a big biscuit box, the lids of which usually close tightly, and about 1 oz. of chloroform poured on a piece of flannel or sponge laid on a small saucer by their side will send them painlessly to sleep.

"The reason I strongly advise that the English foster should nurse the _best_ of the litter is but an echo of the old cry, 'Want of bone.' Fed by the sturdy British puss, the delicate tiny balls of silver fluff will gain greater strength, and be mothered for a longer period than would be possible with their real parent.

[Illustration:

"FUR AND FEATHER."

(_Photo: Mrs. S. F. Clarke_)]

"It is necessary to remember that, although the foster mother needs extra food when nursing—just as in the case of the silver mother—more caution must be exercised when beginning the more liberal diet, for very probably, if this is forgotten, a liver attack—which will also affect the precious kits—will be the result of her unusually liberal fare. Remember, also, to inquire of the owner of your foster as to how she has been fed. With this knowledge, common sense and careful watching of cat and kittens will

quickly show if it would be better to increase or diminish her meals either in quantity or quality. It is of enormous value to bespeak the foster mother, if possible, four or five weeks before the birth of the kittens, for then it will not hurt to give her what is almost certain to be necessary—_i.e._ a worm powder.

"I always allow my mother pussies as much milk as they like (although, as a rule, my cats drink water), but it should be boiled, and one tablespoonful of lime-water added to each half-pint. When I once urged this care of the foster mother to a friend who owned two kittens she was extremely anxious to rear, I was laughed to scorn, and assured that such fussiness about a strong English cat was more than foolish. Yet I would remind breeders who are inclined to agree with the above opinion that on the perfect health of your head nurse rests the future of your much-prized litter. On her depends their growth, their first chance of throwing off their natural delicacy. Mr. House, in one of his articles lately published in _Fur and Feather_, advises that kittens should be kept with and fed by their mothers as long as sixteen weeks. In my humble opinion this is too great a strain on any Persian cat, but there may be great wisdom in keeping the kits with the mother or foster for as long as it is possible without overtaxing the cat. The same authority speaks of a relay of foster mothers. I confess this puzzles me, for I should imagine that the food supplied by the second mother would be too weak in quality (as Nature provides it shall be of different quality to suit the age of all and every kind of baby) for the big kits after that of the first foster, and I should have also imagined the second foster would refuse to nurse kits so much bigger than those she had just left.

"When my kits are four weeks old I give them raw lean beef—scraped, not chopped—beginning with half a teaspoonful daily, then the same quantity twice daily, then three times a day; and at the same time teach them to lap, using a plate, which, being shallower than a saucer, causes less choking and fear to the little things."

Mrs. G. H. Walker, of Woodheys Park, is the chief supporter of the Northern Counties Cat Club, and is a member of the National Cat Club Committee. For several years she has been a well-known breeder and exhibitor of silver Persians, and has a most excellently planned cattery, which I had the pleasure of seeing when on a visit to Woodheys Grange. Mrs. Walker kindly had some views taken, specially for reproduction in these pages. I consider the arrangements for the pussies' comfort and well-being as complete as it is possible to make them. The floors of the outside catteries, which face south, are cemented, so that they can be washed over every day. The roofs are boarded, and then covered with galvanised iron, so that all the rain runs away easily. The spacious apartments are fitted with benches and ledges, and trunks of trees and leafy shrubs are planted in the ground for the cats' special amusement and exercise. The kennels—which, for the purpose of photographing them have been placed outside—are the cosy sleeping dens of the pussies. There is a maid in attendance on these fortunate cats, and the man who looks after the kennels of dogs also gives a helping hand.

[Illustration:

"THE SILVER LAMBKINS."

BY "RAHMAN" _ex_ "BEAUTY."]

In one of the pictures will be seen a staircase, and this leads to three charmingly arranged rooms. All the appliances and utensils connected with the animals are kept in one of these apartments. Another is set apart for mothers and their families, and a third is kept in case of illness for an isolation ward. In one of the loose boxes near at hand the cooking for the pussies is carried on, and there is a larder specially for the cats' food. Mrs. Walker devotes much of her time to looking after her pets, and great has been her sorrow over the untimely death of some of her treasured pussies. After one of the large shows, infection crept into her cattery, and worked most cruel havoc. Such losses as Mrs. Walker sustained were enough to damp the ardour of the most enthusiastic cat lover and fancier; but the lady of Woodheys Grange bravely faced the situation, and after a period of sad reflection she once again resumed her hobby with renewed interest. At the Northern Counties Cat Show at Manchester in 1902 Mrs. Walker exhibited a really wonderful silver kitten. I say wonderful, for this youngster, bred from the owner's "Woodheys Fitzroy" and "Countess," was the most unshaded and unmarked specimen of a silver I have ever seen. This unique specimen will be watched with interest by silver fanciers. May his shadings ever grow less!

The average number of inmates of this cattery is about thirty, but at one period of Mrs. G. H. Walker's catty career the silver fever ran high, and there were sixty-three cats and kits within the precincts of the spacious and luxurious catteries of Woodheys Grange.

Mrs. Martin, of High Wycombe, who has often acted as judge, has been a most successful breeder of silvers, and the progeny by "St. Anthony," her noted sire, have distinguished themselves by winning over one hundred prizes. "St. Anthony" has retired into

private life, but he will always be remembered if only by his two children "Silver Dove" and "Fascination." Mrs. Martin says, "I am all in favour of the male being older than the queen in breeding silvers; also select a good-coated stud cat, short in the legs. Eyes are a worry just now. Of course, I like green best, but if a cat is good in all points but colour of eye, this should not upset an award. I find that if a kitten is born almost self silver, it will develop into an indifferent silver tabby later; but if the body is dark, and head and legs light and clear, you may hope for a very unmarked specimen in due time."

Mrs. Wellbye's silver cats "Dossie," "Silver Lotus," and "Veronica" were at one time well-known winners, and for length of coat and beauty of eye have seldom been surpassed. Mrs. Wellbye is a most astute judge of silvers, and her remarks on this her favourite breed will be read with interest:—

"This handsome variety of the Persian ranks high in the estimation of cat lovers; indeed, its ardent admirers consider it the _crème de la crème_ of the cat world. And why not? Surely there is nothing to compare with a lovely young chinchilla Persian in full coat. Its very daintiness and seeming pride in itself is quite charming. One is reminded of a pretty child dressed out in its party frock, for puss appears to know it is well dressed and desirous to show her charms to the best advantage. She dances, pirouettes, and throws herself into the most graceful and entrancing attitudes, until we feel in sympathy with the Egyptians of old and are willing to fall down and worship our adorable pets. We all love beauty, but to those who love cats there is something beyond even beauty, for only they who keep and care and treat them well know the comfort these little creatures are, and the happiness they can bestow by their sweet caressing ways, perhaps more especially to those whose hearts are starved of human love, but still to all whose sympathies are wide of the varieties of silver cats. I will first treat of the chinchilla.

"The Crystal Palace show of 1895 or 1896 was the first I remember with a class for chinchillas; previous to that, I believe, they were not recognised as such, but were shown with the silver tabbies. Strictly speaking, the name chinchilla is a misnomer as applied to these cats. The soft grey coat of the little animal called the chinchilla, whose lovely fur is so much prized as an article of ladies' dress, differs diametrically from the cat so-called.

"The fur of the chinchilla is dark at the roots, and shades quite pale grey at the tips. The cat's fur, on the contrary, is absolutely pale grey, almost white at the roots, but tipped with black at the outer edges.

"The points as laid down by the Silver Society are as follow: 'Chinchillas should be as pale and unmarked silver as it is possible to breed them.'

"The aim of the breeder of this variety, therefore, is to obtain a cat with none of the markings of the original stock (the silver tabby), the dark tippings to be slight and faint.

[Illustration:

BROWN TABBY AND SILVER PERSIANS.

(_From a Painting by Miss F. Marks._)]

"Breeders have found this ideal most difficult to obtain; although some kittens are born pale all over, with no markings, in a few weeks—or maybe months—the hope of the family is no more, for the lighter the kitten the more delicate. 'Whom the gods love, die young.' Or, again, if the cherished one lives over its baby troubles, and starts on the change from its first, or kitten coat, to the second coat, too often do the markings appear, the shadings get darker, or fine black hairs are seen amongst the pale grey. Some of the best chinchilla kittens have been born quite dark, and with tiny stripes all over. At a month or six weeks these marks have disappeared, and later the coat has become an even silver.

"The breeder must not even then build high hopes. Again change may occur. There is no cat which varies so much; it is quite chameleon-like in this respect.

"A few years ago the Cat Club adopted the name of 'self silver' as applied to the chinchilla—another misnomer, as a self silver should have no tippings or shadings, and the silver cat has not been bred that had fur the same shade throughout from roots to tips.

"The slight dark edging to the fur constitutes to most people the charm in these silvers. Sometimes it is almost imperceptible to the casual observer; or when the cat is in full coat (the fur being from three to seven inches long on the tail—sometimes as much as nine inches) the tiny fleckings are lost in wavy, tossing, billowy coat. But let the coat become damp, however slightly, it will be seen that the dark edges are clearly in evidence.

[Illustration:

"JUPITER DUVALS."

OWNED AND BRED BY MISS S. MEESON. (_Photo: F. Parsons, Southend-on-Sea._)]

"As, however, breeders could not always produce the pale shade of silver, the litters, even with the most careful mating, being generally assorted in good, bad, and indifferent so far as colour was concerned, many fine cats—dark silvers—had no place assigned to them.

"It was then suggested that a class should be given at the shows to be called 'shaded silver,' the points according to the Silver Society being as follows:—

"'Shaded silvers should be defined as pale, clear silver, shaded on face, legs, and back, but having as few tabby markings as possible.'

"The dark or shaded silvers, it was understood, should have pale, clear under-coats; but instead of the fleckings of the self silver (so-called), the dark edges ran a considerable way into the fur. The shaded silver is a handsome cat, but too often much marked on the face and barred on the legs, a defect most difficult to overcome. Many cat fanciers describe the shaded silver as a 'spoilt tabby.'

[Illustration:

THE ELDER MISS BLOSSOM.

SILVER, OWNED BY MISS HORSMAN.]

"The third in the group of silvers is the silver tabby. The points are here stated:—

"'The colour of a silver tabby should be a pale, clear silver, with distinct black markings.'

"This variety ought in equity to have been mentioned first, as it is the original stock, but it has been overshadowed by the superior attractions of the chinchilla. (Silver tabby enthusiasts will perhaps pardon this eulogy of my favourite breed.) There is not the slightest doubt this handsome cat, the silver tabby, has suffered materially from the craze for the newer variety, and consequently the type has not been kept pure. They have been mated over and over again with cats of less markings in the hope of breeding chinchillas, until at the present day there are very few silver tabbies true to type.

"The position of the silver tabby in the feline scale is very peculiar. As a Persian it is, of course, necessary that its coat should be long and fine, whilst as a tabby it is desirable that the markings should show up to advantage. How to reconcile the two is the puzzle, for the longer the coat the less the markings are evident, as the stripes are merged in the flowing coat, so that we sometimes see at the cat shows exhibits woefully out of coat placed in the first rank, as the markings are much more distinct. It follows, then, in this variety of the silver, a long coat is distinctly a disadvantage when competing at shows.

"Having now obtained three types for silvers, and the Cat Club willing to give classes for them at the great shows held in St. Stephen's Hall, Westminster, the outcome was looked forward to with much interest. But it was one thing to get four types, and quite another matter to get silver breeders to understand the fine distinction; consequently, the cats were entered in self silver, shaded silver, and silver tabby classes indiscriminately. The result was, of course, muddle and confusion, many exhibitors having the mortification of finding 'Wrong Class' on the cat pens.

"At a recent show held at Westminster under the auspices of the Cat Club, the judge was asked by the Honorary Secretary to go round the classes first, and if any exhibit was wrongly placed to re-classify before judging. This worked satisfactorily so far as disqualification was concerned.

"At this show, however, the judge was confronted with another difficulty, it being found that most of the cats in the classes for shaded silver had deviated materially from the standard of points laid down by the Silver Society. Instead of the clear, pale under-coat, the fur was a dark grey right down to the skin. The majority of these cats were quite dark, and, rightly speaking, were not silvers—that is, if one bears in mind the metal so named. It is difficult to say in what class they could be placed, unless a new class was created, to be called 'clouded or oxydised silver.' If we go on to these subdivisions we shall not know where to stop. Self silver or chinchilla, shaded silver, clouded silver, and silver tabby—a truly appalling problem for the bewildered judge to decide, for the majority of exhibitors would not appreciate the variations.

"It may come to this eventually, but at the present time the threefold classification leads to much confusion, for as nearly—or very nearly—all silver cats are more or less tabby marked, so will exhibitors be in doubt as to the class to which their cats rightly belong.

"It is a question if the introduction of the shaded class at shows has not done more harm than good, for as previously we saw very few of the dark silvers—it not being worth breeding the variety when there was no class in which to show them—so now the tendency of exhibits, as anyone who attends shows can see, is to run to darkness rather than light; and breeding for colour, purity of colour, and absence of markings has received a set-back, for with some judges colour is nothing, and prizes will be showered upon a 'spoilt tabby' if it happens to have, perhaps, a broader head or a bulkier body—good points, as everyone will allow, but points which the common or garden cat may possess; and we do not pit our dainty chinchillas against all and sundry.

"Without wishing in any way to detract from the good qualities which the more plebeian branches of the cat tribe undoubtedly possess, it is impossible not to award the palm for grace and beauty to the highly bred aristocratic chinchilla. Coal and iron are useful, but we give our admiration to diamonds and pearls."

[Illustration:

"DOLLY DAYDREAM."

(_Photo: E. Landor, Ealing._)]

Before closing the chapter on silvers, I will allude to the Cat Club show held at St. Stephen's Hall, Westminster Aquarium, in January, 1903. On this occasion there was quite a record entry in the male silver class, which contained twenty-one cats. The list was headed by Mr. J. F. Dewar's handsome "Father O'Flynn II." Many well-known prize-winners had to be content with a V.H.C. card in this class of quantity and quality. The females numbered eighteen, and here again a noted winner was awarded the highest honours. Miss Chamberlayne's "Cap and Bells" is very pale and pure in colour, and carries a soft, silky coat. In the silver kitten class the sexes were not divided, and Miss Ford's lovely kittens scored first and third. A sweeter face and rounder head than that possessed by "Silver Button," the first prize-winner, would be difficult to find, and Miss Ford may be congratulated on having bred such a gem. Mr. T. B. Mason judged the silver classes at this show, and he doubtless experienced some difficulty in testing the colour of the exhibits in the bad light of St. Stephen's Hall, more especially as on the opening day of the show a dense fog hung over the city. Another difficulty which must present itself to our most capable judges is the awarding of specials offered for silvers and shaded silvers. Perhaps the easiest way out of this difficulty is to give the shaded silver prizes to the darkest cats; but all are shaded, even the palest, and therefore some judges might justify themselves if they awarded both sets of specials to the one cat. At this show Lady Marcus Beresford offered three special prizes in each silver cat class for the palest specimens, one of these in the male class being won by her own handsome "Beetle," a son of the famous "Lord Southampton." The classification for silvers at the specialist societies' show at Bath, which followed close after the Westminster show, was the largest that has ever been given, consisting of classes for novices and breeders, in addition to the ordinary division and subdivision for cats and kittens. The sensible plan of a ring class for neuters _only_ was adopted.

Members of the specialist society for the encouragement of silvers must on this occasion have felt proud of the liberal classification and of the long list of handsome special prizes offered for their favourite breed of long-haired cats.

[Illustration:

"I WANT TO GO HOME."

(_Photo: E. Landor, Ealing._)]

[Illustration:

"THE MARQUIS OF DINGLEY."

SILVER TABBY, OWNED BY MISS ANDERSON LEAKE. (_Photo: Cassell & Company, Limited._)]

CHAPTER XIII. SILVER TABBY PERSIANS.

There can be no question that a really good silver tabby will carry off the palm even from the most exquisite unmarked silver cat, and in this assertion I feel I have the support of all our professional judges, for with the "mere man," it is well known, the pale silvers

do not stand high in favour. Men call them "wishy-washy," insipid, and wanting in expression, and are generally displeased at this sport in the fancy that has spoiled the handsome silver tabbies of years gone by.

No doubt there is just cause for complaint, for the inter-breeding of silvers with silver tabbies has undoubtedly done much to destroy the clear defined markings which in tabby cats is their chief glory. Now, of course, it is easily understood that these tabby markings in a long-haired cat cannot be so distinct as those that appear to such advantage in the short-haired breeds. "The better the coat the weaker the markings," may be said of Persian silver tabbies, and judges have been known to give the highest award to an out-of-coat specimen just because the markings are more evident than in a cat in full pelage. Harrison Weir states that "Tabby is not a Persian colour," and goes on to say, "Nor have I ever seen an imported cat of that colour." His definition of a silver tabby reads thus:—"Markings: Jet-black lines, not too broad, scarcely so wide as the ground colour shown between, so as to give a light and brilliant effect. When the black lines are broader than the colour space, it is a defect, being then black marked with colour, instead of colour with black. The lines must be clear, sharp, and well defined, in every way distinct, having no mixture of the ground colour. Head and legs marked regularly, the rings on the throat and chest being in no way blurred or broken, but clear, graceful, and continuous; lips, cushions of feet, and the backs of hind legs, and the ear points, black." And here it will be interesting to give the discussion which took place and the list of points drawn up at the inaugural meeting of the Silver Society in 1900, and which standard is still adhered to in the present Silver and Smoke Persian Cat Society:—

SILVER TABBIES.

At the meeting of the Silver Society, discussion arose as to whether the markings on silver tabbies should be broad or narrow. Lady Marcus Beresford proposed that Miss Leake and Mrs. Herring should be asked to express an opinion, both being breeders of prize-winners. Miss Leake said she thought there were two distinct types of cats, the one with broad markings, the other with narrow stripes, and that both were correct silver tabbies, the superior beauty of either being a matter of personal opinion. Mrs. Herring agreed, and said the markings should be a dense black. Miss Leake considered they should be black at the tips, but shading to light at the roots. Mr. Abbott objected to the word "dense," as black was black, and the word "distinct" was substituted. Finally the following was resolved:—The colour of a silver tabby should be a pale clear silver, with distinct black markings, any brown or cream tinge to be considered detrimental. The eyes should be orange or green:

Head and expression 25 Colour and markings 25 Colour of eyes 5 Coat and condition 20 Shape 15 Brush 10 ——— Total 100

The adoption of the preceding descriptions and scale of points as a whole was carried unanimously.

[Illustration:

MISS LEAKE'S SUMMER CATTERY.

(_Photo: Cassell & Company, Limited._)]

As regards the eyes of a silver tabby, Harrison Weir says "deep bright yellow." The Silver Society gives an option of "orange or green"; but the mandate of present-day fashion and personal bias is in favour of green eyes for silver tabbies. From an artistic point of view, there is no doubt emerald green is a better contrast to silver than yellow or orange.

The Rev. R. Maynard, whose name has for many years been connected with silver tabbies, recently complained in the papers of the tendency to breed green eyes in this variety. He writes: "In former days we never had anything to do with a cat that had green eyes, and now that so much is being done to improve the feline race, why should we try to think the green eye right and even desirable?" Another authority says: "The fiat has gone forth that silver tabbies are to have green eyes. Happily there still remains room for a difference of opinion on the subject, for the oldest and most perfect breeds of silver tabbies have always been distinguished by their deep hazel eyes."

[Illustration:

SILVER TABBY KITTENS OWNED BY H.H. THE PRINCESS VICTORIA OF SCHLESWIG-HOLSTEIN.

(_Photo: E. Landor, Ealing._)]

This vexed question of eyes, certainly outside the "self" classes, ought not to be one of such vast importance. As Louis Wain aptly writes when complaining of this undue proportion of points, "Everyone, judges and exhibitors alike, are bitten by the craze for the

'correct coloured eyes.'" It is a fault that judges are prone to commit, and truly one point ought not to be allowed to outweigh others, and it is just this balancing of merits with a mingling of common sense that makes the good all-round judge, whether of self or tabbies, of long- or short-haired cats. In judging a class of tabbies, first and foremost in the judge's estimation must rank the markings, and in Persian tabbies coat must next be taken into consideration. I have always thought that judging long-haired tabby cats in a ring class would be specially welcomed both by judges and exhibitors, for it is when a good cat of this breed runs or walks the beauty of his markings can be seen and admired. Then the dark spine lines will show up to advantage, the side markings will stand out, and the bars on the legs and the rings round the neck may be clearly discerned. I think it is not to be wondered at that fanciers who have bred tabby cats are not easily satisfied as regards selfs and silvers. A friend of mine declared, "I always miss the stripes which give a tabby cat such a sweetly expressive countenance." Yet in spite of the beauty of the silver tabby, there are very few fanciers of this variety, and to those wishing to take up Persians I could not recommend a more interesting field for speculative breeding. The number of good show specimens can be counted on the fingers of one hand. Silver Tabby classes at our shows are full of nondescript cats with shaded silver bodies and markings only on legs and head.

When judging the silver tabbies at the Crystal Palace in 1902, I was greatly struck with the number of cats and kittens which ought really to have been marked "Wrong Class," for some of these were absolutely wanting in any definite marks at all; some had faint grey pencilling on the head and legs, but not a sign of the dense mottling on the sides. It is, no doubt, disappointing to exhibitors to have their specimens labelled "Wrong Class," or for really lovely kittens to be passed over without even a card; but it is only by thus treating exhibits so lacking in the essential point of the class for which they are entered that fanciers will learn to discern between the genuine article and what may be called a spurious one. These pretty nondescript silvers, which are neither one thing nor the other, should be disposed of as pets; but to enter them at our shows in classes for tabbies is only throwing away money and risking the animals. No cat has come nearer to the perfect ideal of a silver tabby in our day than Lady Pink's "Shrover II.," now gathered to his fathers. He possessed the wonderfully clear silvery white ground with distinct dark markings, and was always the admired of all admirers at our leading shows. Lady Pink is not without some worthy descendants of her famous "Shrover II.," and writes to me thus: "I have a smoke male by 'Shrover II.,' and hope to show him at Westminster. 'Shrover III.' is just like his father 'Shrover II.,' but I shall not exhibit him, as I am too afraid of losing him. I have suffered many losses after shows. 'Shrover III.' is a fine, big fellow, even better marked than his father, with long silky, wavy coat, lovely eyes, and a perfect temper."

[Illustration:

"BEAUTIFUL DUCHESS."

OWNED BY MRS. G. H. WALKER.]

[Illustration:

WINTER QUARTERS AT DINGLEY HILL.

(_Photo: Cassell & Company, Limited._)]

Mrs. Herring has bred some fine silver tabbies, notably "Duchess Lestock," a sensational kitten at the Westminster show of 1900, when she was claimed at a high price by Mrs. G. H. Walker, of Woodheys Park. Mrs. Herring's "King Alfred" was the sire of "Shrover II.," and is quite "one of the best." Miss Anderson Leake is justly celebrated as a most enthusiastic and successful breeder of silver tabbies, and is our greatest authority on this variety, As far back as 1887 "Topso of Dingley" was exhibited by Miss Leake at the Crystal Palace. This cat was said to be of Irish descent, but his ancestors were sunk in oblivion. Not so, however, his progeny, for the winnings of his son "Champion Felix," owned by Miss F. Moore, of Beckenham, are fresh in the minds of those who, like myself, can remember beautiful cats of bygone years. In 1889 Miss Leake entered "Topso" and two toms in a class for "blue or silver tabbies, with or without white." "Felix" was also in this class, as a winner of the Challenge Cup. Miss A. Leake's "Abdul Zaphir" and the present representatives of the breed "Abdul Hamet" and "Marquis of Dingley" are household names amongst silver tabby fanciers. Miss Derby Hyde has long been faithful to this breed, and "Thames Valley Silver King" and "King Alfred" have often had to fight it out together at our shows, sometimes one being favoured by the judge and sometimes the other carrying off the honours. Miss Cope has recently been bitten with the silver fever, and her tabby kittens are always to the fore. Her "Roiall Fluffball" took first and seven specials at Westminster in 1901, and her "Silver Tangle" is a well-known winner. Mr. Furze, another Midland fancier, is also making a speciality of silver tabbies, and the Hon. P. Wodehouse possesses a fine silver tabby female in "Silver Saint." Mrs. Slingsby owns "Don Pedro," a beautiful specimen, and Miss Meeson has bred some good silver tabbies as well as silvers. But the ranks need filling, and with the assistance of the society now in existence the classification at

shows will become more liberal, and instead of silvers and browns being often placed together at our smaller shows, separate classes are guaranteed, for it is certainly most unfair on judge and exhibitor to place these two very distinct breeds together. "Comparisons are odious," we are told, and certainly it is hard on the brownies for the more brilliant silvers to be placed side by side in competition. As regards the mating of silver tabbies, the essential point to try and breed for is markings, and it behoves the fancier to endeavour to find a sire with bold, distinct tabby markings, and if it is desired to strengthen the colour, then a black is not at all a bad cross. There are two distinct kinds of tabbies—the blotched and the pencilled varieties; and it is a matter of choice which is considered the handsomest. But it does not do to mate these two varieties together. A well-known authority on breeding silver tabbies writes thus in _Fur and Feather_:—"A great deal has been said as to the disadvantage of crossing chinchillas with silver tabbies, but we think this applies more to the detriment of chinchillas than of tabbies. Provided the tabby, on one side, is of a very decided type, the chinchilla, having come originally from the same stock, may not prove a bad cross. Miss Cope's 'Silver Tangle,' for instance, one of the best-marked silver tabby queens, is the child of the chinchilla 'Silver Chieftain,' and of a queen bred from a silver tabby sire. A good young queen, belonging to Mr. Hoddinott, was bred from 'Lord Argent' and a tabby mother. 'Champion Felix' was bred from 'Topso,' a heavily marked tabby, and 'Lady Pink,' a cat that would nowadays have been called a light shaded silver with white markings. 'Climax' came of the same parents, and both have broad dark markings, and transmitted them to their offspring. The union of two strongly marked silvers is not always a complete success. A brown tabby makes a most excellent cross, and some of the purest and best silvers we have seen have been obtained in this way. Of course, you must be prepared for a brown tabby kitten or two; but you need not fear sandy smudges and yellow noses. The colour seems to be concentrated in one or two examples, and leaves the silver free. In short, in colour breeding we must be content with one or two perfect specimens in a litter, and, retaining them, try again for yet further perfection."

The cat fancy needs some new sensational cat to appear on its horizon, and if only a perfect silver tabby, male or female, could be penned at one of our leading shows a great impetus would be given to this variety, and a thoroughly good strain might be established. Then we should not read such remarks as these from the pen of the reporter: "The silver tabbies, we regret to say, were only a shade of days that are gone. There is room for an enterprising enthusiast in this breed. The beautiful clear silver colour with deep black markings seems to be quite a thing of the past. Who will revive them?" And echo answers, "Who?"

From such an authority as Miss Anderson Leake the following article on silver tabbies will be of great interest, and the photos of her cattery at Dingley Hill, Bradfield, near Reading, have been specially taken to illustrate these notes:—

"Possibly amongst the rarest of our long-haired cats may be classed the really well-marked silver tabby. Twenty years ago he existed, and was, indeed, more commonly met with than to-day. For at that time chinchillas were practically unknown, save for a few scarce specimens, and the silver cats of that day were more commonly called 'grey' Persians, and were nearly always tabbies. But with the popularity of the pale chinchillas began the downfall of the heavily marked tabby. Instead of breeding for the preservation of markings, everyone worked their hardest to breed out markings, and real tabby kittens were almost unsaleable. Those that were produced were very frequently ventured, and sold at a low price for pets. The lightest specimens in a litter were preserved for breeding purposes, and rarer and rarer became the deeply marked silver tabby. But at last the tide has turned, and people are beginning to realise that there is a character, a beauty, and a contrast of colouring in a good tabby, which lend to them a charm all their own. Added to this, they are exceedingly rare and difficult to produce.

"Competent judges agree that to breed regular, symmetrical, and well-coloured markings is no easy task, for _contrast_ is the grand point in a silver tabby. His ground coat from tip to tail should be pure pale white silver. On this light silver ground-work lie the most beautiful even dark mottlings, dark to the point of blackness. These markings are most difficult to describe. A dark stripe runs the whole length of the spine. Then comes a light stripe on either side, then two more dark stripes, but these are broken just behind the shoulder by a transverse bar of light silver, and widen on the shoulder into considerable sized patches. The markings on the sides are not stripes, but patches, elliptical in shape, generally three in number, and partially encircled by dark stripes. The shoulder is particularly heavily barred and striped, as are also the hind quarters. The legs are barred throughout their length, the face should be dark, with dark tufts, and the back part of the hind legs from the knee downwards is black, as in a Southdown sheep.

"The head is most beautifully pencilled, the cheeks possess double or treble swirls, the eyes are outlined by dark rims; on the forehead the lines form a complete triangle, which is repeated at the nape of the neck. The chest is encircled with a perfect dark ring, called the 'Lord Mayor's chain,' but this is concealed when the large light frill is in full beauty, as is also the neck triangle. The whiskers often contain all the different shades of colour found in the coat. The ear tufts should be long and light. The tail is generally ringed from trunk to tip, but this is not noticeable after kittenhood, owing to the great length of the hair. Also the hair to the root is much darker in colour on the tail than on the body.

[Illustration:

IN THE STUDIO.

(_From a Painting by Madame Ronner._)]

[Illustration:

MISS COPE'S "STARLET."]

"The correct colour for the eyes of a silver tabby is neither green, orange, nor yellow, but hazel—a deep nut-brown. This shade of eye is very difficult to obtain, and it fades with age; but once seen, its beauty and suitability to the colouring of the cat will never be denied. Many of the most noted prize-winners have not possessed this coveted hazel eye. The nose is by preference dark, but this, so far, has not been considered as a point.

"Not only evenness and regularity of markings go to the making of a good tabby, but sharpness and depth of colour in the dark parts, and clearness of colour in the light parts. A great deal has been said of late regarding the depth of the black markings; but it is quite as necessary to insist on the purity of the silver tone. No suspicion of brown must be tolerated, neither any blue nor grey tone.

"There is no question that, as a tabby, a long-haired cat is handicapped by his length of coat. There are some people who would rob him of his crowning glory in order that his beautiful striping may the better appear. But surely it were better for them to confine themselves to short-haired cats if they cannot appreciate the marvel of long-haired tabby markings. For marvellous they truly are, when we consider that the dark marks are only formed by tips to the hair of some quarter of an inch in length. When the coat is quite short these tips are massed together, and the blackness is, so to speak, concentrated. When the hair is at its full length—of from two to four inches—it can be readily understood that the long floating locks mix and mingle with the paler coat, and some distinctness of marking is lost. The massive frill and the long light shoulder tufts give the cat a very pale frontage; and if he be placed in a show pen side by side with a cat whose coat is just coming, whose marks show up, in all probability he will take a second place. No stroking, blowing of the coat, or other device will show off a tabby cat. He must be made to get up and walk. Then the long coat falls apart, the spine lines reveal themselves, the side patches fall into place, and bars, stripes, swirls, and rings all are to be seen. Even then you will not see them all at once, but as he moves and turns one by one the points will show themselves. As a show cat, a tabby is not a success, for his period of perfect beauty is exceedingly short. When he proposes to moult he changes colour, and if you are unwise enough to exhibit him at this stage ominous whispers of 'Brown tabby blood' will pass from mouth to mouth. For a thorough good rusty brown shade, commend me to a moulting silver tabby. Then a little later he completely loses his side markings, and you must wait until the new coat makes its appearance before you can venture him in the show pen. In the first beauty of that new coat, when the hair is about an inch long, he is a dream of colour contrast, and somehow suggests such ineffable cleanliness!

"How to breed silver tabbies is a moot point. One thing is certain, that if we expect whole litters of well-marked kittens we shall be grievously disappointed. Personally, we have had the best results from pairing two marked cats slightly related and of good silver pedigrees. A smoke of silver origin is another good cross, but the sire should always be a tabby. The blacker the kittens are at birth the better. There is no sign of light under-coat, but generally narrow pencillings of silver are to be seen, and face and paws are fairly light. The kittens which at birth show contrast of dark and light rarely turn out good tabbies. The markings, as a rule, become too faint. At a month old the light markings should widen and develop, and at three months old the full beauty will be seen. Before the change to cat coat, many of the kittens become more shaded than marked, and up to the sixth or eighth month there is always a possibility of their proving disappointing. If, however, after this age the markings return, harden, and develop, they will endure for ever, except during periods of moulting. In extreme old age both the purity of colouring and distinctness of markings are lost. Exposure to the sun considerably injures the colour of the silver tabby cats, giving them a brown tinge. We believe exhibitors of magpies never allow their birds to enjoy the rays of the sun for a similar reason, but it is a question whether it is not wiser to study the beneficial effects of a sun-bath on the health of our cats rather than the slight detriment to their coats caused by its enjoyment. I have said nothing about size and shape. The silver tabby should be a large cat, with good bones, and very heavily coated. The old-fashioned cats were very long, low on the legs, and a trifle narrow in head. Nowadays we have remedied this defect, and the modern cats are decidedly more cobby than their progenitors. The ears should be set wide apart, and be small and not too sharply pointed. If only fanciers will now devote themselves to the production of such cats as I have tried to describe, we shall soon see the silver tabby classes at our shows filled with typical animals, instead of, as is too often the case, with spoilt silvers, too heavily

marked to be called chinchillas, too unevenly or lightly marked to be correct tabbies."

I have mentioned Miss Cope as a breeder of silver tabbies. Her remarks on her favourite breed are as follows:—

"There is no doubt that until quite recently interest in this fascinating breed had, to a great extent, died out, owing to the craze for chinchilla breeding. But I hope their day is coming again. There is a marked improvement already shown in the silver tabby classes at the best shows.

[Illustration:

A PAIR OF SILVER TABBIES.

(_Photo: E. Landor, Ealing._)]

"Mr. St. George Mivart, in his celebrated book, asks, 'What is a cat?' But even so simple a question as that appears from his statement to be more easily asked than answered. The same may be said of the question, 'What is a silver tabby?' I will endeavour to answer the question by giving my own idea of what may be considered to be a perfect type of a silver tabby. The chief point of a silver tabby should be clearness and distinctness of markings; the sharper they are the better. My ideal cat would have the two spine stripes clear and well defined from shoulder to base of tail, set off by the 'epaulet' behind each front leg. On each side of the body should appear what may be called the horseshoe; both sides should match exactly. The hind quarters well barred. The fore legs should also be barred, each in symmetrical correspondence with the other. The double cheek swirls, the markings on the forehead, which may be easily imagined to take the shape of a lyre, the shaded eyebrows and whiskers, and dark outlines to the eyes, all these give a character to the face not found except among tabbies. More or less conspicuous will be the dark lines across the chest, known as the 'Mayor's Chain.' Occasionally some more favoured animal is found to have two such lines. The beauty of all these markings is thrown up by the ground colour of the coat, which should be a clear bright silver. The whole effect, if one may so describe it, is like a piece of elaborately wrought black lace on lustrous silvery silk. The colour of the eyes is somewhat a vexed question. Some fanciers prefer green. Personally, I think nothing is more lovely than the hazel eye, enhanced by dark rims. Happily, latitude is allowed in this direction in the standard drawn up by the Silver Society, which decrees the colour shall be the green or orange. But with all these, my ideal silver tabby must have perfect shape of body, so far as it is possible to obtain it, as well as luxuriance of coat. The long, thin-bodied, snipy-headed, spindle-legged cat is an abomination. The ideal cat must be cobby, with short, thick legs, the head broad and massive, ears small, well tufted and set wide apart, the nose short and wide at the tip, the tail short and wide at the extreme end—I consider a pointed tail very undesirable. The coat of the ideal silver tabby should be long and thick, and the texture as silky as possible.

[Illustration:

MISS DERBY HYDE'S "THAMES VALLEY SILVER KING."

(_Photo: E. Landor, Ealing._)]

"Having described my ideal silver tabby, the next question is how to get it. When I succumbed to the fascination of the long-haired beauties some years ago, I resolved to breed only from the very best stock obtainable, and I have unflinchingly adhered to this rule. I would like to impress upon anyone starting this delightful hobby that it is absolutely a waste of time and money to attempt breeding from any but the best. The observance of this principle will save many disappointments, much heart-burning, and not a little money. Having made up one's mind which breed one admires most, it is far better to keep to that particular variety, and win success worth having, than to dabble in a variety of breeds with only a moderate amount of success. To a rigid observance of these principles I owe any honours in the show pen which have been awarded to me. It is of little use taking up the breeding of long-haired silver tabbies unless one is possessed of unlimited patience and perseverance. It is sometimes very disappointing to find the kitten one fondly hoped would prove a coming champion merging into a shaded silver—exquisite in colour and as far as head, shape, and coat are concerned, but none the less not a silver tabby. Here comes in the study of pedigree. It by no means follows that the mating of two tabby parents will result in a litter of pure tabby kittens, unless both sire and dam are of pure silver tabby lineage. Hence purity of pedigree on both sides is of great importance.

"If there is a trace of chinchilla blood in the ancestry it is certain to manifest itself at odd times in the progeny. Nevertheless, do not despise your shaded silver, if it be a queen, providing all other points are perfect. As Miss Leake says—and I quite agree with her—'You no longer have a show specimen, but you have a cat that, crossed with a heavily marked cat, will probably provide you

with splendid silver tabbies.' This, however, can scarcely be called the true science of breeding, as the progeny of two such cats may hark back to some of the original characteristics.

"My own practice is to mate silver tabby with silver tabby invariably, and of the purest pedigree I can find. I should never breed from a sire that I knew possessed a brown tabby ancestry. I would far rather choose a good black sire, and in this way strengthen the markings. Of course, one would not expect a mating of this kind to produce a litter of champion silver tabbies; but if I secured one well-marked kitten I should feel quite repaid. On the general question of breeding, Mr. C. A. House, who is no mean authority, and whose suggestions I have often followed with advantage, recently said: 'If I were asked to pick out in a certain cattery a pair of silver tabby Persians which would be likely to make a good match, I should proceed on lines similar to the following:—Shape and size with quality of coat I should expect the dam to possess. Marking, colour, length of coat, colour of eye, and strength of bone, I should demand in my sire. This is, of course, if I were selecting from cats whose ancestry was quite unknown to me. My reasons for so doing are because in nine times out of ten the sire influences the outward characteristics of the progeny, while in like ratio the dam exercises her influence over those points which are more hidden. The dam has far more to do with shape than is generally supposed, and I would rather breed from a bad-headed male than a bad-headed queen. Quality of coat must always be looked for in the queen.'

"With regard to in-breeding I have no hard-and-fast rules to lay down. The whole matter, in spite of what one and another may say, is too experimental and speculative for anyone to dogmatise. The authority I have just quoted remarks on this matter: 'It sometimes happens that a fancier puts together two animals which excel in some particular property, yet not one of their progeny is above the standard of mediocrity, so far as that property is concerned.' Experience has shown me the importance of studying the weak points of the dam. These I try to remedy in selecting the stud cat. But with all my care I sometimes find 'the best laid schemes ... gang aft agley.'

"For the successful keeping of cats and rearing of healthy kittens, my prescription begins and ends with two words—liberty and fresh air. I have found cats can stand any amount of cold, providing, of course, they have never had artificial heat previously. Two things must be carefully guarded against—damp and draught. These are fatal. Kittens so reared will be healthier, grow better coats, and will be much better able to stand the wear and tear of show life. My own cats live in wooden houses, raised at least one foot from the ground, the size at least seven and a half feet by five and a half feet. Each house is fitted with an inner wire door, as well as the outer wooden one. Along the entire length of the upper part of one side is a wire netting window, with a broad shelf fitted beneath. This opening has also a sliding shutter fitted with glass panels. I am thus able to give ventilation at will, or fasten them up securely in bad weather. In one corner of the house is a cosy sleeping box: in another corner an equally cosy chair. All cats love a chair. Cats kept outside, when they are admitted to the house, invariably find out the most comfortable corner of the most comfortable chair. In such a house as I have described, kittens can be successfully reared; there is ample room for them to scamper round should a wet day keep them in. Unless it is absolutely raining all my cats have the run of a large garden the whole day, and are only shut up at night. I never coddle my kittens, but try to bring them up as naturally as possible.

"I am sometimes asked how it is my kittens attain such good proportions. The secret, if secret there be, lies in this—I never allow my mother cats to nurse more than two kittens after the first week. If a foster cannot be found, I select the two I consider the most promising, and the lethal chamber claims the rest. Some may consider this foolish. I can only say I would far rather rear two thoroughly healthy kittens than five or six little puny things that will require weeks of care and attention, and then fail to reach the end in view. Baby silver tabbies, I must admit, are not altogether things of beauty and of joy. More often than not they are dark and uninteresting. The time to decide which is the best-marked kitten is while the coat is comparatively short. When compelled to make a selection, I usually give the preference to the darker kittens. Experience has taught me that the lighter kittens, so attractive in themselves, even at that early stage, and whose colouring is so exquisite at eight or nine weeks old, are apt to prove deceptive in the end, and often develop into shaded silvers."

To Miss Cope's last statements I can add my testimony, but I will also mention a curious case coming under my direct notice and regarding my own silver stud cat. "Cambyses" is by "Mowgli" (a noted pale silver of "Silver Lambkin" strain) and a handsome silver tabby unknown to fame, being a house pet. When I became possessed of "Cambyses," then five months old, he was a decided silver tabby, taking after his mother; he has since shed all his markings, except faint grey pencillings on head and legs, and is one of the lightest silvers at stud. When mated to smokes and silvers I have not known or heard of any tabbies in the litters; but on one occasion, when crossed with a silver tabby, he had some very densely marked tabbies. I have remarked that this beautiful breed of Persians has not been taken up by American fanciers in the same enthusiastic manner as have blues, orange, and especially silvers. In an account given by _Field and Fancy_ of the Beresford Cat Club show in New York, January, 1903, I find mention made

that over 125 long-haired cats were entered, and that in the silver classes alone there were thirty-five entries, almost as many as were entered in the whole long-haired section of the previous year. The smoke male class was cancelled, but eight females of this breed put in an appearance. No mention is made of silver tabbies. Amongst the winners of the challenge cups offered by the Atlantic Cat Club, a silver tabby called "Queenie," owned by Mrs. Wagner, carried off the trophy. Miss A. Leake, of silver tabby fame in the English fancy, has exported some of her stock, and no doubt our American cousins will not let this beautiful breed remain long neglected, but some enthusiastic fancier will establish a strain on the other side of the herring pond.

At the Westminster Cat Club show of 1903, held about the same time as the Beresford New York show, the entries in the three classes provided for silver tabbies numbered twenty-seven, which is an increase on previous years, but with two or three exceptions quality was lacking. No new names appeared in the catalogues, and Miss Anderson Lecke and Miss Cope carried off the highest honours.

The winner in the female class was "Roiall Fluffball," whose portrait appears below, and who is the best-marked silver tabby that is now before the public. Miss Cope must be proud of having bred so fine a specimen by Miss Anderson Lecke's "Abdul Hamel of Dingley," whose picture appropriately forms the heading of this chapter on silver tabbies.

[Illustration:

"ROIALL FLUFFBALL."

THE PROPERTY OF MISS COPE.

(_Photo: E. S. Baker & Son, Birmingham._)]

[Illustration:

MRS. STEAD'S SMOKE LITTER BY "RANJI."

(_Photo: Russell & Sons, Baker Street._)]

CHAPTER XIV. SMOKE PERSIANS.

[Illustration:

"JO" and "TINY" (SMOKES).

(_Photo: Gross, Brooklyn, N.Y._)]

It is only within recent years that smoke Persian cats have really come into notice at all, and even now these lovely cats may be said to be sadly neglected in the fancy. It was not till the year 1893 that they were considered sufficiently popular to deserve a class to themselves. They were formerly relegated to the "any other colour" class, and very often at smaller shows this is where we find the smokes penned. A really good smoke is a thing of beauty, and it seems certain that as the fancy expands and the Silver and Smoke Cat Society looks after their interests, a good time will be in store for breeders of this handsome variety.

Smokes may therefore be called a new breed, and it is a very distinctive one, made up, as it were, of the three self colours—black, white, and blue. It is a shaded cat without markings, the fur being pure white underneath and gradually assuming almost a black tone on the outer coat. The face, paws, and back down to the tip of the tail are the darkest parts, shading to a dark grey down the sides and on the under part of the tail. A very great beauty in smokes is the light frill and ear tufts, which lend an air of much distinction to this breed. The great failings in many smokes is the appearance of tabby markings; these especially mar the beauty of head and face, and take away from their value in the show pen. The tail should be quite free from any rims of light and dark, and should have the upper part an even dark colour, and underneath a cinder grey. Some smokes are so dense in the surface coat as to be really black cats with white under-coats, having none of the modulated grades of dark and light grey. These cats are often minus the light ear tufts and ruff, and therefore cannot be regarded as correct smokes. Then, again, there are light smokes which might almost be called silver smokes—very beautiful cats to look at, but far removed from the ideal smoke.

Perhaps at some future time there may be a special classification for these cats, which are now without an abiding place at our shows. It is most important that the coat of a smoke should be long and of the true Persian flakiness, otherwise the chief beauty of

the contrast between the light under-coat and dark outer coat is not seen to full advantage.

I think I may say without fear of contradiction that, of all long-haired breeds, smokes present the most altered and absolutely dishevelled appearance when out of coat. The glory of the light frill disappears, and multitudes of lines and streaks can be plainly discerned. Then a very rusty brown tinge appears on the back, and the rich, glossy black surface coat vanishes. I owned a lovely smoke cat once that at certain times of the year—and, I may say, for most part of the year—was nothing better than a bad black, his only claim to the title of smoke being the general appearance of a dark cat that had spent his life in an ashpit. But when "Pepper" was in full feather, he was a joy to behold.

It is curious that when the kittens are first born they appear almost a dead black, with no trace of a white under-coat. This appears gradually as the kittens grow, and at three weeks old the lighter coat becomes visible. Their faces and paws should be intensely black when born, as the tendency in smokes is to get lighter and not darker. If a kitten is born with the appearance of a smoke it will generally turn into what I have termed a silver smoke later on. As with black kittens, so with smokes: they are often very rusty in appearance, but this will disappear with their kitten coat. This also applies to tabby markings, though, of course, if there is any tabby blood in the strain the markings may be retained. For this reason it is most undesirable to mate smokes with tabbies; neither is it advisable to select a blue as a cross. The blue tinge destroys the purity of the white under-coat, which is one of the glories of a perfect smoke. It is a case of "like to like" in breeding smokes, and, failing this, choose a good black sire for your queen with amber eyes. This is especially advantageous if your queen should be light in colour, and throw light kittens; but if she is already too dark, mate with a chinchilla, avoiding, if possible, a green-eyed one.

Above all things shun, as you would Sin, tabbies of any colour, and let your choice fall on a heavily coated sire. I have been told by smoke fanciers that it is much more difficult to breed a good smoke female than a male, and that the latter sex predominates in litters.

I will here give the officially approved table showing the proportion of marks which should be awarded for points of smokes. This is as drawn up by the Silver and Smoke Persian Cat Society, which has Mrs. H. V. James, our principal breeder of smokes, as Honorary Secretary:—

[Illustration:

MISS BARTLETT'S TWO SMOKE KITTENS.

(_Photo: E. Landor, Ealing._)]

SMOKES.

Smoke cats should be black, shading to smoke (grey), with as light an under-coat as possible; light frill and ear tufts; eyes to be orange.

Value of points:—

Head and expression 20 Colour of eye 15 Colour of under-coat 10 Absence of markings 15 Coat and condition 20 Tail 10 Shape 10 ——— Total 100

I think there are no fanciers or breeders of smokes who feel that any option should be given as to the colour of eyes in this breed, for, as in the black cats, the eyes should be amber or light golden. However, I must confess that brilliant green eyes are to be preferred to the pale yellow, which too often spoil the beauty of many of the smokes now exhibited. I should never place an indifferent smoke with orange eyes over a good specimen with eyes of emerald green. In the early days of the fancy, smokes were entered in the "any other variety" class, and were sometimes called Smoke Blues or Smoke Chinchillas.

In 1891 Miss Manley (now Mrs. Strick) exhibited a fine smoke called "Bayadere." Amongst the names of our oldest smoke breeders who still continue to breed I may mention Mrs. Cartwright, of Upwood. In 1895 this lady showed smokes at Cruft's show bred from her "Timkins." The Upwood cats are very pure in colour, having the dense outer coat very white at the roots. At one time the Lindfield smokes held their own everywhere, Miss Molony winning first at the Crystal Palace in 1893 with "Lindfield Bogie." Mrs. Bluhm, better known as a silver breeder, also owned about this time a famous smoke female called "Smuttie."

Mrs. Robert Little has for years combined the breeding of smokes with blacks. In 1897 "Namouska," a smoke female, won first at the Crystal Palace, and her descendants continue their career as first-class smokes. In more recent times the following are noted winners: Lady Marcus Beresford's "Cossey," Mrs. H. V. James's "Backwell Jogram," Mrs. Sinkins' "Teufel," Mrs. Stead's "Ranji," Mrs. Stillwell's "Victoria," Miss Snell's "Dusky Girl," Mrs. Collingwood's "Minouche," Rev. P. L. Cosway's "Maritana," Mrs. Neild's "Silver Soot," Mrs. Hamilton's "Bulger," Miss Rose's "Judge." Perhaps the most consistent and successful breeder of smokes now in the fancy is Mrs. H. V. James, who started in 1893, and has been faithful to this breed ever since. I have had the pleasure of visiting Mrs. James's smoke cattery, and I felt that the lovely old-fashioned garden surrounding the Grange at Backwell was truly an ideal place for successfully rearing live stock of any kind, and all the pussies were pictures of robust health. I am glad to be able to insert the following valuable article on smoke Persians from the pen of Mrs. James, who is certainly our best authority on this breed.

"Before entering upon the distinctive points of smokes, I will give a short account of my smoke cattery, and how I first took up this breed. It is curious to look back and see what mere chances govern our actions. I have all my life been devoted to Persian cats of one colour or another, but never intended to go in for any special breed. However, in 1893 I purchased a blue kitten, which, on its arrival, appeared far from well. The man who sold it offered, if it died, to replace it. In a few days I was in a position to accept this offer, for the kitten succumbed, and another—which was also supposed to be a blue—was sent to replace it. As time went on this kitten darkened, and, much to my disgust, turned to a deep cinder colour. In 1894 there was a grand West of England Cat Show held at Bristol, and, to please an old servant who had taken great care of the kitten, I entered 'Jubilee.' I was not much up in cat showing then, but 'smoke' seemed to answer the description of the kitten better than any other colour; so into the smoke class he went, and, to my surprise, carried everything before him. This started my career as an exhibitor. I showed 'Jubilee' again at Cruft's and Brighton the next year, where he again carried off firsts, and was described as the best smoke cat seen since the days of the famous 'Mildew.'

[Illustration:

MRS. JAMES'S CAT HOUSES AT BACKWELL.

(_Photo: F. Holmes, Clifton, Bristol._)]

"At the Palace in 1894, I bought a smoke female kitten from Miss Bray as a mate for 'Jubilee.' This mating proved successful, and I had several grand litters of smokes, most of which, I am sorry to say, went to swell the ranks of neuter pets, being given as presents to my friends. In time I learnt wisdom, however, and kept my smokes myself. 'Jubilee's' career as a show cat was unfortunately cut short after his Brighton win in 1894. He escaped one night, and in a fight with another cat had his ears so torn that I was unable to exhibit him again. A year later, when I was away from home, he was let out one day, and never returned, having, I expect, been trapped in the woods. At that period my smokes nearly died out, as I had only one litter a few weeks old by 'Jubilee.' Of the two smokes one was promised, and the other I kept, and he is still alive as 'Champion Backwell Jogram.' So I think I may consider I have had my share of luck, though, like most breeders, I have had my bad times, and have lost sometimes as many as twelve cats and kittens in a few days from distemper, and once or twice a very promising female has strayed into the woods and been seen no more. I hope, however, that for some years, at least, 'Jubilee's' descendants will continue to flourish, as there are a number of 'Jogram's' kittens scattered over England, and several have left these shores for America.

"In mating my smoke queens I have several times tried a black sire, and have always been successful in getting good smokes from this cross. 'Jubilee II.' is an example, being by 'Johnnie Fawe,' Dr. Roper's famous black Persian. I have only once—years ago—tried a blue cross, but the result was a mixed litter of blacks and blues. I have found that all the blue queens mated with 'Jogram' have had chiefly blacks. Smokes may be considered a very hardy breed, perhaps from the fact that there has been little in-breeding so far. 'Jogram' lives in an unheated wooden house all the year round, and has never even had a cold. Kittens will also stand the same treatment.

[Illustration:

MRS. A. M. STEAD'S SMOKE PERSIAN "CH. RANJI."

(_Photo: E. N. Collins, S. Norwood._)]

"And now I will endeavour to give my ideas as to the points which go to make up a perfect smoke. A good smoke is perhaps one of the most beautiful of the many beautiful breeds of long-haired cats, a bad smoke one of the plainest. The novice—for whom this

article is principally written—may therefore be glad to have a clear definition of a smoke to start with.

"The definition drawn up by the Silver Society when it first started reads as follows: 'A smoke cat must be black, shading to smoke (grey), with as light an under-coat as possible, and black points, light frill and ear tufts; eyes to be orange.' But the word 'black,' having sometimes led novices to suppose that a black cat possessed of a white under-coat is a smoke, it would be perhaps safer to say 'a smoke is a deep cinder-coloured cat shading to grey, with a white under-coat,' etc. In order to distinguish the difference between black and the true cinder colour of the smoke, it is an excellent plan to keep a sound black cat in a smoke cattery.

"Smokes are, comparatively speaking, one of the newer breeds of long-haired cats, and arose from the crossing of blues, blacks, and silvers, and appeared as a freak in litters of blues or silvers, and, being beautiful, were kept by their owners. No serious attempt, however, was made to breed them until quite recently. If beauty and a hardy constitution count for much, they should be more popular even than they are at present; but no doubt the extreme difficulties of breeding a good, unmarked shaded cat deter many breeders from taking them up. With a whole-coloured cat it is fairly plain sailing when a strain, sound in shape and bone, has been established; but with a shaded cat it is quite another matter. Litter after litter of kittens appear, grand in shape, strong in limbs, apparently perfect in shading. In a few months the kittens moult, and the shading becomes perhaps a hopeless jumble of light and dark. Where it should be dark it has turned light, and _vice versâ_. Still worse, the shading disappears, and the markings—the bugbear of all smoke breeders—appear, showing traces of the far-away silver tabby ancestors. These markings have perhaps been lying dormant for a generation, and appear as a reminder of the silver tabby origin of the smoke.

"To all smoke breeders who wish to succeed I would say, 'Never part with a well-shaped smoke until at least a year old, lest you find you have, in rejecting the apparently ugly duckling and keeping the gem, thrown away the substance for the shadow.' On the subject of mating, there is much to be said. I am afraid many owners of smoke queens mate with any coloured cat which takes their fancy in the hopes of getting something in the litter besides smokes.

"I have sometimes heard owners say, 'Oh! I mate my smoke queen with all sorts of colours. She always has one or two good smokes in each litter.' That may be true, but if a smoke strain is to be built up, you are making a fatal mistake. The kitten thus bred goes to a new home and is expected to produce smokes as good as herself. She is mated with a smoke male, and when the litter arrives there are perhaps no smokes, she having thrown back to her sire, so as a breeder she is useless. Smoke to smoke must be the rule, except in special cases—when, for instance, the queen is on the light side; then a cross with a black may be found to be necessary. Or the queen may be too dark and given to breeding black kittens. Then the choice should fall on a silver as free as possible from silver tabby relations. On no account must a tabby of any colour be chosen or a sire with any white. A blue should also be avoided, as the under-coat is liable to take the blue shade and become blurred instead of _white_ at the roots.

[Illustration:

"CHAMPION BACKWELL JOGRAM."]

"Orange eyes are much prized in smokes, and I believe, from my own experience in breeding smokes for the last ten years, that it is from the mothers that the kittens get their eye colour. If the queen has pale green eyes you may mate her with all the orange-eyed sires in the kingdom, and the eyes will still be pale. But if the queen has deep orange eyes, the kittens will inherit them also, even should the sire have only pale eyes.

"Thanks to careful mating by some of our smoke breeders, smokes are not the flukes they once were, and a smoke queen, well mated, may now be relied upon to produce whole litters of smoke kittens. As a rule, the kittens at birth are quite black, and remain so for a week or so; and my experience has been that if a kitten shows any trace of grey at birth, it will grow up too light. There are, however, a few well-known queens who throw almost silver kittens, which remain so for weeks, and then shed this kitten coat for a darker one; so no hard-and-fast rule can be laid down as to what a smoke kitten should look like when born. Try in-breeding for coat to avoid the sleek or woolly-coated smoke, and aim at getting a cat with a coat of the true Persian flakiness described by Mr. Harrison Weir in his book on Persian cats, otherwise the chief beauty—the light under- and dark outer coat—is not seen to advantage as the cat moves. One point to be remembered in this breed is that the new coat growing is dark just at the roots. These marks, when the smoke is changing coat, have often been mistaken for tabby markings, so for this reason it is most unwise ever to show a smoke when out of coat. Wait until your cat is in full coat before accusing it of having tabby markings.

"There is a fashion in smokes, as in everything else; and at present in England the very dark smokes are the rage, but in America the light ones are more sought after. That grand cat 'Watership Cæsar,' who was considered too light for English taste, was last

year bought by the late Mrs. Thurston and taken to America, where he carried off all the smoke honours, also taking the prize for the best cat in the show. The same happened to Lady Marcus Beresford's 'Cossey,' a lovely cat of the lighter type. The tide may turn, however, even in England, where the slightly lighter smokes may share the honours with their darker brothers. It is better, however, to be on the safe side and breed for the darker smoke, as the lighter are apt to lose the smoke characteristics and overstep the line which divides them from a shaded silver."

Mrs. Sinkins, to whom I have alluded as a smoke breeder, owns a splendid stud cat called "Teufel" that has made a name for himself as a first prize-winner. This cat is as nearly a perfect specimen as it is possible to find. Mrs. Sinkins has written a few notes on smokes.

"I must consider myself honoured in being asked to write about smoke Persians in 'The Book of the Cat,' as I am, comparatively speaking, a beginner in the cat fancy, only having kept Persians for three years or so. I began by buying a well-bred queen in kitten, and she presented me with two chinchillas and a perfect smoke female, which I named 'Teufella,' and showed at Westminster in 1899. She carried all before her, winning everything in her class, and was claimed at once at catalogue price. From a silver half-sister of hers I then bred 'Teufel,' whose picture is in this issue, and who is a great pet, being extremely sweet-tempered and affectionate. His chief characteristics are his _absolutely unmarked_ black face and the lovely white under-coat, so desirable in a perfect smoke, and for which he received a special this spring (1902) at Westminster. I hope some of his descendants will take after him in these respects and make smokes increasingly popular.

"In my opinion, it is a fatal mistake to mate smokes with blues, as they then lose this white under-coat. I think one obtains it best by mating a _smoke-bred_ smoke cat with either a _silver-bred_ smoke or else with a silver cat, as unmarked as possible, who possesses a smoke ancestor. Some day I should like to try mating a black with a pale silver, just as an experiment.

"As to eye colour, there can be no two opinions. The deeper the orange, the better.

"I do not find smokes at all delicate, no more so than the common or garden cat. All my queens have entire freedom, one in particular being a first-rate ratter and mouser, even catching moles sometimes. And they live out of doors in unheated houses all the year round, even in the most severe winter.

"It seems hard that all Persians should have to pass through an 'ugly' period—luckily a short one—when they change their coats, looking ragged and certainly not their best. Smokes and blacks then show the brown tinge even worse than chinchillas, as it gives them the poverty-stricken appearance of rusty moulting—though I must say 'Teufel' has so far been the exception, taking all honours at one show when in full moult.

"However, their good time fully compensates for the shabby period, and a typical smoke, with his large orange eyes set in his black face, with light ear tufts and frill, his white under-coat showing with every movement, is a thing of beauty hard to beat, and I feel sure the smoke variety has a great future before it."

[Illustration:

MRS. SINKINS' SMOKE PERSIAN "TEUFEL."]

Mrs. Stead, the owner of "Champion Ranji" and "Rhoda," a winning smoke female, has kindly given me her opinion on smokes:—

"My ideal of perfect smoke cats is that they should be black, shading to smoke grey, with as light an under-coat as possible, light frill and ear tufts, eyes orange. This is the standard up to which I try to breed. I find the kittens go through several stages before they approach this perfection. For instance, a kitten I had in the spring of 1902 lightened considerably, and developed markings on the face, but at eight months old he was nearly up to the standard. A litter of six I have recently bred were entirely unmarked at birth, being, in fact, quite black. Five are now medium-coloured smokes, and one a very dark one, with beautiful light under-coat. I strongly advise all breeders not to despair of colouring until their kittens are fully grown. Permanent markings are, of course, very detrimental, and there is always great anxiety as to the final colour of the eyes. If, however, both parents are good in this respect, the result is generally satisfactory."

The following article on smoke cats in America is taken from _Field and Fancy_ of October, 1902:—

"Smokes, with us, will probably rank with the silvers, and are destined to always hold a measure of popularity, though we have not such a very strong lot; in fact, we may say that good smokes are never so numerous anywhere as to become a nuisance, and we

may fairly congratulate ourselves at this stage of the game upon what we have had and bred.

"Opinions differ as to what is a smoke, and at times we have to be rather lenient in the judging of these cats, for they are apt to be off colour—too light or too streaky. No one has yet, in America, taken up the colour solely to breed smokes and nothing else, which seems a pity, for they can be bred and kept with blacks, and each sets off the other, and when visitors come to the cattery the contrast is made more apparent.

"Those not conversant with the colour are apt to think anything smoky is a smoke exhibition cat, and no doubt, when good, those cats with dark faces and paws and light bodies are very handsome, but more often than not they are streaky and are smoke tabbies. After mature consideration and after seeing a good many, we, as well as other breeders, still think that unless the 'Southdown' cats, as some have called them, are very good we had better stick to the old definition of a smoke, and demand them dark enough.

"A really dark, rich smoke without marks is, without doubt, one of the richest in colouring of all our long-hairs, and the stars are few. One may go away from the original definition of a smoke, but when brought face to face with a good one it forces one to confess that this is the genuine article, and, when in grand condition, a thing of beauty and a joy for ever."

[Illustration:

"LUCY CLAIRE."

OWNED BY MRS. CLINTON LOCKE.]

[Illustration:

SMOKE AND ORANGE PERSIANS.

(_From a Painting by W. Luker, Jun._)]

[Illustration:

MRS. SINGLETON'S "ORANGE GIRL."

(_Photo: J. G. Christopher, Crewkerne._)]

CHAPTER XV. ORANGE PERSIANS.

In the short-haired varieties, these cats are sometimes called red tabbies; but I do not think the term gives such a true idea of the correct tone of colour, which should be just that of a ripe orange when in perfection. As I write I have in my mind's eye the mass of bright colour presented by a pile of oranges in a greengrocer's shop, and this is the tone that is to be desired in our orange cats. There is a dash of red in the ideal orange cat, suggestive, perhaps, of the blood-oranges with which at Christmastide we are familiar. Anyhow, an orange cat should be as far removed as possible both from sandy or yellow or, as I have heard them called, lemon-coloured cats.

I have left out the term "tabby" from the heading of this chapter, and I think advisedly; for in the Persian varieties the markings are gradually but surely vanishing, and orange cats may be said to stand in the same relation to orange tabbies as shaded silvers do to silver tabbies. I mean that most of the orange Persians now exhibited have shaded bodies, with tabby marking on head, face, and paws. The body markings, never very strong in Persian tabbies, are even less distinct in the orange than in the silver varieties. It may therefore be said that in judging this breed as they are represented in the show pen to-day, colour is taken into consideration first, and tabby markings are of less account. As regards other distinctive features of this breed, I may say that it is the exception, and not the rule, to find good round heads and short noses. The longest faces I have ever seen in any felines have been those possessed by orange Persian and short-haired cats. I have really sometimes felt quite sorry for a magnificent puss of this colour whose nose was so self-assertive that every other point, however excellent, seemed to be lost sight of, and that nose with the accentuated terminus stood out with distressing prominence. Until the year 1894 the classification at the Crystal Palace was "brown or red tabby, with or without white," and the descriptions given in the catalogue by some owners on entering their cats read "brown and red," "red-marked tabby," "spotted red tabby," "sandy Persian." In 1895 orange and cream cats were placed together in one class.

[Illustration:

"PUCK," SON OF MRS. VIDAL'S "ELLWAYDA."

THE PROPERTY OF MRS. MOXON.

(_Photo: E. D. Percival, Ilfracombe._)]

A specialist society for orange, cream, fawn, and tortoiseshell cats was founded in 1900, and although the number of members is small, yet they have proved a strong body of staunch supporters of these breeds, and a really astonishing amount of good work has been done by these few enthusiasts. The classification at the large shows has been greatly supplemented, and, whereas before the formation of the society the sexes were never separated, now this energetic little club asks for, obtains, and often guarantees extra classes. The result, therefore, to breeders of orange and cream cats is much more satisfactory, and males and females have their respective classes; and right well have they been filled. It was in 1900 that classes for creams were introduced at shows. At the Richmond show in 1902 there were thirteen entries in male and thirteen in female orange and cream classes, the sexes, but not the colours, being divided. This was really a splendid testimony to the efforts of a specialist society of less than two years' standing. It is such a short time ago that orange, cream, and tortoiseshell cats were relegated to the "any other colour" class, even at our largest shows; now it is often remarked by reporters in the cat papers that the well-filled cream and orange classes were the chief attractions of the show.

[Illustration:

Photo] [_Vidal._

"SWAGGER."

BRED BY MRS. VIDAL.]

I will here give a copy of the circular issued by the honorary secretary inviting members to join, and the points for orange cats, as drawn up by the specialist society, which were decided upon at the inaugural meeting:—

ORANGE, CREAM, FAWN, AND TORTOISESHELL SOCIETY.

LONG AND SHORT HAIRED.

As societies have been lately formed to promote the interests of one or more colours in the cat world, it has been thought by a few fanciers of orange, cream, fawn, and tortoiseshell cats that there is an opening for a society for the purpose of encouraging the breeding of these colours. The objects of such a society would be:—

(1) To secure better classification for these varieties at the different shows.

(2) To encourage fanciers to breed and show these colours by offering special prizes, etc.

(3) To improve the type of cat bred.

(4) To secure recognition for all shades of orange, cream, and fawn; and, inasmuch as many fanciers disagree as to the merits of the different tints for eyes, to encourage the breeding and showing of specimens with green, orange, hazel, and blue eyes.

Miss Mildred Beal, Romaldkirk Rectory, Darlington, has undertaken to act as hon. sec. to the society, and will be glad to hear from any fanciers who may wish to support it.

November, 1900.

ORANGE SELF OR TABBY POINTS.

Colour and marking.—Colour to be as bright as possible, and either self or markings to be as distinct as can be got. 25.

Coat.—To be silky, very long, and fluffy. 25.

Size and Shape.—To be large, not coarse, but massive, with plenty of bone and substance; short legs. 20.

Head.—To be round and broad, with short nose, ears small and well opened. 15.

Eyes.—To be large and full, and bright orange or hazel. 5.

Condition.—10.

It will be noticed that the heading of these points is "orange self or tabby"; but, as I have pointed out, the cats exhibited as orange Persians are neither self-coloured nor can they be called tabby. So it remains to be seen which type of cat will in due course be the established one. I incline towards a self-coloured orange in the Persian breeds, and a very handsome cat this would be—of just one tone of bright even colour, perhaps slightly lighter on the flanks and stomach, under the tail, and with a frill of paler tone. In fact, very much the type of a smoke cat, in two shades of brilliant orange. At the same time, if real orange tabbies can be bred with the distinct body markings these should be encouraged.

At the Cat Club shows it has been customary to give the classification for orange cats _marked_ or _unmarked_, so that then the judge may not have to take tabby markings into consideration, but give his awards according to colour and other points of excellence. It is the same when a class is given for sable or brown tabby, silver or shaded silver. In such classes it would be unfair to consider either the tabby markings in the one or the amount of shadings in the other. Of course, it is possible that in time orange cats may be bred to such perfection that two distinct classes will be given, namely "orange" (selfs) and "orange tabby." In former years blues (selfs) and blue tabbies were included in one class, but gradually blue tabbies have been disappearing from our midst. If, therefore, orange tabbies—I mean, of course, long-haired cats—should likewise become extinct, our browns and silvers would be the sole representatives of tabbies in the long-haired varieties.

[Illustration:

"BENJAMIN OF THE DURHAMS."

THE PROPERTY OF MRS. D'ARCY HILDYARD.

(_Photo: Burgess, Market Lavington._)]

As regards the eyes in orange Persians, the standard given in the foregoing list of the specialist society is "bright orange or hazel." I should prefer the terms "golden bronze or hazel," as there is a special shade of gold with a dash of bronze or brown which seems to tone best with the bright coats of these cats. Certainly the pale yellow or greenish-yellow eye is not desirable—better a bright green eye. I often wonder if ever fanciers will be fortunate enough to breed an orange Persian with bright blue eyes, such as are seen in whites and Siamese. I have heard of a short-haired orange cat with blue eyes, and sometimes I have been told by a fancier of the Persian tribe that they had bred an orange, and its eyes had not turned from the deep kitten blue at four months, so they were fondly hoping they were going to astonish the cat world; but their hopes were dashed to the ground, for surely and sadly a change came o'er the colour of that cat's eyes, and it was a case of the blue that failed! I once noticed an advertisement in one of our cat papers which announced, "For sale, a unique orange Persian male with perfect deep blue eyes"; but I also remarked that the age of this unique specimen was not given, and I did not think it was worth while to write and inquire.

The texture of coat in this breed ought to be particularly soft and silky, and is often of great length and thickness. The kittens when born are usually dull in colour, and gradually brighten as they grow older. As is well known to cat fanciers, orange females are rarer than orange males, so their market value is higher. There is, therefore, always a flutter of excitement on the arrival of a litter, and too often fate has decreed that all are males!

Orange cats make a splendid foil for other varieties. This is especially the case as regards blues and blacks; the contrast in colour enhances the beauty of each. I know one lady who, having an eye to the artistic, keeps a blue and an orange neuter, and a lovely pair they make. I think the largest cat I ever saw was an orange neuter that simply filled the show pen with a mass of bright colour—but he had a white shirt front and white gloves!

As regards mating orange cats, they make a good cross with blacks and tortoiseshells; and if a brown tabby lacks the admired tawny or golden tint, then an orange may assist to brighten and improve the general tone, and do away, perchance, with that drabbiness which is so undesirable in a brown tabby.

[Illustration:

"TORRINGTON SUNNYSIDES."

THE PROPERTY OF MRS. G. W. VIDAL.

(_Photo: G. W. Vidal._)]

I do not think orange cats have ever been very popular, and I have remarked at shows that a certain number of people refuse to give anything but a passing contemptuous glance at the classes which contain what they call "those yellow cats."

A very common defect among orange Persian cats is the white or very light chin. Sometimes there is the still more damaging blemish of a white spot on the throat, spreading, perhaps, further down the chest. It is very rare to find an orange that has really a dark under-lip, and chin level in tone with the body colour. The white lip is a bugbear to breeders and exhibitors, for Nature repeats itself, and judges make notes of the defect; and in these up-to-date catty days of specialist clubs and standards of points a cat full of quality failing in one particular is too often a white elephant, if desired for anything more than a pet. I have observed that orange cats will sometimes develop a light or nearly white chin in their old age. I never consider a white spot or tuft of white hairs such a blemish to a cat if these are on the stomach, as compared with the same defect on the throat. Such a spot would not be so likely to be handed down to successive generations; and, of course, a blemish that has to be sought for in an obscure part of the body is not such an eyesore in a self or tabby cat. I have often observed orange cats with very light hair underneath which has almost approached white; but such defects are sometimes only temporary, whereas a white spot on the throat or a white chin remains once and for ever.

In the early days of the fancy, orange cats were decidedly more tabby marked than they are in the present day. A noted one of this type was "Cyrus the Elamite," born in 1889, and bred by Mrs. Kinchant, an enthusiastic fancier at that and later periods. In 1893 and 1894 Mr. Heap exhibited a handsome orange, "Prince Charlie," at the Crystal Palace. He also owned another, called "Prince Lyne," of the same breed, the celebrated tortoiseshell "Queen Elizabeth" being the mother of both these cats. "Puff" was exhibited by Mrs. Spackman in 1894; this orange cat was not much marked, and "Lifeguard" was bred from him. It was about this date that unmarked orange Persians became more fashionable. Among females, "Lifeguard's" sister, "Goldylocks," owned by Mrs. Marriott, was one of the very best queens ever shown. Mrs. Foote, who is still well known in the fancy, had several beautiful orange females, notably "Marigold," "Buttercup," and "Cowslip." With these cats Mrs. Foote tried to breed unmarked creams and oranges, "Ripon," a noted cream, being the sire. She built up several storeys of her catty castle, but then sold them to Lady Marcus Beresford. "Trilby," litter sister to "Zoroaster," a famous cream, was one of the brightest and deepest coloured orange females—or, indeed, orange cats—that has ever been seen.

[Illustration:

"LIFEGUARD."

FORMERLY THE PROPERTY OF LADY MARCUS BERESFORD.

(_Photo: E. Landor, Ealing._)]

Coming down to the present day, I may remark that the number of orange cats placed at stud is very limited. A great loss to the ranks of male orange Persians was "Lifeguard," formerly the property of Lady Marcus Beresford. This cat was almost unmarked, of a beautiful bright shade, and had an unusually round head and short face, with long silky coat. He was purchased by Miss Cartmell, who is well known as an enthusiastic breeder of orange Persians, but who never exhibits. This lady has been very successful in breeding numerous fine female orange cats, and many a winner has been born to blush unseen in the Barham Cattery, near Canterbury.

Another noted winner and stud cat is "Torrington Sunnysides," of whom a portrait is given. This cat is the property of Mrs. G. H. Vidal, and has done a lot of winning. His colour is exceptionally good, and he has sired several prize kittens, some of which have been sent out to America and gained distinction over the water. "Torrington Sunnysides" has a most luxurious house in the spacious garden surrounding Mrs. Vidal's residence at Sydenham. The photograph is by Mr. G. W. Vidal, who dislikes taking orange cats, because the tone is so difficult to reproduce in photography. Mrs. Davies, of Caterham, has owned some good orange cats. Her male "Hamish" was a grand specimen, but was only twice exhibited, when he gained highest honours. He was then purchased by Mrs. Vidal, and sent out to Mr. Storey in Chicago. A son of "Torrington Sunnysides" has also found a home in a Chicago cattery. "Red Knight" was sent by the writer to Mrs. Colburn, and in an article in the American _Field and Fancy_ mention

is thus made of him:— "'Red Knight,' an orange male, with deepest orange eyes, was imported from England. He is a very good type, and has sired some beautiful kittens, notably two by Miss Adams' 'Daffodil,' very fine specimens of pure orange, with cobby bodies, wide heads, tiny ears set far apart, and beautiful coats. They have been fed on 'Force,' and Miss Adams is going to call the male 'Sunny Jim.' Another son, seven months old, of the same parentage, is the largest cat ever seen for his age, and if he continues growing will certainly be enormous."

[Illustration:

ONE OF MRS. NEATE'S OUT-DOOR CATTERIES AT WERNHAM.]

One of Mrs. Vidal's orange kittens, "Puck" by name, is now owned by Mrs. Moxon, of Ilfracombe, from whom I have obtained a photograph for reproduction.

A few notes on orange Persian cats by Mrs. Vidal will be interesting to my readers:—

"It is difficult to imagine a more gorgeous colour than a really good orange lying full length in the sun. There is, however, rather a prejudice against them, chiefly because some people persist in calling them 'sandy' or 'red,' both of which names are quite misleading. I have several times had people say to me when visiting my cattery, 'I have always thought I did not like sandy cats, but I have never before seen a cat of such a lovely colour as the one you have just shown me.' Six years ago, when I first took up cat rearing, it was rare to see any orange cats at the shows, but now they and the creams form one of the most beautiful classes, and they have a specialist society of their own and an energetic secretary in Miss Mildred Beal.

[Illustration:

CURIOSITY.

(_Photo: Mrs. S. F. Clarke._)]

"There are two classes of oranges, one which has the ordinary tabby markings, more or less distinct, and the other which is 'flecked' all over the back in small patches, and which is usually not nearly so bright in colour as the so-called 'tabby' markings. The correct thing is to breed a totally unmarked orange; and, although many people claim this for their pets, it is very rarely seen. The absence of markings usually means absence of the rich orange colour so much admired. Any white on chin or bib is, of course, a blemish, and for breeding or show purposes such an animal is perfectly useless.

"An orange stud cat is a very useful animal to have in a cattery, for crossing with him will improve many colours, viz. tortoiseshell, brown, grey, and sable tabbies; while if he is mated to a blue queen the kittens, if orange, are beautiful in colour—brighter, I think, than if two orange cats are mated together. In mating with other colours it is a toss-up what colour will predominate, but the only way to ensure _all_ orange kittens is to mate with orange queens, when, according to my experience with my stud cat ('Torrington Sunnysides'), the results are _all_ orange. Mated with tortoiseshells the orange kittens are very good; but mated with blacks the strongest colour carries the day, and the kittens are mostly black or tortoiseshell, seldom orange. Silvers, chinchillas, and smokes should, of course, never be mated with oranges, as the result would be a horrible mixture! Orange queens were at one time very rare, and even now are not plentiful, being delicate and difficult to rear.

[Illustration:

ANOTHER VIEW OF MRS. NEATE'S CAT HOUSES.]

"The time at which the kittens change the colour of their eyes from the baby blue to orange varies a great deal in individual animals, from seven to twelve weeks. When the eyes are very deep blue, they change to bright rich orange or hazel; but if of a pale blue, they change very quickly to a poor yellow, and never get the rich dark orange which the deeper blue get. Therefore rejoice when you see your kittens with deep blue eyes. Some of our kittens have had the most lovely deep blue eyes, and great has been our sorrow as we found the inevitable change coming on. If I could only manage to get some kittens with the permanent blue eyes that the best white cats have, I should indeed be proud; but thinking of the kittens with terrible white chins and under-coats, which would crop up in every litter and would have to be drowned, quite deters me from sending my orange queens to white studs with blue eyes! All who have been accustomed to frequent the show pens will remember Miss M. Beal's splendid old orange queen 'Jael,' who up to the last, although nearly fourteen years old, always took first prize, and was a very good specimen of what an orange queen should be—of a bright rich orange, without any suspicion of light under her chin or chest (the usual weak point), and having

the splendid head, short nose, and good cobby shape which all breeders strive for. Short-haired orange cats are often seen about our towns and villages, and are always called 'sandy,' but are not, I think, held in much account. They are distinct from the so-called 'red tabby,' which is a recognised colour in our shows."

[Illustration:

MRS. NEATE'S CAT HOUSES.]

Among the prize-winning females of the present day I must not forget to notice Mrs. Singleton's "Orange Girl," bred from Miss Beal's noted strain. This cat has had many honours showered upon her during a very short career, and as there must always be a scarcity of queens in this breed, this fine specimen is a valuable possession.

So long as there are two cat clubs and two registers there will be a confused multiplicity of names, and so yet another orange male called "Puck" inhabits the cat world. This handsome fellow is owned by the Hon. Mrs. McLaren Morrison, to whom I had the pleasure of awarding first prize and many specials at the Botanic show held in June, 1902. His vivid colouring and well-shaped limbs and splendid eyes will always make him a conspicuous specimen in the show pen. Alas! his photograph does him but scant justice. Quite a surprise packet appeared at the Crystal Palace show of 1902 by the appearance of a very handsome young male in "William of Orange" exhibited by Mrs. Stillwell, and bred from Dr. Roper's noted black "Johnnie Fawe" and tortoiseshell queen "Dainty Diana." This cat was awarded first and many specials, and was claimed by Lord Decies at catalogue price. As "William" was not a year old when he won his laurels, it may readily be believed that he has a distinguished career before him, and may add another to the long list of winners owned and exhibited by Lady Decies. No orange male cat is better known in the fancy than that splendid fellow "The King's Own," belonging to Mrs. Neate. He has had a most successful career, and may be considered as nearly self-coloured an orange as any yet exhibited.

Mrs. Neate is a devoted admirer of this breed and also a great cat lover, and has recently started an arrangement for boarding cats, and truly I know of no place better adapted for successful cat keeping than the home of Mrs. Francis Neate, at Wernham, near Marlborough; situated as it is in the very heart of the country, a mile from any other house, her cats can enjoy their liberty with perfect safety.

A large range of brick-built and slated outhouses has been converted into catteries and comfortably fitted. All have wooden floors, wire doors, and large runs attached. A number of portable houses and runs are dotted about the kitchen garden and meadows. An empty cottage serves as an isolation hospital, or place of quarantine for cats returning from shows.

A herd of pure-bred goats supply the inmates of the cattery with milk, and rabbits, which abound, form their staple food when in season. The largest of the outhouses is fitted with a Tortoise stove, carefully guarded. The pride of Mrs. Neate's cattery is, of course, the famous orange stud "The King's Own." He is the sire of the two winning orange queens "Mehitabel of the Durhams" and "Glory of Prittlewell."

Fitting mates for him are "Wernham Titmouse" (tortoiseshell-and-white), "Evening Primrose" (a cream daughter of "Champion Midshipmite" and "Hazeline"), also "Mimosa" (an orange bred by Miss Cartmell from "Richmond Bough" and "Mistletoe"): these occupy the house adjoining the stables.

"Champion Bundle" and "Betsy Jane," a lovely little blue with glorious orange eyes, are the only blues of the establishment. Latterly Mrs. Neate has reduced her own stock of breeding queens, and makes a speciality of receiving cats during the holidays. Judging by the number of cat fanciers who sent their pets to Mrs. Neate during the summer of 1902, it is certain that a great want has been most efficiently supplied. Not only does Mrs. Neate give personal supervision to her catty boarders and visitors, but they have splendid caretakers on the premises. These custodians are Mrs. Neate's big St. Bernard and a chow-chow, who jealously guard the Wernham cattery. These dogs are on the very best terms with the feline inmates, and the strange pussies very soon appear to settle down to an amicable cat-and-dog life. The accompanying photographs, as will be seen, were taken in the depth of winter. These brick-built houses, slate roofed and with wooden floor, are splendidly adapted for keeping the cats snug and warm during the cold weather. One of the buildings illustrated is 25 feet by 15 feet, and has three windows. This house is provided with large table, shelves, and chairs, and cosy sleeping boxes. An outside wire run, of the same length and width as the building, is erected for an exercise ground in summer weather.

Mrs. Neate has kindly supplied me with a few notes on orange Persian cats:—

"It was in 1897, at Boscombe show, that I claimed the winner in a class of twenty-six kittens, my now well-known orange Persian stud 'The King's Own.' The same year, at the Crystal Palace, I purchased a lovely orange female kitten sired by Mrs. Pettit's 'Champion King of Pearls' and the tortoiseshell-and-white 'Dainty Doris.' From her I fondly hoped to establish a breed of blue-eyed oranges, which feature would be charming in the variety; but alas! she came home to sicken and die, as so many another valuable kitten has done, and I have never since been able to obtain an orange of either sex sired by a blue-eyed white.

"It is most difficult to breed oranges without white lips and chins; the pink nose, too, is a feature in the breed that I do not like.

"I have found crossing an orange male with a cream female the surest way to breed sound-coloured specimens of both sexes and varieties, _e.g._ 'Mehitabel of the Durhams' (a really rich-coloured unmarked orange queen, and quite free from the objectionable light shading on lips and chin); she was bred by Mrs. D'Arcy Hildyard from her cream female 'Josephine of the Durhams' and 'The King's Own.' Again, from a blue male and a tortoiseshell queen you are more certain of breeding good oranges (though seldom of the female sex) than from mating tortoiseshell and orange together; in the latter case more often than not black kittens predominate in the litter, and there is rarely, if ever, an orange female amongst them.

"Mrs. Vidal's famous orange stud 'Torrington Sunnysides' was a son of my light blue 'Champion Bundle' and a tortoiseshell dam 'Torrington Owlet,' herself of an orange strain. Mrs. Walford Gosnall's 'Rufus' (whose name discloses his colour) was also the result of this union. 'Red Ensign,' the orange kitten who won first and three specials at Westminster in 1902, was bred by me from 'Champion Bundle' and 'Mimosa,' an orange queen of cream breeding, and with his litter brother 'Scarlet Lancer' took first and silver medal for the best pair of kittens. The latter is now the property of Miss Cartmell, and has grown into a fine cat. Unfortunately for the cat fancy generally, 'Red Ensign' was claimed at the show, and is now a house pet.

"The best orange kittens I have bred were from my 'Wernham Titmouse,' a tortoiseshell-and-white who owns an orange dam, and 'The King's Own'; the whole litter were females, and redder than any oranges I have seen. These never lived to see a show, and their death was one of the greatest disappointments I have experienced in my career. The demand for good orange and cream females is greater than the supply; in fact, these colours are decidedly 'booming,' and better classification is given for them at our principal shows.

"At the Crystal Palace show of 1898 there were only four entries in the open class for orange and cream males, and four of the same varieties in the female class, compared to the ten entries in orange and cream male classes and the same number in the female classes at the Cat Club's show, held at Westminster, 1902. These facts speak for themselves of the increased interest now taken in these varieties.

"Unlike some of the warmer tinted of us humans, orange cats of both sexes are particularly sweet-tempered, showing great attachment to their owners. They are of strong constitution and attain to great size, being at present free from the in-breeding that is practised amongst many other varieties of our show cats. A small piece of sulphate of iron in the drinking water will enrich the colour of orange and tortoiseshells, besides being an excellent tonic, especially during the moulting season.

"Orange Persian cats do not, as a rule, make good photographs, as they lack expression compared to the short-haired tabby varieties of this colour."

The Misses Beal, of Romaldkirk, near Darlington, have long been associated with orange and cream cats. "Jael" was quite unique as an orange female, and at fifteen years of age could yet win in her class by reason of her grand colour, perfectly shaped head, short face, and tiny, well-set ears. Such a cat stands out in any breed, and such a cat may never again be bred. "Jael" died in 1902, after a long and successful career.

[Illustration:

MUSING.

(_From a Painting by Madame Ronner._)]

Miss Beal's male orange "Minotaur" is one of the most beautiful cats of this breed now exhibited, and has quite the best round head and face, with sweetest expression. These are qualities too often lacking in orange cats.

Miss Beal's name is, perhaps, more closely associated in the cat world with cream cats, and in my next chapter on this breed she has kindly supplied some notes.

Another fancier of both orange and cream cats is Mrs. D'Arcy Hildyard, and to her I am indebted for the following notes on orange Persian cats:—

"Until comparatively lately I confined myself entirely to the breeding of creams, and my efforts were attended with considerable success, both in multiplying the number of cats of that colour—I bred thirteen one year—and in filling the classes given for cream females. I was particularly lucky in breeding many creams of the gentler sex.

"The birth of the Orange and Tortoiseshell Society fired me with ambition to start breeding oranges. I was much fascinated with the colour, though I hate their being penned beside the creams at shows, as they completely take all colour out of the lighter animals and give them a washed-out appearance. I started by crossing my cream queen 'Josephine of the Durhams' with Mrs. Neate's famous 'The King's Own.' This proved a most satisfactory cross, the results being three rich-coloured unmarked orange kittens, one male and two females. I sold one female to Miss Scratton, of Prittlewell Priory, and it has, I hear, grown into a very handsome cat; the other two I kept, and they won all before them at Manchester Kitten Show, 1901, and were shown at Slough after, where the male was claimed. The remaining one, 'Mehitabel of the Durhams,' I kept, and she won me many prizes last winter, and being mated this year to 'Champion Romaldkirk Admiral' has presented me with a litter of two creams and an orange. Certainly creams and oranges cross well, and often I think produce a brighter and deeper tone of colour than is obtained from other shades. I have lately purchased an orange tom, and by crossing him with 'Hazeline,' one of my cream queens, have got a splendid litter of seven pure oranges. This, I think, proves that the cream and orange cross is good, and that they breed very true. Oranges bred by crossing other colours seem to me rather spasmodic, if I may use the term. When breeders try crossing an orange and a tortoiseshell they very often get blacks and blues as well as oranges; on the other hand, from a blue and a tortoiseshell cross sometimes an orange is obtained. But they do not seem able to count exactly on the results.

"Reliability is what I claim from the cream and orange cross. I emphatically believe in mating creams to creams if you wish to get a good pale colour and few markings, and oranges and creams crossed have certainly produced good specimens of both colours for me. I speak from my own experience.

"I hope to do great things by trying a cross between my orange tom 'Benjamin' and 'Mehitabel.' Miss Winifred Beal's 'Minotaur' was the result of a cross between a cream and a tortoiseshell. Her well-known 'Garnet' is the daughter of a cream and a blue. At present there is, to my mind, no orange female on the show bench to compare with the late 'Jael,' owned by Miss Mildred Beal, whose brilliant colour and perfect head with its tiny ears made her hold her own at all the shows up to within two months of her death at quite a venerable age; but I hope in the future, as oranges become more popular and breeders work hard at producing good specimens, we may see her like again. I was much taken at Richmond show with Mrs. Singleton's 'Orange Girl,' and also with the kitten of that colour exhibited by the same lady at Manchester. Every year, I think, shows that the general world is becoming more alive to the beauties of orange and cream cats, as proved both by the large increase in entries of these colours at the principal shows and the great demand for kittens when any are offered for sale. Undoubtedly breeders owning creams should stick to them, if they wish to produce good oranges—see the many splendid specimens sired by 'Midshipmite' and 'Admiral.'

"It is a hard matter to say decisively what tint orange kittens should be when born. I have known them enter the world a bad cream, and gradually grow redder till they develop into the brilliant colour we all look to see in a cat of orange hue. Personally, I prefer them born a dark shade; they usually lighten and brighten a little, but on the whole I think that is the more satisfactory of the two. It is distinctly discouraging to see a washed-out looking kitten when you are expecting a bright orange one.

"Fanciers differ about the eyes which are supposed to be correct in this breed. Hazel eyes are universally acknowledged to be the right thing. Personally, I admire green, or rather _eau-de-nil_ eyes, as giving more contrast to the colour of the coat, but you do not often see them. I have always wished to breed a cream with blue eyes—I do not mean the baby blue, but the colour that Siamese have—and only the other day I sold a kitten three months old with brilliant blue eyes of this tint, and shall be anxious to know whether they change in time or not.

"I think the time is approaching when the orange and cream cats are going to be among the most attractive classes at our bigger shows. Already the classes are much better filled than when I first joined the fancy, and you always find an admiring crowd in front of their pens. I wish, though, that a nice sprinkling of blues could always be placed between the two colours at shows. The close company of the oranges is so excessively unbecoming to the creams, while when you see the three colours together they are especially lovely. To see cream and orange cats at their best they should be at large in the country and running about on the green grass."

[Illustration:

OUT IN THE COLD.

(_Photo: E. Landor, Ealing._)]

In 1902 an Orange and Cream Cat Club was started by a few enthusiastic breeders of these varieties over in America. The Misses Beal, Mrs. Vidal, and Miss Frances Simpson were elected as honorary members. The following is an extract from _Field and Fancy_, the American weekly paper:—

ORANGE CATS.

There is very little doubt that this is a colour that has from the beginning of the fancy in America been very popular, and has had a very strong hold upon the American love for colour. But, of course, as is generally the case with the popular ones, the supply has never been too plentiful, and probably never will be as regards the queens, for they only appear once in a while, according to what seems to be one of Nature's rules, that the queens should be tortoiseshells.

The Orange and Cream Club is probably destined to do a great deal for the variety, which is one of the colours from which it takes its name. Breeding orange cats opens quite a field, for in attaining your end you can at the same time indulge in other colours, for undoubtedly a cross with a tortoiseshell will be found necessary to keep the colour sufficiently intense, and at other times it may be quite as well to throw in a little black. The tendency for the queens to be tortoiseshells may possibly be somewhat overcome in time, but these inherent traits in colours in animals and birds are often so strong that they have a knack of reappearing even after several generations. We occasionally see queens of the orange colour, and these are usually high quality ones, both in colour and type; but the orange queens are not destined to at present make heavy classes by themselves. Though the standard calls for orange eyes, it is a curious coincidence that the most consistently successful cat of recent times has been Miss Beal's "Jael," who had green eyes; but so good was her colour, so good her type, that she generally won when exhibited.

The struggle carried on in the British Isles for some years to breed these cats without marks has been hardly a success, and there have not been very many evolved of that colour that were really without marks, and it is a great question if in this craze for absence of marks they have not been passing by a lot of good cats. As far as we personally are concerned in the matter, we see little to be gained by the absence of marks in the orange cats. If the colour had been very prolific in numbers it might have been a good idea to try and split up the classes, but they were never too well filled, and there is room still for plenty more, though we cannot complain so much at the representation that they have had in America last season, either in numbers or quality.

[Illustration:

HIGHER EDUCATION.

(_Photo: Mrs. S. F. Clarke._)]

CHAPTER XVI. CREAM OR FAWN PERSIANS.

This may be said to be the very latest variety in Persian breeds, and one which bids fair to become very fashionable. The term "cream" describes exactly what is the desired tint of these cats, but few and far between are the specimens which are pale and even enough in colour to be correctly described as creams. No doubt, in times past now and again a cream cat would be seen exhibited in the "any variety" class, but then they might be designated as freaks or flukes. Now, however, fanciers of these cats have a system in their matings, and therefore, as a result, there is a breed of cats established which until late years were not recognised or classified.

[Illustration:

MRS. CLINTON LOCKE'S CREAM KITTEN.]

It is true that the cream Persians seen in the show pens are often much darker than is implied by the name, and, indeed, are really fawn-coloured. The great thing, however, is to obtain an even tint throughout, whether dark or light, and to avoid any patches, streaks, or tabby markings. I think the very pale creams are more dainty and fascinating than the darker cats, but the lighter the coat the more difficult it is to obtain perfect uniformity of colour. Of course, there will always be a certain amount of shading in

cream cats—that is, the spine line will be slightly darker, shading off on the sides and under the stomach and tail. I think that creams are making more rapid strides towards attaining the "almost unmarked" stage than are silvers. Certainly, good creams of to-day are very slightly barred on head or legs or tail, and this cannot be said as regards some of our best silver cats. This is probably to be accounted for by the cautious and wise discrimination used in mating creams by selecting blues or tortoiseshells, and thus avoiding tabby-marked cats. It is a peculiarity of cream cats that the eyes are generally almond-shaped, and are set rather slanting in the head. It is rare and a great treat to see bold, round, owl-like eyes in cream cats. These in colour should be golden or hazel, the brighter the colour the better. I will here give the points of cream or fawn cats, as drawn up by the specialist society:—

CREAM OR FAWN.

Colour.—To be as pure as possible without marking or shading, either paler or darker, dulness and white to be particularly avoided. All shades from the palest fawn to be allowable. 25.

Coat.—To be very long and fluffy. 25.

Size and shape.—To be large—not coarse, but massive, with plenty of bone and substance; short legs. 20.

Head.—To be round and broad, with short nose, ears small and well opened. 15.

Eyes.—To be large and full, and bright orange or hazel in colour. 5.

Condition.—10.

[Illustration:

A CREAMY SMILE.]

Much has been done by this energetic specialist society to get a better classification for creams at our shows; and perhaps, as time goes on and a larger number of fanciers take up these breeds, a distinct classification will be given for creams and fawns. It may always be a little difficult to draw the line between the two; but such a division of colours would, I think, give satisfaction to the breeders of both creams and fawns, for at present judges are more inclined to give a preference to the palest-coloured cats, perhaps because more beautiful and more difficult to breed.

In the former breeds, more especially blues and silvers, that I have described in this work it would have been impossible to name all those cats that were noted in the fancy, for the simple reason that their name is legion; but it is different in a breed like creams, for, as I mentioned in the beginning of this chapter, in times past it was a case of only here and there a cream Persian appearing on the scene, then vanishing perhaps to America, or else being purchased for a pet and retiring from public life. These "sports" in the fancy were not seriously taken up, and no one thought of trying to establish a strain; so that one can, as it were, put one's finger on the cats of this variety, if not so easily in the present day, certainly in the past.

The first recorded cream Persian in catalogues or stud books is "Cupid Bassanio," born in 1890, bred by Mrs. Kinchant; no pedigree is given. He was a big, broadheaded, heavily coated cat, with a good many marks and shadings, and was sold to Mrs. Preston Whyte, and passed on to Miss Norman. In the same year Mrs. Kinchant exhibited cream kittens at Brighton. "Ripon" was another well-known cream of imported parents (a blue and an orange). This cat was purchased from Mrs. Foote by Lady Marcus Beresford, and eventually disappeared when in the possession of Miss Cockburn Dickinson. Mr. McLaren Morrison in 1893 owned a pale cat called "Devonshire Cream." In the following year Miss Taylor bred a splendid specimen from "Tawny," her noted tortoiseshell. This cat, called "Fawn," was an absolutely self-coloured fawn with brown eyes, and would do some winning if alive now to compete in our up-to-date classes for cream or fawn. It was in 1895 that Miss Beal first exhibited some of her creams, upon which at that time she did not set much store, more interested as she was in blues; but of her now celebrated strain more anon.

[Illustration:

MRS. F. NORRIS'S CREAM KITTEN.

(_Photo: E. Landor, Ealing._)]

One of the best known creams of late years is "Zoroaster," bred by Mrs. Bagster from her tortoiseshell "Pixie." This was a remarkably large pale cat with glorious eyes, but he was a good deal patched in colour when I saw him at Mrs. Mackenzie Stewart's

cattery. Mrs. Cartwright bred a well-shaped light cream, "Upwood Junket," by "Timkins," a blue, and a daughter of "Cyrus the Elamite." Mrs. Davies, of Caterham, has often had creams in her possession, notably "Lord Cremorne," quite one of the palest seen in the show pen. Two noted creams now placed at stud are Mrs. Norris's "Kew Ronald" and Mrs. Western's "Matthew of the Durhams." Both these cats are bred from Miss Beal's famous "Heavenly Twins." Regarding "Matthew," a reporter in _Our Cats_ thus writes after the Botanic show of 1901:—"Creams are, we prophesy, the coming cats. There seems to us great possibilities in this variety. 'Matthew of the Durhams' is one of the cats we would bring forward in support of this view. Eminently aristocratic, breathing an air of refinement, this cat might be the petted darling of a princess whose cats are all selected by a connoisseur." Mr. Western is justly proud of his purchase, for he claimed this fine cat at the Sandy show, 1901, when he was exhibited by Mrs. D'Arcy Hildyard. "Matthew" has on four separate occasions taken second to his father "Admiral's" first. He has sired some lovely creams, notably "Wynnstay Myrtle," also owned by Mrs. F. Western. This female is one of the best of her breed, and is sure to have some influence over the creams of the future. At the Crystal Palace show of 1902, where she was awarded first and many specials, she was the admired of all admirers. As a rule, cream females have been very much behind the males in quantity and quality. Almost the first two were bred by Miss Hester Cochrane from "Cyrus the Elamite" and "Brunette." "Crême d'Or" is quite one of the best, and was owned by Mrs. Wellbye, who sold her to Mrs. Norris. This cat declined to enter into any matrimonial alliance for some time, but at last presented her owner with a family by "Darius," Mrs. Ransome's noted blue. Two of these cats, "Kew Laddie" and "Kew Ronald," are well known in their different spheres. "Kew Laddie" I purchased to send out to Mrs. Clinton Locke, in Chicago, and she presented him to the honorary secretary of the Beresford Club, Miss Johnstone. This lady exhibited "Laddie" at the big Chicago Cat Show, where he won high honours, and in a letter received from Miss Johnstone I learn he is growing a grand fellow and, in fact, is quite _la crême de la crême_ in catty society over the water.

The picture of a perfect kitten on the opening page of this chapter represents a cream female, "Jessica Kew," bred by Mrs. Clinton Locke from "Lockhaven Daffodil," sired by Miss Johnstone's "Laddie Kew." Mrs. Clinton Locke is justly proud of this lovely kitten, and writes: "Jessica is the finest kitten I have ever seen; all her points are perfect. She was five weeks old when this photo was taken. Her grandfather was my 'Victor,' an orange, her great-grandmother a tortoiseshell-and-white."

[Illustration:

"KEW RONALD" AND "KEW LADDIE."

(_Photo: E. Landor, Ealing._)]

I have mentioned Mr. F. Norris as a breeder of creams and the owner of the handsome pair of cats illustrated on this page. He has kindly supplied me with the following notes:

"Cream cats are of a modern colour in Persians, but are now being more freely bred and finding numerous supporters.

"There are, however, very few good ones in the fancy, for size and colour are difficult to obtain. The great failing with them is that, although they are called cream cats, the best and soundest coloured ones are really of a fawn shade. So many show markings, patches, or shadings, whereas the colour should be one shade and sound throughout; better be a little dark in colour rather than shade from cream to white, as is the case with so many specimens exhibited.

[Illustration:

MISS BEAL AND HER KITTENS.]

"For one grand-headed and good-eyed cat you see a dozen snipy, long-faced ones with curious slit eyes, instead of a short, snub head, with glorious big round golden eyes.

"In my opinion, to get the short head, good eye, fine body shape, and short legs, it is best to mate a cream with a good cobby blue. From my experience nothing beats a blue, although you can mate them with a red, tortoiseshell, or black. Mating two creams together I do not advocate, unless one of them has a distinct out-cross in the first generation to totally different blood.

"All the creams shown are descended from Miss Beal's two brothers 'Romaldkirk Admiral' and 'Romaldkirk Midshipmite,' and to keep the colour, breeders have bred in and into them again; and that is why they have lost so much in type and character, which would have been improved by using an out-cross.

"I have heard people say, 'Cream females will not breed.' If they only studied the question a minute, they would know the reason well enough, which is that they have been too much in-bred. If breeders will only try the blue cross more, they will, I am sure, be pleased, and we shall see a better cat being shown. Breeding from blue you will get pure creams and some cream and blue mixed. Keep the blue and cream females, and when old enough mate them to a cream, and you will get some fine sound-coloured cream kits.

"It is very curious that there has been nothing yet bred in males to beat the twin cats 'Admiral' and 'Midshipmite.'

"In females the best I have seen is 'Miriam of the Durhams,' who has a lovely body and coat, but is long in face and has those bad-shaped eyes. 'Crême d'Or' runs her close, as she has such a good head, with perfect eye, but is a wee bit long in the leg."

Miss Beal's females "Calliope" and "Mignonette" were both noted prize-winning cream females. Mrs. D'Arcy Hildyard has been most successful in her endeavours to breed creams from creams, and a letter from her in _Our Cats_ of April, 1901, will be interesting to breeders of this variety:—

[Illustration:

MRS. D'ARCY HILDYARD'S CREAM KITTENS.

(_Photo: E. Yeoman, Barnard Castle._)]

BREEDING OF CREAMS.

SIR,—Being much interested in the breeding of creams, I should like to say a few words on the subject and state my experience. Though only a novice, I have up to date succeeded in breeding twenty creams—two in 1899, thirteen in 1900, and seven this year. I began by mating my mixed blue and cream queen "Senga" to a cream tom "D'Arcy," which I bought from Mr. Hutchinson, of Egglestone. From this pair I got four kittens, all females—two cream and two marked blues. I kept the creams "Josephine" and "Hazeline," winners at Westminster as kittens, first and second special and medal, 1900. Later on in the year I mated them, "Hazeline" to Miss Beal's "Midshipmite," "Josephine" to her "Admiral." Both litters were entirely cream, "Josephine" producing six kittens, "Hazeline" producing five, two of which I have kept. "Matthew" and "Miriam of the Durhams" both won as kittens at Manchester, and "Miriam" has since taken first and specials at Barnard Castle, Westminster, and Reading. "Matthew" is growing into a very handsome cat, and I hope to exhibit him at the Botanic. On Saturday last, April 13th, "Hazeline" again kittened and produced five creams, having again been mated to "Midshipmite." This I think distinctly proves that good creams can be got from a pair of the same colour. On April 14th "Senga" also presented me with two more creams, also two marked blues, this time the result of a mating with Miss Beale's "Romaldkirk Toza."

AGNES D'ARCY HILDYARD.

Mrs. Barton Collier has two good creams, "Bruin" and "Dolly of Brough." Again these cats are from Miss Beal's strain, the male being a fawn and the female quite one of the palest of creams.

Miss H. Cochran, who formerly took a great interest in this breed, writes:—"I should be inclined to mate a pale cream male or female with a white, and the progeny with an unmarked orange, or _vice versâ_. I had a litter from 'Buttercup' and 'Zoroaster,' consisting of two oranges, two fawns, and a cream. The fawn and creams were females, but all died in their youth. I made other attempts with similar crosses, as I had been told it was impossible to breed cream queens, and in the first year all the creams were queens, and the males red! My idea was to select a male of the required colour, and mate a queen of suitable breeding with him, then to mate the resulting queens with their own father. I believe this plan would have been a success if I had followed it up. My idea is that the natural males are the fawns and oranges, and that their complementary queens are the blue tortoiseshells and the ordinary tortoiseshells. No harm is ever done to a cream or orange strain by crossing with black, and it may do much good to the latter by deepening the colour of the oranges, and promoting patchiness as opposed to streakiness in the tortoiseshells."

[Illustration:

"MIRIAM OF THE DURHAMS."

(_Photo: E. Yeoman, Barnard Castle._)]

I have made frequent mention of Miss Beal's noted creams during my chapters on orange and cream cats. These two celebrated champions are commonly known in the fancy as the "Heavenly Twins," their registered names being "Romaldkirk Admiral" and "Romaldkirk Midshipmite." They are really fawn Persian cats, very sound in colour, well made, big boned, and are always exhibited in the pink of condition, and at all seasons of the year are in marvellous coat. Certainly, the cold climate of the Romaldkirk cattery, which is situated 730 feet above the sea level, must, anyhow, suit this variety of Persian cat. I suppose the day will come when these welltried and well-seasoned veterans will have to retire from public life and make way for some of their already noted offspring. In the North, South, East, and West these "Heavenly Twins" have reigned supreme, and Miss Beal must almost have lost count of the number of prizes won by them, which, I think I am safe in saying, would give an exact record of the number of times exhibited. In response to my request, Miss Beal has sent me some notes regarding her cattery arrangements. She says:—

[Illustration:

"CHAMPION ROMALDKIRK ADMIRAL."

(_Photo: G. W. Vidals._)]

"Most of the houses are old farm buildings round about our stable yard, and I have recently utilised an old granary which is over the coachhouse. This is about 40 feet long, and has a room at one end, with five windows and good ventilation above. In addition I have three big cat houses and a loft, where most of the queens reside. 'Middy' and 'Admiral' (the 'Heavenly Twins') have small wooden houses, felted inside and out, with wired runs and concrete floors.

"I have the use of two laundries and a tool-house fitted with fireplaces, and these I reserve in case of illness."

There are no cats exhibited in better coat and condition than those that come from the Romaldkirk cattery, and the Misses Beal may be justly proud of their splendid specimens of creams, oranges, tortoiseshells, and blue Persians. Miss W. Beal has kindly supplied me with a short article on cream and fawn Persians:—

"The cream and fawn Persian was a few years ago looked upon as a 'sport,' and when cream kittens appeared in an orange strain they were considered spoilt oranges, and were either given away, sold for a few shillings, or in many cases destroyed as useless. Now, however, it is very different; there is a growing demand for cats and kittens of this colour, and at the big shows they usually have two classes, _i.e._ male and female, for them. They were certainly slow in coming into general favour, owing, I think, to the following facts: First, that the specimens formerly exhibited failed very noticeably in head, being very narrow in face and long in nose; secondly, that cream females were practically unknown; and, thirdly, that a show, where they are generally seen, is emphatically the worst place to see cream Persians to advantage, as the journey and being in a town, etc., takes off the spotlessness of their coat and dulls their colour, and the dingy grey of the pens and the yellow of the straw combine to spoil the effect of their colour.

"The place, without doubt, to see creams to perfection is the country, where against a background of vivid green lawn their pure, soft colouring is indeed a thing of beauty, and rarely fails to command admiration. The colour is rather difficult to describe, and there are two distinct tones of colour bred, the one which is generally seen and is so far most successful at shows being a cream rather deep in shade, almost buff, with a distinct pink tinge about it, which is very different from the washed-out orange or sandy colour some people imagine it to be. The other tone of cream colour is much paler in shade, but, instead of the pink, it inclines to a lemon tinge, and, though paler, it is, as a rule, more 'flaky' and uneven than the darker shades, and it is also very apt to fade into white underneath.

"Nearly all the best-known creams are bred in the first place from orange and blue strains, though creams have appeared as freaks in many colours—silvers, tabbies, etc.; but I believe the present strains sprang from crossing blue and orange, and you can _generally_ rely on getting some creams by crossing a tortoiseshell, cream, orange, or blue tortoiseshell queen with a blue sire. But, so far, reversing the mating, _i.e._ a blue queen with a cream or orange sire, is not successful from the cream breeders' point of view, though very good from that of those breeders who want blues, as the kittens generally excel in purity of colour. Cream females are now fairly common, and so in a few years there ought to be a well-established strain of cream-bred creams; but, as in all other breeding for colour, people are apt to get surprises—for instance, one strain of cream females mated to a cream sire invariably produces whole litters of creams, while another strain, more cream-bred than the first named, mated to the same sire produces equal numbers of creams and orange and creams. If people wish to start breeding creams, and cannot afford a cream female, it is a good plan to buy a well-bred nondescript coloured female, either blue and cream, tabby, tortoiseshell, or anything that

has cream or orange about it, and if it is properly mated there are nearly sure to be one or two creams: thus a cream strain can be gradually built up.

"There are several things to be remembered in trying to breed good creams. One point to be aimed at is to keep the colour as _level_ as possible, whether it be of a dark or light shade, and to keep it pure, not tinged with blue or dull. Among other faults to be bred out are the light lip and chin, which are very common defects, and the long head, which is still seen sometimes, though creams have improved vastly in this respect in the last few years. Creams have been taken up greatly in America as well as oranges, and there they seem to be formidable rivals in popularity to the silvers, which have so far over here outdone them in that respect.

"One great point in favour of creams is their hardiness, for they do not possess the delicate constitutions which seem to belong to most of the other very pale varieties of Persians. With other coloured cats—blues, silvers, etc.—creams make a splendid contrast, and with oranges add greatly to the effect of a group. They also cross well with several colours—blue, black, tortoiseshell, etc.—for breeding; and many breeders think the result of the growing fancy for these colours, _i.e._ cream and orange—for, though so different, they are hard to deal with separately—will be that they will be better catered for at shows as to classes, and more extensively bred than they are at present."

[Illustration:

MRS. F. WESTERN'S "MATTHEW OF THE DURHAMS."

(_Photo: E. Yeoman, Barnard Castle._)]

[Illustration:

"TOPSY OF MEREVALE."

THE PROPERTY OF MRS. BIGNELL.

(_Photo: O. Hardee, Chislehurst._)]

CHAPTER XVII. TORTOISESHELL PERSIANS.

Many years ago, when I first took up the cat fancy, I used to think tortoiseshells ugly and commonplace, and I am afraid even now I have not that admiration for the breed which I feel a really good specimen of this variety ought to inspire. To begin with, it is seldom that a true type of long-haired tortoiseshell is seen or exhibited, and perhaps this may account for the breed being so much neglected. They are not taking-looking cats, and make a poor show in the pen. I have often remarked, however, that this is a favourite breed with the sterner sex, and that our professional men judges will almost invariably pick out a tortoiseshell when judging an "any other colour" class, and give it some mark of distinction. This may be accounted for by the fact that, of all varieties, a really good tortoiseshell is most difficult to breed, and therefore any specimen approaching perfection should be encouraged. There are splashed and sable tortoiseshells and tortoiseshell tabbies, all handsome cats of their kind, but not the genuine article. Real tortoiseshells may be called tricolour cats, for they should bear three colours, like a tortoiseshell comb, on their bodies, namely black, red, and yellow, in distinct patches or blotches, solid in colour and well broken up, with no trace of stripes, bars, or tabby markings. A brindling effect is to be avoided, and a white spot on chin is a great blemish. It is most undesirable that the black should predominate, in which case the specimen will lack brilliancy. The three colours should, if possible, be pretty evenly distributed over the body, legs, and tail, and should not run into each other. The red and yellow may preponderate over the black with good effect.

A blaze, so-called, up the face is considered correct, and this should be of the red or yellow, and in a straight line from the nose upwards. This is a very distinctive feature in the breed, and one that judges will look for in a good show specimen. It is incorrect for the tail to be in any way ringed with the colours. The texture of the coat is often coarser and more hairy in this breed, and it is not usually so long and flowing as in other varieties of Persian cats. There is no difference of opinion as to the correct colour for the eyes of tortoiseshells. They should be a bright golden or orange, and these seem in perfect harmony with the colouring of the coat. Tortoiseshells never attain any great size, and may be called a small breed of Persian cats. I give the list of points as drawn up by the specialist society:—

TORTOISESHELL.

Colour and marking.—The three colours—black, orange, and yellow—to be well broken and as bright and well defined as possible; free from tabby markings, no white. 30.

Coat.—To be silky, very long, and fluffy. 20.

Size and shape.—To be large—not coarse, but massive, with plenty of bone and substance; short legs. 25.

Head.—To be round and broad, with short nose, ears small and well opened. 15.

Eyes.—To be large and full, and bright orange or hazel in colour. 5.

Condition.—10.

They are quite one of the most interesting from which to breed, and experiments can be tried successfully in crossing a tortoiseshell queen with black, cream, orange, and blue cats. The litters will often be a study in variety. I have known one family to consist of a black, a white, a cream, an orange, and a blue! The owner of such a litter would have something to suit all comers. A really good tortoiseshell queen may, therefore, be considered a valuable property. And what of a tortoiseshell tom? A mine of wealth would such a possession be to any fancier. Among short-haired cats a tortoiseshell tom is a rare animal, but I do not think a long-haired specimen has ever been seen or heard of. Several experiments have been tried, but it remains for some skilful and scientific breeder to solve the problem of the manner and means to be employed to produce males of this breed. The classification at our smaller shows for tortoiseshells is generally of a meagre and discouraging description. There are so few specimens that executives of shows fight shy of giving a class for even tortoiseshell _and_ tortoiseshell-and-white together. So tortoiseshells are mixed up in the "any other colour" class, and therefore this breed can seldom, if ever, be really judged on its own merits, or comparisons made between the different specimens that are exhibited. At our largest shows there are classes provided, which, however, are poorly filled.

Tortoiseshells may be said to have had no past. There are no celebrities in feline history save and except "Queen Elizabeth," and not only was she the finest of her breed, but she also made her name famous by severely injuring Mr. W. R. Hawkins, who was examining her when making his awards; and I have good reason—or rather bad reason—for recollecting her, on account of her fixing her teeth into my hand when I was removing her from her basket to pen her at the Westminster show in 1899. It seems that she had a great objection to travelling, and resented making an exhibition of herself in public! She was a grand specimen, however, and, besides always carrying off highest honours herself, she was the mother of many prize-winning orange and tortoiseshell cats, amongst others "Prince Charlie," "Prince Lyne," and "Mattie." I have failed to obtain a photograph of this celebrated cat; and, even had I succeeded, a tortoiseshell makes a terribly poor picture when reproduced in photography, for the reason that the yellow comes out only fairly light, the orange appearing as dark as the black patches.

[Illustration:

MISS H. COCHRAN'S TORTOISESHELL "BRUNETTE."]

Miss H. Cochran had a dear old pet puss called "Brunette," a dark tortoiseshell, and from her were bred some of the first cream females ever exhibited. The Hon. Mrs. McLaren Morrison has a good tortoiseshell, "Curiosity" by name. The best three specimens now before the public are Dr. Roper's "Dainty Diana," Miss M. Beal's "Pansy," Miss Kate Sangster's "Royal Yum Yum," and Mrs. Bignell's "Topsy of Merevale." As regards the last-named, Mrs. Bignell has kindly supplied me with particulars of "Topsy's" litters when mated with different-coloured cats. "Topsy's" first litter in 1896, when mated to the "Duke of Kent" (a blue), was two creams and two smokes. When mated to "Johnnie Fawe" (a black) her kittens were all of the father's dusky hue. Again, when crossed with another blue male her litter consisted of two orange males and a tortoiseshell female, and again to the same cat one black male and two orange males. "Topsy" is a noted prize-winner, and one of her smoke children, "Lucy Claire," went out to Chicago, and is considered the finest smoke specimen in the American fancy. Dr. Roper's "Dainty Diana" is one of the best-known tortoiseshells, and her colouring as good as any exhibited; she is the mother of many winners. Miss Kate Sangster, who is a great admirer of this breed, writes: "My 'Champion Royal Yum Yum' was bred from a black and a tortoiseshell, and her grandsire was a cream. She is over seven years old, and has had twenty-two kittens, namely, five cream, five blue, five orange, four black, and three tortoiseshell."

[Illustration:

"TOPSY."

OWNED BY MISS SARGENT.

(_Photo: J. P. Bennett, West Norwood._)]

Miss Mildred Beal, who with her sister is so well known in connection with cream and orange cats, is also the owner of some fine tortoiseshells. "Wallflower" (well so named) is the mother of a noted prize-winning cream called "Sunlocks." "Pansy," Miss M. Beal's special pet, is a well-known tortoiseshell. "Snapdragon," another prize-winner, was exported to America, where quite a number of the Romaldkirk cats have found their home. We need a few more enthusiastic admirers of tortoiseshells like Miss M. Beal to take up this rather despised breed and follow in her footsteps. Some notes by the owner of "Pansy" will be of interest:—

"Even fanciers who will go into raptures over the blue, orange, cream, or silver members of the establishment have no admiration to spare for a tortoiseshell, however striking its record of prizes may be; and yet to those who breed and understand them there is something very fascinating about these quaint creatures, though the taste for them is certainly an acquired one.

"Among non-catty people great ignorance prevails as to what colour a tortoiseshell cat really is. Many people, if asked to describe a tortoiseshell cat, would say that it was a sort of sandy colour all over; others imagine that the 'chintz' cat, as it is called in the North—white with black and red patches—has a right to the name. So let it be said at once that three colours, namely, orange, yellow, and black, and these only, enter into the composition of the true tortoiseshell. There must be no white, neither should there be any trace of tabby markings, though this is very difficult to attain. The three colours should be patched or 'broken' all over the cat, and the more distinct each separate colour is in these patches the better. Brilliancy of colour is another point which breeders have to consider; many tortoiseshells have far too large a proportion of black in their colouring, which gives them a dingy and uninteresting appearance, and is sure to go against them in the show pen. The eyes should be orange, and in other points, such as shape, head, and texture of coat, the standard is the same as for the other varieties of long-haired cats.

[Illustration:

TORTOISESHELL AND TORTOISESHELL-AND-WHITE PERSIANS.

(_From a Painting by W. Luker, Jun._)]

"One curious fact in connection with long-haired tortoiseshells, which is well known to fanciers, may be mentioned, namely, the non-existence of the male sex. Among short-haired tortoiseshells toms are exceedingly rare, though one or two do exist; but an adult long-haired male appears to be absolutely unheard of. The writer knows of one male kitten born some years ago, but it was either born dead or died in very early infancy. Darwin's theory that the orange tom and tortoiseshell queen were originally the male and female of the same variety is borne out by the fact that until recently orange females were also rare. Of late years a good many of these have been bred and reared, and therefore, if the Darwinian theory be correct, it seems hard to believe that the tortoiseshell tom must be regarded as unattainable. If the difficulty has been successfully overcome in the one case, why not in the other? Breeding with this object in view is very slow work, for some tortoiseshell queens will produce litter after litter without a single kitten of their own colour, and a family consisting entirely of tortoiseshells would be as welcome as it is rare. But it would be a pity to despair of breeding the long looked for tom; if he ever does make his appearance, he will be hailed with sufficient interest to gratify any quantity of feline vanity.

"At present, breeders hardly seem to recognise the great value of a tortoiseshell queen for breeding almost any variety of self-coloured cat. If the queen is mated to an orange, a cream, or a blue tom, she will be very likely to produce at least one or two really good specimens of the same colour as the sire, and sometimes a far larger proportion of the litter will 'favour' him. Much, of course, depends upon how the queen herself is bred, and this no doubt accounts for disappointment in some cases.

"Tortoiseshells compare very favourably with the other varieties of long-haired cats in the matter of intelligence. The writer knows one which enjoys the well-earned reputation of being the cleverest thief in the cattery. Nothing is safe from her nimble paws; she has often been known to remove the lid from the saucepan in which the meat for the cattery supper had been placed, and make off with the contents; and if the cook's back should be turned for only half a minute, woe to tomorrow's dinner or to anything else tempting which may chance to be within reach!

"Though tortoiseshells may be distinguished for brains, some of them certainly fail considerably in temper. They seem to find it most difficult to keep the peace with the other members of the cattery. I sincerely hope this breed will receive more attention from

fanciers in the future.

[Illustration:

MISS KATE SANGSTER'S "ROYAL YUM YUM."

(_Photo: W. V. Amey, Landport._)]

CHAPTER XVIII. TORTOISESHELL-AND-WHITE PERSIANS.

These cats, both long- and short-haired, have always had a great fascination for me. One of my first Persian pets was a tortoiseshell-and-white, with a gorgeous coat, stand-out frill, and wide-spreading tail. She was so stately and dignified that we called her "The Lady Mayoress." In those days cats were of no account, and shows were non-existent. My pretty pet roamed at will and made her own matrimonial arrangements: the kittens were consequently mostly consigned to the bucket.

With my present knowledge of the feline race, I realise that "The Lady Mayoress" was a grand specimen of what a tortoiseshell-and-white should be. She was not a white-and-tortoiseshell, as so many now seen in the show pen might be called. In these cases the white predominates, and in reality the four colours should be about equally distributed. The patches of black, red, and yellow should cover the back, head, and tail, leaving the chest and paws and part of the hind quarters white. There should be patches of the three colours on each side of the face, with a white blaze up the nose.

[Illustration:

"PEGGY PRIMROSE." OWNED BY MISS TERRILL.

(_Photo: W. Baker, Birmingham._)]

As in the tortoiseshells, so in this breed it is better for the brighter colours rather than the black to predominate. I believe an old-fashioned name for this breed was chintz cats. I think they might also be called patchwork cats! There is a great deal in the manner in which the colours are distributed on either side of the head, for expression in a cat goes a long way, and if the patches are badly placed and unevenly distributed the effect may be displeasing, and perhaps grotesque.

Harrison Weir, in writing of this breed, says: "In a good tortoiseshell-and-white there should be more white on the chest, belly, and hind legs than is allowable in the black-and-white cat. This I deem necessary for artistic beauty when the colour is laid on in patches, although it should be even, clear, and distinct in its outline; the larger space of white adds brilliancy to the red, yellow, and black colouring. The face is one of the parts which should have some uniformity of colour, and yet not so, but a mere balancing of colour; that is to say, there should be a relief in black, with the yellow and red on each side, and so in the body and tail. The nose should be white, the eyes orange, and the whole colouring rich and varied, without the least 'tabbiness,' either brown or grey, or an approach to it, such being highly detrimental to its beauty."

This is another of the breeds of long-haired cats that may be said to have no history in the fancy, and I doubt if tortoiseshell-and-whites will ever be taken up seriously. There will always remain the difficulty of obtaining good mates for the queens, as males in this variety are almost as rare as in the tortoiseshells. It would seem that the corresponding males to tortoiseshells and tortoiseshell-and-whites are orange and fawns. I do not remember ever having seen or heard of a long-haired tortoiseshell-and-white tom cat; and as regards notable females, these have never at any time been numerous, and few really good specimens have been exhibited.

[Illustration:

MISS YEOMAN'S TORTOISESHELL-AND-WHITE "MARY II."

(_Photo: D. Pym, Streatham._)]

The most perfect type was Lady Marcus Beresford's "Cora," an imported cat of great size and beautiful shape. Her colouring and markings were lovely, and her round snub face and short nose lent great charm to this unique specimen. It was a grievous loss to her owner and the fancy when poor "Cora" suddenly developed dropsy, and succumbed to this rather unusual complaint amongst cats. Mrs. Davies possessed a fine tortoiseshell-and-white named "Chumly," and Mrs. Bampfylde's "Susan" was a good type. Many of the cats exhibited have either too much or too little white, and often there is a grave suspicion of tabby amongst the black and

orange.

Coming down to the present-day cats, I may mention Mr. Furze's "Beauty of Birmingham" and "Peggy Primrose," both of which he disposed of after shows where they were exhibited. There is no doubt these cats are very taking in the show pen, where darker feline beauties are at a considerable disadvantage.

I have had a difficulty in obtaining any good photographs illustrative of these cats, for, as with tortoiseshells, the colouring cannot be successfully portrayed by any gradations in tone, so that the orange and black both appear dark on a white ground, and thus the individuality of the breed is lost. It is different in painting, when it may be generally noticed that artists choose to depict these broken-coloured cats in preference to the self-coloured ones. In Madame Ronner's lovely pictures, of which several adorn these pages, it will be remarked that almost all the fascinating fluffy kittens are patched in colour.

As I have remarked, one of the reasons why these cats have not been seriously taken up by fanciers is the difficulty experienced in selecting suitable mates that will be likely to perpetuate the breed. In fact, this is not possible with any degree of certainty. Tortoiseshell-and-whites may be crossed with black or orange cats, and it is a toss-up what the progeny may be. Creams are sometimes bred by mating with blues, but there is always the danger of white spots and white toes. I once mated a pretty tortoiseshell-and-white with my silver "Cambyses," and the result was a good pale silver and an almost unmarked cream. Considering all things, I cannot prophesy any future for this breed in the fancy; in fact, I think there is every chance of these really pretty pussies disappearing from our midst. At the Westminster show of 1903 there was only one solitary entry in the tortoiseshell-and-white class! This was Miss Yeoman's "Mary II.," whose portrait appears on the foregoing page.

[Illustration:

AT HOME.

(_From a Painting by Madame Ronner._)]

[Illustration:

MISS SIMPSON'S BROWN TABBY "PERSIMMON."]

CHAPTER XIX. BROWN TABBY PERSIANS.

My first prize-winning kitten was a brown tabby, exhibited many years ago at the Crystal Palace. He became my stud cat "Rajah," called after an Indian prince who was visiting us at that time. "Rajah" was wholly and devotedly attached to the lady of his choice, namely, my blue Persian "Mater." These two names occur in the pedigree of many a prize-winner of the present day, and very numerous were the lovely litters I reared from this eminently respectable pair of Persians. I never knew either "Rajah" or "Mater" troubled with a day's illness, and if one of their kittens had died such an event would have caused as much astonishment as grief. But I must return to my tabbies.

I cannot explain it, but certain it is that of all the feline race (blues not excepted) the warmest corner in my heart has always been kept for the brown tabbies. There is something so comfortable and homely about these dear brownies—they seem to have more intelligent and expressive countenances than any other cats, and I am firmly of opinion that no Persian cats are so healthy and strong as brown tabbies. They are a hardy race, and as such I have frequently recommended novices in the fancy to start with a good brown queen, and with ordinary care they may reasonably expect to rear litter after litter without the difficulties and disasters that one hears of in connection with the bringing up of Persian kittens in general.

I know there is a kind of idea that brown tabbies are a common sort of cat, and this breed is often spoken of in a most disparaging way. Then, again, the ignorant in the cat world have an extraordinary notion that tabbies are always females! Perhaps because we sometimes hear a meddlesome or gossiping woman called a "tabby"—and I had a dear old friend who always bade me beware of "tabby bipeds" among catty communities!

The word "tabby" is supposed to have had its origin in a certain street in Bagdad called "Atab," which was chiefly inhabited by weavers of a particular kind of material called "Atabi." This is what Harrison Weir says on the subject:—"The word 'tabby' was derived from a kind of taffeta, or ribbed silk, which when calendered, or what is now termed 'watered,' is by that process covered with wavy lines. This stuff in bygone times was often called 'tabby,' hence the cat with lines or markings on its fur was called a

tabby cat. Certain it is that the word 'tabby' only referred to the marking or stripes, not to the absolute colour, for in 'Wit and Drollery' is the following:—

Her petticoat of satin, Her gown of crimson tabby.

Be that as it may, I think there is little doubt that the foregoing was the origin of the term. Yet it was also called the brindled cat, or the tiger cat, and with some the grey cat—'graymalkin.'" We are told also by the same authority that tabby cats in Norfolk and Suffolk were called cyprus cats, cyprus being a reddish-yellow colour, so that the term may have applied to orange as well as brown tabbies. The term "tiger cat" is, I believe, often used in America, and it well describes the true type of a brown tabby. The ground-work should be of a bright tawny shade, with a dash of burnt sienna, the markings a dark seal brown—almost black. As regards the colour of eyes in brown tabbies, I prefer the golden or orange; but some of the finest cats in this variety have possessed the green eye, and some fanciers are disposed to prefer this colour, which I think should be the speciality of the silvers. Anyhow, a good brilliant green is preferable to a washed-out undecided yellow.

[Illustration:

MISS MELLOR'S BROWN TABBY "LADY SHOLTO."

(_Photo: N. N. Statham, Matlock Bridge._)]

There are two distinct types of brown tabbies—the splashed or heavily marked, and the barred or ticked. I think the former the handsomer breed, with the well defined and evenly balanced side markings, the dark spine line (not too wide), the clear rings round the chest (commonly called the "Lord Mayor's chain"), the paws ringed in graduated bars to the foot. On the head and face the markings should be very clear and distinct, the narrow dark head lines running symmetrically till they join the broad spine line. The ruff should be of the light shade, and ears of the same tone lend great distinction to this cat. As in the other tabby breeds, the browns are terribly addicted to white chins; in fact, I think it is certainly rarer to find a brown tabby without this blemish than an orange, more pains having been taken to eradicate the evil in orange tabbies. There is no denying the fact that brown tabbies are a very neglected breed, and at present the only one, except tortoiseshell-and-white, that is not taken up by a specialist society. This is a crying shame, and it remains for some ardent admirer of the dear brown tabbies to form a club, and to try to breed really good specimens of the golden-brown order; not the drab or grey animals that are so frequently seen at our shows, and which are very far removed from the genuine article.

I do not think that any breed can produce such fascinating kittens. They have such remarkably intelligent expressions, and, as a rule, the sturdy cobby shape and broad heads of brown tabbies are very conspicuous. This breed should distinctly be massive in build, with plenty of bone and muscle; in fact, with brown tabbies the larger the better, if well proportioned. With the sterner sex brown tabbies are decided favourites, and I cannot help noticing that the very few fanciers who have taken up this breed amongst the gentler sex are what might be termed strong-minded.

[Illustration:

"CHAMPION CRYSTAL."

OWNED BY C. H. JONES, PALMYRA, N.Y.]

I have also remarked that when once fanciers start breeding brown tabbies they continue, and this cannot be truly said of other breeds—silvers, for instance; but I would fain see a steady increase to the ranks of breeders of brown tabby Persians, and more encouragement given at shows. I know that as matters now stand fanciers complain they cannot get any market for their tabby kittens, and that classification is poor at shows and prizes scarce. It is all too true, but surely it is a "long lane that has no turning," and as every dog has its day, so perhaps in the future, whether near or distant, this beautiful breed will gain all the admiration and attention that it deserves. There is a distinct kind of brown tabby, so-called, which may better be described as sable. These cats have not the regular tabby markings, but the two colours are blended one with another, the lighter sable tone predominating. At the Crystal Palace Cat Show of 1902 the class was for brown tabby _or_ sable. I was judging, and, considering the mixed entries, I felt that markings must not be of the first importance, and so awarded first and second to Miss Whitney's beautiful sable females, the third going to a well-marked though out of condition brown tabby. These sable-marked cats are rare, but still more beautiful would be a cat entirely of the one tawny colour—a self sable, without markings. "The most suitable factors to obtain this colour," so writes Mrs. Balding, "would probably be tortoiseshell-and-sable tabby, as free from marking and as red in ground colour as possible. A

cross of orange, bright coloured and as nearly as obtainable from unmarked ancestors, would be useful. Some nine years ago I purchased a dimly marked bright sable coloured cat, 'Molly,' shown by Mrs. Davies at the Crystal Palace, with a view to producing a self-coloured sable cat; but 'Molly' unfortunately died, and I abandoned the idea." The nearest approach to a self sable I have ever come across was a cat I obtained for the Viscountess Esher, which had, alas! been neutered. He was almost unmarked, and of the colour of Canadian sable, with golden eyes—a most uncommon specimen.

Another species is the spotted tabby, but I have never seen a true specimen in Persians. Some brown tabbies are ticked or spotted on the sides, but they have the spine line and markings on neck, head, and tail.

Very few and far between have been good brown tabbies in the history of the fancy. Amongst the males two names may be said to stand out conspicuously—Miss Southam's "Birkdale Ruffle" and my own "Persimmon." Both these cats, of quite different types, have gone to their rest.

As regards the famous Birkdale strain, the following account, kindly supplied to me by Miss Southam, will be of interest:—

"There is no doubt that, until quite recently, our old friend the tabby has been deliberately placed in the background, and regarded in the show world with an indifference which has proved an unmistakable stumbling block to the improvement of this particular breed.

[Illustration:

A ROOM IN BRAYFORT CATTERY.

(_Photo: W. Lawrence, Dublin._)]

"Nor is this very much to be wondered at, when we take into consideration the hideous combination of the drab, colourless browns, dowdy greys, and indistinct markings which had hitherto constituted the chief charms of the typical tabby. Instead, it would appear that the commonplace and unattractive grey was openly encouraged, rather than otherwise; for, although the silver tabby was provided with a classification of his own, only one class was relegated to "brown and grey tabbies," either colour being considered equally worthy of carrying off premier honours!

"It was at this period, when the nondescript tabby was reigning supreme, that Champion 'Birkdale Ruffie' made his _début_ in the show world, my sister, Miss Emily Southam, being the first to bring the sable tabby into prominence. Whether, however, it was that the public was not sufficiently up-to-date to appreciate the sudden departure from the usual sombre colours with which it had hitherto been satisfied to a brilliant sable, or whether he was particularly unfortunate in his choice of judges, it is difficult to say; at any rate, it was not until four years after his first appearance in the show pen that he met with the justice that his many beautiful points so richly deserved. In fact, after exhibiting him at several shows, where he was deliberately passed over for other and most inferior cats, he being in the pink of condition, my sister was so annoyed at the treatment he received that she simply burnt the schedules which poured in upon her and kept him at home, determined he should not be further insulted by such flagrant injustice!

"It was at the West of England Cat Show in 1894 that 'Birkdale Ruffie' scored his first real success—I believe under Mr. Gresham—winning two first prizes in the open and novice classes and two specials. Here at last his beautiful sable colouring, his dense black markings, and wonderfully expressive face were appreciated.

"The year 1896 was the occasion of his sensational win at the Crystal Palace show. He simply swept the board, carrying everything before him—first prize, championship, several specials, and the special given by the King (then Prince of Wales)—for the best rough-coated cat in the show, the prize being a handsomely framed portrait of the King with his autograph attached. Mrs. Vallance was judge. Again, in 1897, he was shown with great success at the Crystal Palace, winning first prize, championship, and special.

[Illustration:

MISS WHITNEY AND HER NEUTER BROWN TABBY.

(_Photo: W. Lawrence, Dublin._)]

"This was the occasion of 'Birkdale Ruffie's' last appearance before the public, as it was during the following month my sister was taken dangerously ill, and for this reason his pen at the Brighton show was empty. After her death we determined to subject him no more to the trials and discomforts of the show pen, so 'Ruffie,' who was now seven years old and a great pet, both for his own sake

and that of his mistress, only too gladly retired into the privacy of home life, spending the cold winters by the fireside in his own little snug retreat, and in the long summer days lying under his bower of shady hops, lazily watching his facsimile, his little son 'Master Ruffie,' growing up more beautiful each day and ready to take up the thread of his father's famous career in the exhibition world.

"Into the latter 'Master Ruffie' made his _début_ without any of the numerous anxieties encountered by his celebrated parent. The way was paved for him, and when he appeared at the Crystal Palace show in 1899, in all the full glory of his youth and beauty, it was difficult for the judges to realise that it was not their old favourite who was now confronting them through the wires!

"'Master Ruffie' has only been shown on two occasions—in 1897 as a kitten, and in 1899 at the Crystal Palace, when he returned home with his box literally filled with cards, his winnings including three first prizes, four specials, and a championship.

"I am sorry we can manage to get no really good photo of 'Master Ruffie.' Time after time we have attempted it—in studios, out of doors, by means of professionals and amateurs—including many kind relatives and friends with their ever-ready little Kodaks! 'Master Ruffie' steadfastly refuses to face the camera. Again and again the button is pressed in vain, and only the glimpse of a vanishing tail upon the negative is all we have to show as 'Ruffie's' portrait!

"But we have only to look at 'Birkdale Ruffie's' picture, and we have 'Master Ruffie' too! The only difference between them is that the latter is a very cobby little fellow, being perhaps shorter in the legs, which makes him appear to be a somewhat smaller cat than his father. In fact, at the Crystal Palace show he was pronounced by the judges to be perfect in every point.

"'Birkdale Ruffie' was noted for the extreme beauty of his expression; he had certainly one of the most characteristic faces ever seen in a cat, and his son inherits the same. The former was constantly the subject of sketches in the illustrated papers, those by Mr. Louis Wain being especially lifelike.

"Some of 'Master Ruffie's' descendants are, I believe, in the possession of Miss Witney, and have met with great success in the show pen.

"Our cattery is built on the principle of shepherds' huts, each house having a separate wire run, with shrubs planted, and a thick wall of ivy in the background, which gives a picturesque appearance to the whole of the little colony. In summer a mass of luxuriant hops makes a welcome shade from the hot sun.

"The houses are warmed by gas stoves, on which the cats love to sit, purring contentedly, and with the pretty curtained windows, carpets, wickerwork armchairs, and cosily cushioned benches, I think 'Master Ruffie' and his seven feline playmates have a pretty easy time in this tempestuous world!

[Illustration:

"BRAYFORT FINA."

MISS WHITNEY'S "BRAYFORT PRINCESS."

(_Photos: W. Lawrence, Dublin._)]

"The one bone of contention is that the cats have appropriated the sunniest corner of the garden, their houses having the much desired southern aspect, which our gardener looks at with longing eyes for his beloved peaches and early peas. Happily, he bears the little occupants no grudge, and when we go from home takes over the whole of the cattery into his charge."

Here let me give a few details of my dear departed puss. "Persimmon" was a well-known character in the fancy, and had the distinction of being a champion in the National Cat Club and the Cat Club. It was in 1899 when, judging at Brighton, I was greatly taken with a wonderful-headed brown tabby that came under my awards. I gave him first in his class, and when later I obtained a catalogue and saw his price was a very reasonable one, I purchased him, and I may say I never made a better bargain, in or out of the cat fancy. "Persimmon" (as I afterwards called him, in memory of the Derby winner) was bred by Mr. Heslop, of Darlington, that astute and clever cat fancier; and his grandsire was "Brown Prince," a noted Northern prize-winning tabby. I have never seen such a wonderful head as that which made "Persimmon's" chief glory.

[Illustration:

"LONSDALE CHRYSALIS" AND "LONSDALE MOTH."

BRED BY MRS. GREGORY.

(_Photo: W. G. Lewis, Bath._)]

His face was very round, and his nose quite a snub, and he was blessed with tiny ears and short tail. His shape was perfect, but the markings on his back were rather too heavy, and alas! he had a white under-lip. But, taking him all round, he was a grand specimen, and a most lovable puss. He fretted himself to death when a change of residence from the country to London obliged me to board him out.

"Persimmon" sired some splendid kittens, which whenever shown proved themselves worthy of their sire's long prize-winning record. At the Crystal Palace show of 1902 Miss Whitney exhibited two of his progeny—a superb neuter "Persimmon Laddie," who covered himself with glory and his cage with cards, and a beautiful kitten that had previously won at Manchester and has since been purchased at a high figure by a lover of the brownies. At the Specialist Show at Bath in January, 1903, "Persimmon Laddie" was again to the fore, and won in the open and ring classes. "Persimmon" was a great loss, for good brown tabbies are rare. I hope, however, to purchase a fine, well-grown son of my dear old "Simmy," and as "Persimmon II." I trust it may be a case of "like father like son," and that by-and-by we may find quite a long list of brown tabby Persians "at stud" in the columns of the catty papers.

I think I may with truth assert that brown tabbies are more appreciated, and that better specimens are produced in the North than in the South of England. I have mentioned Mr. Heslop as having owned some splendid specimens, and at one time he used to exhibit quite a number at our Southern shows. Miss Eggett, of Manchester, has a grand tabby of the golden order named "Cleopatra." Mrs. Whittaker has some nice specimens, and Mrs. Mackenzie's "Cleo" was much admired at the Westminster show in 1900, when she took first in her class. Mrs. Ricketts has always been partial to the breed, and Mrs. Stead's "Timber" has done some winning. Miss Gray's "Lady Babbie" was one of the finest brown queens that used to visit "Persimmon," and another was Miss Meeson's "Jolie," whom I used greatly to admire. Miss Derby Hyde exhibits a wonderful copper-coloured brown tabby called "Maraquetta," who, if only possessed of a good head and shorter face, would be a splendid specimen. Mrs. Davies formerly owned "Susan," a cat now in the possession of Mrs. G. Wilson, very good in colour and markings, but failing in head and face. Mr. Western, of Sandy, has a good male in "Wynstay Monarch." In the West of England Mrs. Hellings and Mrs. Gregory are admirers and breeders of brown tabbies.

[Illustration:

MRS. D'ARCY HILDYARD'S "SULPHURLAND."

(_Photo: Boxell & Co., Scarboro'._)]

Mrs. Gregory, of Bath, started breeding brown tabbies in 1899. Her female (a black) she mated to her stud cat "Azor," and, curiously enough, all the litters have consisted of brown tabbies, the kittens numbering sixteen in all. When, however, "Queen Caterpillar" was mated to Mrs. Gregory's blue Persian, her kittens were all black.

A picture of two pretty brown tabby kittens bred by Mrs. Gregory appears in this chapter. I am happy to say that Mrs. Gregory intends to continue breeding brown tabbies, and has kept a handsome specimen from one of her recent litters to perpetuate the strain. Mrs. Drury, of Graffham, is very faithful to the brownies, and in her lovely old-fashioned cottage near Petworth she is always surrounded by several of her pet pussies. She writes as follows:—

"When first I received a margarine basket, and out of it came a little brown fluffy kitten, I knew no more about Persian cats than the man in the moon—in fact, he probably knew more, as he is frequently the only witness to their nocturnal gambols. I had heard of such things as Persian cats, yet never remember having seen one. However, kind friends soon gave me a helping hand, and as time went on and my fluffy kitten became a fluffy cat, being passionately fond of animals, I soon found out the very fascinating ways of dear 'Miss Wiggs,' so named because the fur on her head in her kitten days would stand erect, and it is the only name she condescended to answer to. She has been—and is so still, in spite of all her maternal cares and five years' experience—one of the healthiest pussies imaginable, and has never had one day's illness since she came into my possession, though I believe, in her babyhood, distemper nearly carried her off; and all her children have been equally healthy—in fact, I have never lost one of her kittens, which is, I imagine, almost a unique experience.

"'Miss Wiggs' came from a blue father and a silver mother, but has, with one exception, always had brown babies, even when mated to a silver. The varied beauties of blues, silvers, whites, and blacks have never taken such a hold upon me as compared with the fascination of the browns, and it is quite a wonder to me more fanciers do not breed them. Nothing looks handsomer, to my mind, than a rich brown, tabby male with tawny markings, like a young lion, and judging from my experience they amply repay any trouble taken by their loving ways and robust health. I have a son of 'Miss Wiggs' and poor old 'Persimmon' now, who follows me like a little dog, even out in the road, and goes for a walk running by my side.

"Perhaps what would astonish a stranger most on coming to see me is the way my catty family lives in peace and contentment with the dogs, and very often I find two or three kittens in the dogs' basket very busily occupied cleaning my little bull-terrier. It is a point of honour amongst the happy family that they never touch each other's food, and very rarely is this broken, and not infrequently we see three, and perhaps four, cats sitting round the dog while he eats his dinner, waiting for any leavings, and the same with the dog. Persians have the reputation of being bad mousers. 'Miss Wiggs' makes quite the exception, and on one occasion caught and killed two mice at the same time; one she held in her paws and the other in her mouth. Young rats also she has many times brought in, to show what a useful little person she is, and her children follow in her footsteps.

"In a great measure I attribute my brownies' good health to the open-air life they lead. From early morning to when darkness approaches they have the run of a large garden, even on a wet day. They go in and out of the houses as they like; never sleep indoors, always in a very dry little outside cattery—in summer on benches, and in winter in nice boxes with straw.

"Perhaps, financially, blues or silvers may be greater successes, but brownies have been my first love and will always remain so. I am only sorry I cannot show what a lovely head and sweet face dear 'Miss Wiggs' has, but she absolutely declines to be photographed.

"In time I hope more fanciers may realise how rich in colour and markings a good brown tabby is, and then we may hope to see this beautiful breed brought more to the fore at all the leading shows.

"As 'Miss Wiggs' has been the foundress of my cattery, perhaps a short description of her would not be amiss. She is a ticked tabby—that is to say, she has not the broad, dark stripes with tawny splashes; her ground colour is a beautiful golden brown, and down the back and sides are pencilled stripes, more like the markings on a silver. Round her face, nose, and ears she has most lovely golden brown shades; eyes are green—they used to be amber; her head is very broad and well shaped; and her expression is very sweet.

[Illustration:

"PIONEER BOBS."

OWNED BY MISS M. WASHBURN, SMITH'S FALLS, ONT.

(_Photo: E. F. Briggs, Smith's Falls, Ont._)]

"When mated to a silver, as she has been twice, the litters have been equally divided—two silvers and two brownies; but both silvers and browns in that case had broad dark and light markings, in no way resembling the ticking of the mother. But when mated to poor old 'Persimmon' the kittens have been equally divided, always two resembling the maternal side exactly, and two following out 'Persimmon's' beautiful splashes. When mated to a brown tabby all the kittens were brown. She has never thrown a black; but her daughter, whose father was 'Abdul Zaphir,' and who I also mated to 'Persimmon,' had two blacks and two very dark tabbies in her litter. 'Wiggs' has in all her five litters had only two females. Her average is four or five kittens; she looks after them entirely herself, and has never been the worse for so doing; but I do not allow her more than one family a year, and until the kittens can lap she is fed every two hours."

The best-marked brown tabby I have ever seen was Lady Marcus Beresford's' "Bassorah," who was unfortunately given away and lost. Her markings looked like oil painting, they stood out in such distinct relief. Another specimen of a different type was imported by Lady Marcus Beresford, namely "Kismet." She was of the ticked order, with small pencilled markings, very compact and cobby in shape. Mrs. Herring has always possessed good brown tabbies. To begin with, "Adolphe," who used formerly to win everything till his son, "Prince Tawny Boy," stepped into his shoes, to be displaced later by his own son, "Prince Adolphe," and his exquisite daughter, "Floriana," now in America. Another good son of "Adolphe's" was Mrs. Bonar's "Lord Salisbury." To go back as far as I can recollect, there was Mr. Horrel's "Nero," and Mrs. Pearce's "Juliet" and "Rosebud," also Miss Malony's "Lindfields Lion" and the

Hon. Mrs. McLaren Morrison's "Cetewayo" and "Mazawattee," this latter a really wonderful cat which was imported by Mrs. Davies at the same time as the celebrated "Nizam," and reported to be his brother. Anyway, he resembled him greatly in everything but colour.

For sables we, of course, go to the Birkdale strain. I remember the incomparable "Birkdale Ruffie" in his full glory at the Crystal Palace—a mass of red-brown fur, of the style of "Persimmon Laddie," but with more distinct markings and a very keen, almost fierce, expression; in fact, he looked like a wild animal!

Then "Master Ruffie" appeared as a kitten, and later as a mild edition of his sire. From this celebrated strain Miss Whitney's lovely sables are descended. This enthusiastic fancier has kindly written some notes on her favourite breed. Her cats are all pets, and lead a life of luxury in their town and country houses on the other side of the Irish Channel. Miss Whitney says:—

"I am pleased to see that brown tabbies are coming to the front again, after being such a long time in the background. It now rests with fanciers of this charming variety of the feline species to improve them in all points. We hear often that they should be a rich tan in ground colour, clear and dense in markings, profuse in coat, ruff and frill, large round head, small ears, and no white lip. I should consider this a perfect specimen; but where is such to be had? I do not say it will not be obtained, but up to this I have never seen it. Now what we are to endeavour is to breed up to this high standard. This will take time, no doubt; but, above all, do not let us give up everything for markings, though they are very essential.

"My idea of a brown tabby is that it must be of a rich tawny ground colour. How could a brown tabby be called a brown if it is only a greyish drab? I should prefer to do without such perfect markings, but to have the more desirable rich colour, and, above all, plenty of coat, ruff, and frill; if it has not these latter qualities, it could not be called a Persian, which must have an abundance of fine soft-textured coat. If we only breed for marking, why not mate to a 'short-hair,' which is more likely to be perfect in that point? But then, where would be our true Persian? Now, as to white lip, I have never seen a good brown tabby without it, but I hear that there are such, though they fail in colour. I would prefer the well-coated cat with good colour and markings and a white lip to one that failed in these other points and had no white lip (I do not mean when it extends to a white throat). Now if we happen to breed a good kitten without a white lip, and should strive to mate her to a really well-marked stud cat, even should he fail in colour—perhaps we might get even one kitten nearly reaching perfection as the result. It would reward the patience, expense, and time; but we need never expect a profusely coated cat to show as distinct markings as an inferiorly coated one will. I breed nothing but brown tabbies, but cannot say I have yet obtained perfection. I have, however, secured coat and colour, and expect to attain the other desirable points in the near future, as we must all persevere, but always let us breed up to the standard of the true Persian.

[Illustration:

"LORNA DOONE."

BRED BY MRS. ELLIS, TORONTO.]

"I first became interested in cats by being given a nice brown tabby Persian kitten, which I called 'Ruffle,' and got very fond of him; but as he seemed lonely I thought of getting another kitten as a companion for him, so I then purchased a pretty little silver tabby from Miss Cochran; but after some time, of all the varieties I saw, none pleased me so well as the brown tabbies. This breed I have gone in for altogether during the past few years, and I feel sure I shall remain faithful to them to the end of my career as a cat fancier. At present I have not a cat of any other colour in my cattery.

"I still have 'Ruffle,' who is now a very large neuter, splendidly marked, but perhaps not quite up to the standard in other points for the English show bench. 'Brayfort Fina' is, I may say, a sable tabby, being particularly rich in colour all throughout—indeed, more often of an auburn tan than brown. She is very profuse in coat, carrying a long body-coat and a big ruff and frill. She is a very large cat, with plenty of bone, and well made, with a fine-shaped head. She was once mistaken for a male by a well-known judge. 'Fina' was bred by Miss G. Southam, and is by 'Master Ruffie' _ex_ 'Bluette,' her sire being a son of the famous 'Champion Birkdale Ruffie.'

"She was already a winner when I purchased her, and has since won many times, including second and special at Bristol, 1899, in a mixed sex class, being beaten by a male. At Belfast, in 1900—the following year—she was beaten out of first by her sister, 'Brayfort Princess.' She then took second at Westminster, 1902; first at Reading, and first and championship at the Crystal Palace, 1901 and 1902. Again first at the Bath Specialist Show in the same year, where her gorgeous colouring was called in question and an unsupported protest was made that she was dyed! She is a most successful breeding cat, her produce being usually winners.

Her sister, 'Brayfort Princess,' is also a sable tabby, and carries an immense coat, ruff, and frill; it is denser than 'Fina's,' and I fancy but for the latter 'Princess' would have been more heard of as a winner, as, except on one or two occasions, she has been usually beaten by 'Fina.'

[Illustration:

"BIRKDALE RUFFIE."

(_Photo: J. A. Kay, Southport._)]

"'Brayfort Persimmon Laddie' is by 'Champion Persimmon' _ex_ 'Brayfort Fina.' He made his public appearance at Bristol when he was four months old, taking first and special in a tabby kitten class and third in novice, against an entry of twenty-five adults; then he won first and special in kittens, and second in open to his mother's first at Belfast in 1900; also he took first and special for best long-haired neuter at Manchester in 1901; first, Liverpool; and first and two specials at the Crystal Palace, 1902. He is too well known to comment on. He is a wonderful sable colour, and is superb in coat. 'Brayfort Sable Boy' is also by the late 'Champion Persimmon' _ex_ 'Fina.' He won first and special at the kitten show in October, 1902, and first and two specials at the Crystal Palace show, 1902; his wins speak to his merit.

"I find all my cats very strong and healthy, and even in the coldest winter they never have artificial heat. I attribute having never lost a pet after a show to taking them away at night. Unless something very unforeseen occurred, nothing would induce me to leave a cat of mine in a show.

"I have found mating to a good brown tabby much the most successful. I tried mating to an orange, but did not like the results. I always mated to the late 'Champion Persimmon,' and had never fewer than six kittens in a litter—sometimes eight—all strong and healthy. Twice only have I lost any, and on these occasions the fault lay with the foster mothers.

"In the spring and summer my cats get a run out in the garden every day; the two neuters go on leads, but the females have their liberty; indeed, unless I were present 'Fina' would not leave the house. Their rooms look out on the grass terrace, so they can come in or out as they please till their breakfast time, which is at about ten o'clock. They are groomed every morning between 8 and 8.30 o'clock, winter and summer, and always fed regularly. Their sleeping houses, as in photo, are about four feet long, lined round with oilcloth, so they can be washed when necessary. In the winter the bedding is hay, and in summer, shavings. The houses are sufficiently long to allow for sanitary boxes during the breeding time. I find Hall's washable distemper very nice for the cattery walls, and it looks so bright and fresh. The floor-covering is linoleum."

In America brown tabbies are beginning to find favour, and several good specimens have been exported. "Arlington Hercules," who took first at Westminster in 1901, was shipped to Mrs. Sarmiento and Mrs. Cutler, and I sent a "Persimmon" kitten out by Mrs. Robert Locke to Mrs. Clinton Locke, the president of the Beresford Club. He was passed on to her honorary secretary, and in _Field and Fancy_ of December, 1902, the following notice appears:—"Miss Lucy Johnstone is the fortunate owner of 'Persimmon Squirrel,' a son of the noted brown tabby 'Persimmon,' who lately died. Good brown tabbies are very scarce, and she should congratulate herself on this possession, as, according to all accounts, he is destined to make a good hit."

Another American lady, Mrs. Gotwalts, of Pittsburg, wrote to me for a brownie, and I sent her one bred by Mrs. Bignell, and the cat has, I believe, had some good litters. The most famous brown tabby, however, over the herring pond was Mr. E. N. Barker's wonderful "King Humbert." This cat arrived in America in 1885, and made a considerable stir in catty circles. Mr. Barker is said to have refused a thousand dollars for him from a New York millionaire. I remember when Mr. Barker was over, acting as judge at the Westminster Cat show, he sought, but did not find anything to beat his noted brown tabby now gone to its last home. Mr. Barker, writing of this breed, says:—

[Illustration:

"BIRKDALE RUFFIE'S" CATTERY.]

"If I were asked suddenly why I admire brown tabby Persians, the liking must be partly attributed to face markings and colour, and to one who grows accustomed to these they are fascinating and add to the general beauty of the cat, and seem natural and as though they ought to be there, and one is not so overweighted with a sense of continual sameness as may be apparent in a whole colour. I must confess, personally speaking, I have become used to bars and stripes. I miss them when I contemplate a self-coloured Persian.

"I once had a good many brown tabby Persians, and people did not fancy them, as they said, 'They are so like ordinary cats'—a great mistake; but by gentle persuasion I managed to get one or two adopted. One lady some time afterwards candidly confessed, 'I could not now be satisfied with any other kind, I should miss the stripes so much on the face.' That is just it; in a tabby you have a little more than your neighbours, who go in for self-coloured cats, and, though for the time being they are not quite so fashionable, you can chuckle to yourself if you own one, and feel quietly superior to fashion and the common herd, and hold your tabby still closer to your heart, and purr softly to yourself with satisfaction at its possession; for I think one may say that for good all-round, everyday, reliable qualities, the brown tabby stands pre-eminent.

"His constitution being good, he is not peevish; he stands cold and heat, change of climate and surroundings, better on an average than any. Brown tabbies should have the under-coat a good golden hue, the markings black, clear, and distinct, rather too many than too few. A good-shaped body, lots of bone, a bold head, red nose, golden eyes, well marked on the chest, and no light colour on the lips and chin. These cats may with advantage be a good size. With care, the under colour may be bred to a grand copper colour; a grey hue in brown tabbies is most undesirable."

"As regards brown tabbies in America, "King Humbert" and his children have always held their own. "Humbert" was bred in England, and as he is now dead I may be allowed to say that when fit and in good condition a better-coloured and smarter show cat never stood in a pen or outside, and he loved to show himself off. The best kitten bred from him was "Jasper." He was very short in leg, and quite lost in coat, his feet being hardly visible."

To the readers of that very excellent American publication _The Cat Journal_ the handsome portrait of "Crystal," the brown tabby, is very familiar. The editor, Mr. C. H. Jones, writes thus to me:—"I am sending you some pictures as promised. The large photo is 'Champion Crystal,' son of 'Humbert,' a beautiful cat as to type and disposition. A peculiar thing about 'Crystal's' kittens is that they do not show very long-hair till they are several months old."

And now a few remarks as regards the mating of brown tabbies. I have tried several experiments, but if I were wishing to breed fine specimens I should continue to mate brown tabbies with brown tabbies. Such mating frequently results in a black or two, and these are generally good ones. The orange cross is sometimes successful in introducing a brighter tone, but I confess I have not had very good results from these attempts. I have on several occasions mated blues to my brown tabby stud, and although blue tabbies have appeared in the litters, I have also obtained blues with very grand heads, plenty of bone, and massive build. My famous "Beauty Boy," a well-known winner and sire of bygone days, was bred from "Rajah" (a brown) and "Mater" (a blue). I have been told by silver breeders that a brown tabby cross with chinchillas has often proved advantageous. It might be imagined that the silvers would be tinged with brown or streaked, but I have been assured this is by no means usual, and that the litters consist of good brown tabbies and equally pure silvers.

A well-known breeder of silvers says:—"Although it may be incorrect to cross silvers and browns, it is often most successful. My first tom was a brown tabby with a white chin, and being mated with a silver queen the kittens were good browns and exquisite silvers, and there were lots of winners amongst them. Many of the silvers were very pure in colour, with lovely markings. My old 'Climax,' whose pedigree was pure silver ('Topso' and 'Lady Pink'), was the sire of the noted brown tabby 'Birkdale Ruffie.'"

Before closing my article, I would remark that the brown tabby and sable, though often classed together, must not be confounded. The brown tabby is supposed to be the common ancestor of all our cats, and hence the tendency to revert to that colour, as in the case of the blue Rock pigeon. This being the case, surely we should have brown tabby cats more nearly approaching perfection than any other colour. They appear in very unexpected places—in a litter of chinchillas or blacks, or among our oranges, and sometimes where no brown ancestor can be traced. In the brown tabby there seems to be little or no inclination to lose the markings, as in other tabbies; rather the contrary, for they overdo themselves sometimes, and form into solid black patches, thus causing the dark saddle, which is a serious fault in this breed. Query: Would generations of in-breeding produce a self brown, as with oranges and chinchillas? I rather doubt it, as I think the common ancestor would, so to speak, "chip in" and assert himself.

As regards the sables, I may remark that they are late in maturing and do not acquire their marvellous colouring till about the second year. Anyway, they rarely make a sensation on their first appearance. As I write I am thinking of "Persimmon Laddie," who seems to have developed his glorious copper coat in the course of a year, and when seen at the Crystal Palace show of 1902 was as near perfection in the matter of colouring as could be desired. I hope that in time this breed of Persians may find more admirers, and that with patience and perseverance a really good strain of grand-coloured, dark-chinned, and above all splendidly marked brown tabby cats may be seen at our shows.

In America, as will be seen from the following extract from _Field and Fancy_, the brownies are making good headway:—

[Illustration:

BROWN TABBY "GOOZIE."]

BROWN TABBIES IN AMERICA.

The brown tabby cat, whose fate seemed to hang in the balance for some time, is now, in America, on the road to social prominence, and daily we hear of the progress of the breed, so that the classes next winter seem to promise greater results than ever. From all over we hear of brown tabbies being bred and reared, and, what is more, finding homes at remunerative prices. In looking at the reasons for the popularity of the browns we do not have far to seek, for when once well tried, these cats wheedle their way into your affections by the strength and vitality they display, as a rule; and the general average being level in their temper, with plenty of common sense, as well as bold, lovable cats, are very satisfactory to deal with. Besides these attributes, when bred properly, their colour is most fascinating, and has a faculty of growing upon one, and weaker colours seem tame by comparison.

So far as we can say, that as regards the brown tabbies, the whites and orange, there have been more concentrated efforts to breed good ones by design than in any of the colours, though the silver breeders are now coming up.

Taking a general look at our cats of this colour, we have little to be ashamed of, and the stock is good enough to make the nucleus of a fine lot of show cats, for they inherit their goodness from several generations of the colour, which is much to the point.

Our breeders will find that to breed good tabbies they will have to keep to blood lines, select the best-marked ones, and not switch about in search of all sorts of blood crosses; for the way to breed tabbies is to keep to the colour and get the marks, which too many crosses with solid-coloured cats are liable to spoil. After a time the purely bred and carefully bred strains will stand out and perpetuate themselves, and the chance-breds will go to the wall.

It has been surmised that the reason why the browns are so hardy is that possibly they more nearly approach the natural colour of cats in a wild state, and are perhaps not quite so artificial; but the number that will be bred of superlative colouring to fill the standard from a show point of view will never be too numerous to command high prices, and the greater the competition the greater the value of the variety, as we see in our dogs. For it is in the popular breeds that the prices rule the highest, and the scarce ones seldom realise the same figures, because there is not the same keen competition to get the best.

When we look back we can call to mind quite a few good brown tabbies in the last seven years, and not very many bad ones, and for uniform quality our browns have been the equal of any colour.

Breeders should be careful to select those with the brown or red body colour, and with the stripes as distinct as possible. In our own experience with the colour we have found three varieties, and these are best described as they appear at birth. No. 1 is the cat with a narrow band down the centre of the back, and thin, narrow lines radiating therefrom. These marks may be very distinct when the cat is young, but are not strong enough for a long-haired cat, and the marks are lost when the coat grows. Though these cats are not the best of exhibition cats, they are very useful to breed to those too heavily marked. No. 2 is the cat that is heavily marked and carries too much black, and is often too grey in his body colour, but these, by being carefully bred to other colours, may throw the desired cat; or No. 3, the cat with the orange body colour and the distinct black marks covering about a third of the surface of the cat. This latter we hope to see in greater numbers now that an organised effort is being made to breed the colour true.

A great many of our browns are clear of one great fault, which is the light chin and throat, and it is to be hoped that this will be continued.

Another fault that wants improving, and which is the prevailing fault in one of our prominent strains, is a rather sour green eye, and this has been the cause of some of them having to take a back seat on occasions. Last year was fortunately a great educator for some of our best breeders, and they are now experimenting along the right lines, and are aware, when they lose, why it is so. As the years roll on those who do learn will not expect to win over better cats just because they think they ought.

[Illustration:

A TRIO OF TABBIES.

(_Photo: C. Reid, Wishaw._)]

[Illustration:

A PICTURESQUE GROUP.

(_Photo: E. Landor, Ealing._)]

CHAPTER XX. "ANY OTHER COLOUR" PERSIANS.

In the early days of the fancy all sorts and conditions of cats were entered in this class. Blacks, whites, and tabbies were considered important enough to have classes assigned to them; then the rest were all huddled and muddled together in the "any other variety" class. Even in these days it is no easy matter to place the awards in a mixed class; but formerly the judge must have felt puzzled over the prizes, and probably finally gave the highest awards to the breed of cat which he most admired. I do not mean anything personal; but, as I write, I recollect a very large class in 1887 at the Crystal Palace, two years before a class for blues was instituted. Mr. A. A. Clarke was judging, and a female blue, "Fanny," which I had given to Mrs. W. M. Hunt as a birthday present, was awarded first. She was a beautiful specimen, and but for her green eyes would have been a remarkable cat even in these up-to-date days of the fancy. Whereas, therefore, for many years this "any other variety" class was the largest in the show, it has gradually become beautifully less—and rightly so, for by degrees the various breeds have been improved, and the number of specimens have increased, and the executives of shows have gone with the times and provided separate classes for each breed as occasion seemed to arise. So orange and cream cats are no longer relegated to what we now call the "any other colour" class, and tortoiseshells and tortoiseshell-and-whites are separately dealt with; therefore it is only tabby-and-whites, nondescript smokes, blue tabbies, and black-and-whites that are received into the fold of the somewhat despised "any other colour" class. Blues and blacks with white spots used to be entered in this class, but of recent years both cat clubs have wisely decided that such cats must be entered in their own classes, for a blue is a blue and a black a black, and having a blemish does not alter their breed, but takes so many points away from them; and, of course, their chances of success even with every other quality is small indeed when in competition with pure self-coloured cats.

[Illustration:

A GROTESQUELY MARKED KITTEN.

(_Photo: E. Landor, Ealing._)]

I am of opinion that ere long the "any other colour" class, at least at our principal shows, will cease to exist, and mismarked cats, white-spotted cats, and doubtful smokes will no longer be considered worth entering, and fanciers owning such specimens will make up their minds to keep their pets at home.

For instance, Mrs. Boutcher, a silver breeder, owned a magnificent cat, a son of "Lord Argent." He was a superbly shaped and grandly coated animal, and was neither a silver nor a smoke—in fact, what might be termed a silver smoke. His face was dark, and tail and paws, and his body was a pale silver grey, shaded to almost white at the roots. His owner entered him in the "any other colour" class one year, and he was disqualified by the judge; then he was next located in the smoke class, but as a different judge was making the awards he was again marked "wrong class." This noble "Lord Sylvester" was the cause of much correspondence in the cat papers, and discussion ran high as to what manner of cat he was. One of our ablest judges—now, alas! no longer in our midst—wrote thus in _Our Cats_ of December, 1900:—

SIR,—In your issue of the 24th I notice at the meeting of the Silver Society Mr. Boutcher asked the opinion _re_ the decision of myself at the Palace as against that of Mr. House at Brighton. In defence of my own award, I unhesitatingly say that, in the same classification as at the Palace, "Lord Sylvester's" class was the A.O.C., in which I fearlessly awarded him first prize. Of course, Mr. House has just as much right to his opinion as I have to mine; but, whether right or wrong, _I do know "Lord Sylvester" is not a smoke_, both on my own knowledge of colour and of that set forth in the standards.—I am, yours truly,

E. WELBURN.

Surely this is the common-sense view to take. A year later "Lord Sylvester" was purchased by Mrs. Champion, and travelled out with her to America, where, no doubt, this splendid animal receives all the admiration he deserves, in whatever class he is entered

on the other side of the herring pond.

Since writing these lines I have read an article in _Field and Fancy_ on the New York Cat Show of January, 1903, and the following mention is made: "In the 'any other colour' 'Lord Sylvester' was to the front, looking splendid."

As regards the advisability of doing away with the "any other colour" class, I will quote from a letter written by that well-known fancier Mr. W. R. Hawkins:—"Why should one class in a show be given up to the bad specimens or mismarked cats of each colour? Surely the intended use of the 'any other colour' class was that when any definite colour had no class of its own it should not be excluded from the show, but take refuge in the 'any other colour' class; for instance, at the Brighton show (1900) we had no class for cream, orange, or tortoiseshell. They were, therefore, shown in the 'any other colour' class, and being good cats of definite breeds were a credit to the class, and in no way a disgrace. But what do we often see? A blue with a white spot or some other freak winning. I say this is absolutely wrong, and that a blue with a white spot is in reality a bad blue, and should not be encouraged. In the same way, a tabby-and-white is a bad tabby, and ought not to go to a show at all, but even if shown has no right in the 'any other colour' class, according to my ideas."

There is one cat that is fast vanishing from our midst. I mean the black-and-white Persian, and yet I confess an evenly marked specimen is a handsome animal. By black and white I mean the ground should be black, dense and glossy; the feet, chest, and nose white, with a blaze of white coming to a point up the centre of the face. The eyes of such a cat should be orange.

Another type is the white and black cat, but unless the black patches are evenly balanced, especially in the face, the effect is not pleasing (see illustration, page 232). Harrison Weir gives particulars of some curiously marked cats coming under his notice—"one entirely white with black ears; another white with a black tail only; another had the two front feet black, all else being white."

I cannot say I have any leaning towards tabby-and-white cats, or orange-and-white, these being the least attractive of any in the fancy. Blue-and-whites are seldom seen, but the photos on pp. 234–5 represent some sweetly pretty kittens of this variety. Their sire was "Yani," a noted blue owned by Miss E. Goddard, and their mother a black-and-white. Blue tabbies, so common fifteen or twenty years ago, are no longer to be seen, at least only here and there at shows, and they have really no value beyond being pretty pets. A cat that has done some winning and has sired some lovely kittens, but must, strictly speaking, be considered an "any other colour" cat, is "Blue Robin," formerly the property of Miss H. Cochran, and now in the possession of Mr. C. W. Witt. This is a blue cat with a tabby-marked head. He was bred from blues and silvers, and his chin, ear tufts, and eyebrows are silver, and his nose pink. As will be seen from his picture, on page 236, he has a grand head and beautiful expression. I am indebted to Miss Hester Cochran for the following notes on "any other coloured" cats:—

"The cats known as 'A.O.C.'s' or 'any other colour,' because they are of a colour for which no class is provided, are hard to write about, because they have no history. They are not bred from A.O.C.'s, and A.O.C.'s are not bred from them. They are either pedigreeless or, more commonly, the result of indiscreet crossing of two definite colours, as, for example, when the owner of a white queen wishes to breed a litter of blue kittens. More rarely they result from a cross which has been resorted to to fix some special point, as when a white and a blue with particularly massive heads or wonderful orange eyes have been mated with a view to producing a strain noted for their eyes. Years ago the classes were interesting, as they introduced all new colours.

[Illustration:

"LOCKHAVEN COLBURN."

A GOOD EXAMPLE OF PERFECT BLACK-AND-WHITE MARKINGS. (_Photo: Koehne & Bretzman, Chicago._)]

"I remember an A.O.C. class at the Crystal Palace not many years ago containing seven entries, all good smokes; soon after smoke classes were given, and then chinchillas began to appear in this class. These cats being specially provided for, creams were the most noticeable A.O.C.'s; but now the blue tabbies and broken-coloured cats—that is, some colour and white—usually occupy the A.O.C. class. Notable instances of cats with white spots were 'Cain,' 'Nankipoo,' and 'Kingfisher,' all grand blues with this blemish.

"In 1892 Mrs. Pattison's exquisitely shaped and coated orange-and-white 'Chicot' (pedigreeless), then shown as tabby with or without white, established a record by winning as best in show at the Crystal Palace. Other tabby-and-white cats have done well. Miss Malony used to show some good ones; the best, 'Lindfield Sweet William,' was a blue tabby-and-white, very massive and heavily coated, son of the smoke 'Lindfield Bogie.' Mrs. Pearce, of New Barnet, also used to win with tabby-and-white cats, and Mr.

Law's 'Buffer' was a celebrity in his day, but whether he was a brown tabby or an A.O.C. is doubtful; he was later known as 'Leopold.' The Hon. Mrs. McLaren Morrison had a really good silver tabby with white feet in 'Kepwick Silver King'; and later Miss Snell's grand-headed 'Wonderland' made a small sensation.

"Another good cat which won in an A.O.C. class is Lady Maitland's 'Cheeky Blue,' a lovely blue with a sprinkling of white hairs on her body. Blue and smoke tortoiseshells are freaks, and not really exhibition cats at all, but are by some people considered useful for breeding. Personally, I do not think they are capable of producing anything which a definitely coloured cat of proper ancestry cannot produce as well or better. When cream queens were unavailable they had to be used, but now they are becoming unnecessary. Perhaps the best is Miss W. Beal's 'R. Fluffie.' Mrs. D'Arcy Hildyard's 'Sengo of the Durhams' was another. Miss Taylor's 'Tawney' began life as a blue with a few yellow marks, and wound up as a good tortoiseshell, though a trifle too red. Mrs. Cunliffe Lee's 'Tiger,' a kind of yellow-brown, more ticked than marked, and principally distinguished by his great coat, made his mark in the A.O.C. classes.

"Of blue tabby cats which have won well (mostly bred from blues and silver tabbies) there is a long list. They became common through the craze for blues, as silver queens were sent to blue toms. Later the desire for chinchillas started them afresh, as blue queens were sent to chinchilla toms.

[Illustration:

THE CONQUEST OF THE AIR.

(_Photo: E. Landor, Ealing._)]

"Mrs. Herring's 'Braemar' was a son of 'Cœruleus' by 'Turko'; 'Upwood Dew' and 'Camera' are from the 'Timkins' strain; Miss Jebb's 'Julius Cæsar,' Miss Rae's 'Romanoff,' Miss Nicholay's 'Sacho,' and Miss Jay's 'Holmwood Skittles' were all celebrated cats. Some of these have thrown beautiful kittens, both blues and chinchillas; and as a makeshift, when a correctly coloured cat of the required pedigree is unavailable, they may, when judiciously mated, be found useful; but good breeders will part with all mismarked kittens for pets. The best and most definitely coloured A.O.C. I ever saw was Mrs. Davies' 'Sin Li,' a deep self-coloured chocolate-brown cat. He was supposed to be one of three Swiss mountain cats imported to this country, and he was a most handsome and interesting animal. Unfortunately, he died young, leaving no progeny. Another interesting A.O.C. cat I have seen was a short-haired neuter, red, with black stripes and white paws and chest. In the future I hope to see a variety of strange cats in the A.O.C. classes, but at present they are very uninteresting. Good suggestions for future colours are red, orange, blue, or white with black stripes, chestnut-brown self-coloured, and black with white tips to the fur. So far as I can see, it should be possible by crossing with various foreign breeds to produce in a few years' time cats of all these colours."

[Illustration:

SILVER TABBY AND ORANGE-AND-WHITE PERSIANS.

(_From a Painting by Miss F. Marks._)]

One of the finest "any other colour" cats of the present day is now in the possession of Miss Moxon, of Ilfracombe. "Cinder" was purchased from Mrs. Davies, who has a rare faculty of picking up uncommon-looking cats. Miss Moxon writes:—"I am sending you a detailed description of 'Cinder,' who is a difficult cat to describe, and is quite the handsomest cat I have ever seen. By 'handsome' I mean striking, as she attracts everyone's attention, and very often visitors to our well-filled cattery have not a glance to spare for our other specimens." The following is the description of this very uncommon long-haired cat:—

"'Tors Side Cinder,' winner of many prizes, including second Brighton A.O.C. kitten class, 1899; first A.O.C. kitten, medal, and two specials, Westminster, 1900; first and special for best cat in show, Maidstone, etc.

[Illustration:

GRACE BEFORE MEAT.

(_Photo: E. Landor, Ealing._)]

"'Cinder' was described to me by the lady from whom I bought her in 1901 as 'a very peculiar colour—a kind of tortoiseshell creamy smoke.' She has a dark seal-brown mask and ears, except for one creamy orange (tortoiseshell) splash above left eye, and another

under chin. These give great expression to her face. Head exceptionally fine, considerable breadth of skull, small tufted ears, short broad face, very sweet expression. Round orange eyes, for which she has won more than one special. Fine outstanding frill of a creamy smoke colour; fur on chest very long and feathery, of a creamy, bluish smoke shade, with a pale cream knot in centre. Seal spine line, splashed with creamy brown, shading gradually lighter to shoulder knots and side puffs, which are of a rather darker tint than the frill. Paws and legs of a dark seal-brown; waistcoat and knickers of a bluish cream. Splendid thick brush—upperside to match spine line, under-side of a bluish cream shade. Slightly bluish tint all over, _distinct_ under-coat of palest cream shading to soft creamy blue."

[Illustration:

"MARCUS SUPERBUS," A SILVER SMOKE.

OWNED BY MISS SHAW. (_Photo: Moffat, Edinburgh._)]

American fanciers have always shown a partiality for broken-coloured cats, and orange-and-white and blue-and-white cats have classifications given for them at the leading shows. In England there is a marked antipathy to these cats, chiefly because they have little or no value for breeding, though they undoubtedly make pretty pets. As a sign of the times, I may mention that at the Westminster show in 1903 the three "any other colour" classes for males, females, and kittens had to be cancelled, no entries having been made.

Speculative, but, I must add, persevering fanciers might derive interest and amusement from trying to breed out-of-the-common specimens. A black-and-white, spotted like a Dalmatian hound, or a cat marked with zebra stripes, could doubtless be produced in time by careful and judicious selection.

[Illustration:

"BLUE ROBIN."

(_Photo: Witcomb & Son, Salisbury._)]

CHAPTER XXI. NEUTER CATS.

[Illustration:

MISS KIRKPATRICK'S "CHILI."

(_Photo: E. Landor, Ealing._)]

It has been my experience in the past year or two that the demand for neuter cats, or, in other words, household pet pussies, is on the increase; and I am inclined to believe that if some fanciers made a speciality of these cats they might do a thriving trade. As it is, owners of male kittens do not care to undertake the trouble and responsibility of having them gelded, or doctored, as this process is sometimes called, and novices in purchasing are always very anxious that the operation should have taken place before they become possessed of their pets. A selling class for neuters at our large shows would not be at all a bad idea, but the age should be limited to eight months, or at most ten months, as it is only natural that purchasers should desire pussies before they reach the prime of life, so that they may grow up as pets in the home. For reasons that are easily understood, it is necessary, if you wish to have a house pet of unimpeachable manners, to have your male cat doctored when he arrives at years of discretion.

For my own part I consider between five and eight months the best time for a cat to be gelded, but I have often known successful operations taking place much later. It is, however, most important that the tom should not previously have shown any desire to mate. In all cases a cat should be kept on low plain diet for two or three days before being neutered, and it is more humane to pay the extra fee for the use of an anæsthetic.

[Illustration:

"KING CY."

SILVER NEUTER BELONGING TO MISS AVERY JONES. (_Photo: F. Bromhead, Clifton._)]

I have been told on good authority that if a female cat is to be made neuter she ought to be allowed to have one litter before the operation is performed. Neuter cats are essentially for the "one cat" person. They undoubtedly make a grand show when exhibited, but those who are possessed of these pet pussies are generally very disinclined to let them run the risks and discomforts of a show pen. I have advocated having neuters shown only in the ring, on the lead. If this course were adopted, I think owners would not mind exhibiting their precious cats, as they could be sent or taken home after their turn round. Certainly neuters are the only cats that ought to be led into the ring, and in this way their fine proportions and generally heavy coats can be seen and judged to the best advantage. It is too often a practice with fanciers to have the worst of the litter kept for a pet and made neuter, and therefore we see many blues with light green eyes, and cats with the blemish of a white spot, in the classes set apart for gelded cats; and if a beautiful, almost perfect, neuter is exhibited, fanciers are apt to protest at what they consider is "a grave mistake." From the lips of some noted and over-wrought breeders of Persian cats I have heard the exclamation, "I shall go in for neuters only!"

[Illustration:

MISS CHAMBERLAYNE'S "BELVEDERE TIGER."

(_Photo: J. Atkins, Upper Norwood._)]

This has been called forth, perhaps, by a succession of failing litters or by a rampageous stud cat that has fought with the neighbour's tom or has wandered off on amorous thoughts intent, perhaps never to return, or on returning to bring disease to the cattery. Certainly, for a thoroughly comfortable domestic pet there is nothing like a neuter cat. They are more affectionate, and with children more docile, not less keen in catching rats and mice, and they are proverbially very clean in their habits. One great advantage that neuters have over the other long-haired breeds is that they retain their lovely coats nearly all the year round. In spite, however, of the many points in favour of neuter cats, they are nevertheless rather looked down upon in the fancy. Certainly, at our shows no cats are more attractive to visitors than the big burly neuters, and I would fain see a better classification for these really fine animals.

A specialist society was started in 1901 by an admirer of these cats, but either through lack of energy or want of enthusiasm the work was not carried on, and the club died a natural death. It remains for some other fancier with a love for pet pussies to start a society, for as it is the neuters fare badly at our shows, the classes provided never numbering more than two, and the special prizes being few and far between. Formerly neuters were judged by weight, and I remember some specimens exhibited at the Palace that really looked like pigs fatted up for market. It was in 1886 that the classification for neuters at the Crystal Palace show ran thus: "Gelded cats, not judged by weight, but for beauty of form, markings, etc." Happily, therefore, this state of things has been abolished, and though neuters should be big, massive cats, yet they need not, and should not, be lumps of inert fat and fur. It is true that a big show cat appeals to the non-exhibitor, and visitors to our shows are always greatly impressed with huge animals over filling their all too small pens. The heaviest and biggest neuter I have ever seen was possessed by Mrs. Reay Green. This enormous silver turned the scale at 20 lb. I believe the record weight at the Crystal Palace was 25 lb. It is a libel to say that neuter cats are lazy and uninteresting. I have always possessed a neuter, either a blue or a brown tabby, and these beloved pets have ably fulfilled their duties as mice-catchers of the establishment. My "Bonnie Boy," who but recently joined the noble army of neuters, is as keen as a knife, and will sit for hours watching a likely hole, and never a mouse escapes his clever clutches. He kills them instantly, and then amuses himself for hours dancing about and throwing his dead prey with wild delight into the air. Then, again, he is, I am sorry to say, just as destructive with the poor London sparrows, and many a time I have had to chastise my pet for stalking the game in our little back garden.

Miss H. Cochran, writing of neuters, says: "There are, without doubt, a great number of people who like to keep a cat, especially a Persian, for a pet pure and simple—one that will be the admiration of all, and of service in ridding the house of mice and rats. They will attain a greater size, and in nine cases out of ten retain all the pretty habits and antics of their kittenhood. Neuter cats are often very troublesome in a large cattery; they fight with each other and with the queens, which have a poor chance against their superior size. I think they do it for fun."

In _Fur and Feather_ "Zaida" thus writes of neuters:—

Undoubtedly it is a crying mistake for neuter cats to be allowed to compete in open classes, but personally I should be delighted to see more classes for them at shows, and much greater interest taken in them. Sometimes one is tempted to think the ordinary run of cats has deteriorated in general beauty, remembering the splendid animals, both English and foreign, which we used to see in friends' houses in our childhood; but the real explanation lies in the fact that formerly "house" cats were almost entirely kept as pets,

and handsome kittens were obtained for the purpose. Nowadays anything not good enough for breeding from is made a neuter, and fanciers undoubtedly look on them with a certain contempt. Why should this be more the case with cats than with horses? For a perfect household pet the neuter cat holds its own, if only the public would universally acknowledge it. But too often every purchaser of a kitten starts breeding, and multiplies a race of weedy, ill-kept animals, who do little credit to their owner. A cat with kittens is undoubtedly a charming sight; but a female cat is more or less of a worry, and is, besides, only in coat for a very short time each year. Then a tom cat roams, fights, and is often objectionable, but the stay-at-home cat is always a thing of beauty, never requires periods of seclusion, will mouse and rat with the best, and be a credit to any establishment. In short, we should like to see more of them, not fewer, and a neuter class for every colour in a show. In many a household cats are now disliked through the ill-advised action of some member of the family in starting breeding with more zeal than knowledge, and without proper convenience. If a lovely neuter, or even two or three, reigned in their glory, there would be an end to the trouble, to the groans of the other members of the family, to the "wasn't engaged to wait on cats" of the servants.

[Illustration:

"BENONI."

THE PROPERTY OF MISS COTTOR. (_Photo: F. Wallace, Dalkeith._)]

In the schedule of the Beresford Cat Club show, held at New York, January, 1903, the classification for gelded cats reads thus: "Class 25, neuter, white or black; Class 26, neuter, blue or smoke; Class 27, neuter, 'any other colour'; Class 28, neuter, any colour tabby with white." It will be seen, therefore, that in America a much more liberal classification is given for long-haired neuters, and for short-haired there are three classes provided. I do not know, nor have I heard of, any remarkable American neuters, and no photographs have been received by me for reproduction in this work.

If we go back some years in the fancy, I remember Miss Sangster's "Royal Hector," a blue of great celebrity; also same owner's "Royal Bogey," a handsome black with a white star. Miss Boddington's cobby, woolly-coated white "Ba Ba" appeared later in exquisite form, winning well till he was eleven years old. At this same period Mrs. Herring's little smoke "Ally Sloper" and Miss Molony's big, heavily coated black "Uncle Quiz" were noted winners.

Then we come to Mrs. Willman's "Charlie," a fine blue of "Beauty Boy" strain, and Miss Knight's "Albion Joey," one of the finest neuters ever exhibited, a huge smoke with the roundest of heads, a trifle marked and not good in eye, but a glorious animal.

A little later came Madame Portier's "Blue Boy," and, as I have received some notes from the owner of this magnificent cat, I will give them:—"I am very proud of my 'Blue Boy,' born on St. Patrick's Day, 1895. He has won twenty-eight first prizes and many specials, and his championship before he was a year old. I had an offer of £20 for him. The greatest honour 'Blue Boy' received was a caress from her Majesty, then Princess of Wales.

[Illustration:

MISS ADAMSON'S CHINCHILLA NEUTER.]

"I often take my pet out for a walk on a collar, and he is quite easily led, and people often stop and ask if it is really a cat. I send you his photo for reproduction in 'The Book of the Cat.'" One of "Blue Boy's" wins was at the Richmond show, 1902, where he was greatly admired for the dignified way in which he comported himself on a lead. In these up-to-date days, however, "Blue Boy" has to run the gauntlet with superior coloured eyes, but in shape, size, and coat he holds his own. Miss Kirkpatrick's "Chili," now no more, was a beautiful creature—a silvery smoke, almost a smoke tabby, with a wonderful fleecy coat and grand frill. Mrs. Reay Green has always been the proud possessor of superb neuters—"Mosca," a blue; "Abdul Zephir," a chinchilla; and later "Ajax," who has done some winning. Viscountess Esher also has quite a cattery of neuters. I procured for her a sable, almost unmarked and very rich in colour, a white with limpid seagreen eyes, and a Siamese with perfect points. Miss Cochran's "Patpaw" (now in the possession of Viscountess Esher), a son of the celebrated tortoiseshell "Tawney," is rather small for a neuter, but full of quality, with wonderful orange eyes. "Persimmon Laddie," owned by Miss Whitney, is, perhaps, the most perfect specimen that has been seen in the pen of the neuter classes. He is not a brown and not a tabby, but a sable; and, having the blood of the "Birkdale Ruffies" and "Champion Persimmon" in his veins, it is no wonder he carries all before him. No photograph can do him justice.

Mrs. Boyce's "Fur" could beat any male chinchilla now on the show bench; for in colour, shape, and head he is well-nigh perfect. Mrs. Millar's "Lord Bute" is a monstrous black, and in spite of his green eyes is generally in the prize list; but in Mrs. Curtis's "Baron

Bonelli" he met more than his match at the Crystal Palace in 1902. This black cat (a son of "Johnnie Fawe") has all the good points of "Patpaw," including his gorgeous eyes, and he is very large. Miss Holmes' "Blue Tut" has won many honours, and Miss Chamberlayne's "Tiger" is a handsomely marked brown tabby. Miss Meeson's "Fluff Duvals," another brownie, won first at the Crystal Palace and Brighton, and after a second at Westminster came home to die! Miss Averay Jones has a splendid chinchilla neuter "King Cy," a possession too precious to be risked at any exhibition.

[Illustration:

"NIGEL THE RAVEN."

MRS. MELLER'S SHORT-HAIRED BLACK NEUTER.]

So much for the long-haired pet pussies, and we will take a glance at past and present short-haired neuters. A lovely coated cat was "Tiger of Kepwick," owned by Mrs. MacLaren Morrison, a brown tabby, as his name denotes. Then Mrs. Butler's orange, which for many years won at the Crystal Palace and Brighton. Mr. Lane had a good yellow-eyed white, "Leonidas." Mrs. Herring owned a well-marked brown tabby in "Sir Peter Teazle." Of late years the most remarkable short-haired neuters have been Miss Cartwright's really lovely Siamese "Chote" and Lady Alexander's blues, "Brother Gamp" and "Tom Gamp," who are rarely, if ever, defeated. A richly coloured orange tabby neuter, "Red Eagle," also hailed from the same cattery.

In judging neuters, I think it is rather a mistake to go too much by points. I consider size should be a most important factor, also coat and general effect. Of course, in close competition points would come into question; but I really think that a large, heavily coated neuter, whose colour was a trifle unsound, or whose markings or eyes were below par, should not be placed below a small mean-looking cat who, however, excelled in these points.

Louis Wain, writing on a general survey of the Crystal Palace show of 1900, referring to the neuter class that he judged, says:—"Neuters have suffered somewhat through the extended schedule of the 'whole' cats. At one time it was quite a usual thing for exhibitors to have their cats neutered to preserve the natural beauties of a fine cat, and very often a really handsome cat was neutered because he stood no chance in a class of twenty or thirty cats, and yet would take first as a neuter in a class of six or eight. The neuter classes have not grown as have the other classes. As 'home' cats neuters should be encouraged, and I feel sure that many are kept at home in fear of the dreaded 'blues,' which are usually unbeatable." Mr. Wain also complains of the poor classification for neuters at our shows, and on this particular occasion he states that the cats were such extremely fine animals that they needed classes of their own for him to do justice to their merits. Certainly there ought at least to be three classes provided for neuters at our large shows, viz.: Neuters, self-coloured (blue, black, and white); neuters, tabby, "any colour"; and neuters, "any other colour."

[Illustration:

MADAME PORTIER's NEUTER "BLUE BOY."

(_Photo: Hana, London._)]

[Illustration:

RASCALS.

(_From a Painting by Madame Henriette Ronner._)]

CHAPTER XXII. MANX CATS.

These quaint cats are rapidly and surely coming into notice in the fancy. As a breed they are intelligent and affectionate, and, I believe, splendid sporting cats. They are undoubtedly great favourites amongst the sterner sex, perhaps because they are such keen and plucky ratters. As a breeder of Persian cats, and having become used to the beautiful wide-spreading tails of these cats, I confess there is something grotesque and unfinished, to my eyes, in the Manx, and from choice I should not care to keep these tailless pussies as pets. They do not appeal to me and to my sense of the beautiful. Having, therefore, never kept or bred Manx cats, I feel diffident in writing about them; but I have carefully studied those exhibited, and have also had opportunities of judging of their points whilst visiting friends who have fallen victims to the fascinations of these curious felines. I know a good Manx when I see one, and to prove this assertion I will tell an incident in connection with a prize-winning Manx of to-day. A friend of mine living in

London took compassion on a little stray black kitten who came crying for food. She fed him, and repeatedly tried to find poor pussy's owner, but in vain. I was appealed to to know what had better be done, and when I saw the little black fellow I strongly recommended my friend to keep it and exhibit it at the next large show, as I considered he would go in and win easily. She followed my advice in the latter respect, but placed too low a figure on "Nig," as she declared she did not wish to go in for Manx. I warned her he would be sold, and sure enough that clever and astute judge of cats of uncommon breeds, Mrs. H. C. Brooke, snapped him up at catalogue price; and since then he has blossomed forth into a champion, and as "King Clinkie" has taken highest honours whenever shown. It is only just to state that Mrs. Brooke most generously handed over some of her winnings to "King Clinkie's" former owner.

[Illustration:

TYPE OF MANX KITTEN.

(_Photo: Russell & Sons, Windsor._)]

I will therefore proceed to give my opinion of Manx cats, but with all due deference to my fellow fanciers who have had personal experience with the breed. I think I have judged every species of cat, long- and short-haired, except Manx; but if I were given a class of this breed upon which to adjudicate, I should first closely examine their tails, or, to be more correct, the place where the tails ought _not_ to be! I remember in former times stump-tailed cats, called Manx, used to win comfortably at shows, but in our up-to-date times I should make a black mark in my judging book against those cats with a stump or an appendage, or even a mere excrescence. I do not fear contradiction when I state that a Manx cat of the true type should have no particle of tail—only a tuft of hair, which ought to be boneless.

The next point for which I should search would be the length of hind quarters, which lends such great individuality to this breed of cat. No doubt the lack of tail in itself makes a cat's hind legs look long, but we want more than that; we need a very short back, so that from the point of the quarters to the hocks there is a continuous and decided outward slope. In fact, the hind legs stand right back from the body, like a well-trained hackney's in the show ring. Coat I should next consider, as this differs, or should differ, considerably from both the long- and short-haired breeds. It should bear more resemblance to the fur of a rabbit, being longer and softer than that of our common or garden cats. I think a good-shaped round head as desirable in a Manx as in other breeds. As regards colour, the most common would seem to be tabbies, either silver, brown, or orange, and often there is a mixture of white. Self-coloured Manx seem to be much rarer, and Harrison Weir tells us he does not recollect having seen a white Manx.

As regards the colour of eyes in Manx cats, it is the custom to say that they do not matter in this breed; but, nevertheless, a cat that has the correct colour of eye must necessarily beat an animal that has just the opposite to what is set forth in the standard for short-haired English cats.

A lady friend of mine, who was brought up in the Isle of Man, has told me that she always understood that Manx cats came from a cross with a rabbit, but if this supposition is correct it seems too strange to be true that cats and rabbits should only form matrimonial alliances in the little island off our coast! It would appear more probable, therefore, that a foreign breed of cat was brought to the island, and the following article from the pen of Mr. Gambier Bolton gives his ideas on the subject:—

[Illustration:

"GOLFSTICKS."

OWNED BY MISS SAMUELS.

(_Photo: Albert Hester, Clapton, N.E._)]

"In the Isle of Man to-day we find a rock named the Spanish Rock, which stands close into the shore, and tradition states that here one of the vessels of the Spanish Armada went down in the memorable year 1558, and that among the rescued were some tailless cats which had been procured during one of the vessel's voyages to the Far East. The cats first swam to the rock, and then made their way to the shore at low tide; and from these have sprung all the so-called Manx cats which are now to be found in many parts of Great Britain, Europe, and America.

"The tale seems a bit 'tall,' and yet the writer feels so satisfied of its truth that he would welcome any change in the name of this peculiar variety of the domestic cat to sweep away the idea that they sprang from the Isle of Man originally.

"Any traveller in the Far East—Japan, China, Siam, and the Malay region—who is a lover of animals must have noticed how rarely one meets with a really long-tailed cat in these regions, for instead one meets with the kink-tailed (_i.e._ those with a bend or screw at the tip of the tail), the short kink-tailed (_i.e._ those with a screw tail like the bull-dogs), the forked-tailed (_i.e._ those having tails which start quite straight, but near the tip branch out into two forks), and finally the tailless (or miscalled Manx) cats; and the naturalist Kæmpfer states definitely that the specimens of this breed now so common in parts of Russia all came originally from Japan. Again, anyone who breeds these tailless cats, and keeps the breed quite pure, must have noticed how they differ in appearance and habits from the common short-haired cats. They are, and should be, much smaller in size; the coat should be longer and more 'rabbity'; the 'call' is much nearer that of the jungle cat of the East than that of the ordinary cat; and their habits, like those of the Siamese cats, are much more doglike. In all these points they keep closely to what the writer firmly believes to be their original type, the domesticated cats of the Far East.

"The photographs illustrating this article give some idea of the general appearance of these delightfully quaint little creatures, and one notices immediately the great point that all judges look for, viz., the high hind quarters, which is so typical of the tailless breed of cats, the few hairs, which represent the spot where the tail should be, constantly appearing even a few hours after birth, although there is not a sign of a caudal appendage beneath them.

"Kink-tailed, screw-tailed, fork-tailed, and absolutely tailless cats have all been exhibited at British shows of recent years, and the writer, from a personal knowledge of nearly all breeds, has no hesitation in recommending the latter as companions, their quaint and doglike ways making them general favourites whenever they are met with.

[Illustration:

SPECIMEN OF A MANX TABBY.

(_Photo: C. Reid, Wishaw._)]

"There are at present six distinct types of Manx, or 'rumpy,' cats being exhibited at our shows, viz.: The long straight-backed cat, the long roach-backed cat, the long straight-backed cat with high hind quarters, the short straight-backed cat, the short roach-backed cat, the short-backed cat with high hind quarters. The last type is the correct one, the first is the worst and commonest type, the others are intermediate and should be judged accordingly.

"Manx cats should always be judged in a good, large, empty pen, and never in their own pens, or when held by the judge.

"_Coat._—Exactly the opposite to the ordinary domesticated short-haired cat. A long and open outer coat and a soft, close under-coat is the correct thing."

At one time, we may presume, the Manx cat was kept pure in the Isle of Man; but, alas! the natives, with an eye to the main chance, have been led into manufacturing a spurious article, and many more tailless cats and kittens than ever were born have been sold to tourists eager to carry home some souvenir of the island to their friends on the mainland. I have been told that the landing pier is a frequent resort of dealers in so-called Manx cats, where the unwary traveller is waylaid and sold! On some out-of-the-way farms on the island I believe none but tailless cats have been kept for generations, and some genuine specimens may thus be picked up, if the tourist gives himself the trouble to go off the beaten tracks.

The following letters which appeared in _Our Cats_, in the issue of June 30th, 1900, will be read with interest. They were written by two gentlemen of prominent position in the Isle of Man, but as they did not wish to be identified as authorities on cats their names were not given:—

[LETTER I.]

Castletown, Isle of Man, 12th July, 1898.

I received yesterday your letter respecting Manx cats. I fear I am unable to aid you much in your inquiries as to the Manx cat, for any personal information I can give.

When I was a boy there was a kind of tradition that the tailless cat was brought here by the Spanish Armada. We have a headland called "Spanish Head," where it has been believed that some tailless cats escaped and took refuge here, and that from such cats all the so-called Manx cats have been derived. During my life I have frequently met persons who have travelled in Spain, and I think

I have always asked from such persons if they had ever met with tailless cats there, but I never met anyone who had seen them. I never heard any other (traditional) origin of the Manx cat alleged. They are very common here, but not so common as cats _with_ tails. Both cats with and cats without tails associate together. In my own house we have always kept cats, and in almost every litter of kittens there are some with and some without tails. I have two tailless cats now—one is a kitten of a few weeks old. It has no sign of a tail, but is (as designated here) a pure rumpy. The mother is one also, but she has a little fur tuft. I have frequently seen kittens having a very small "rudimentary tail," such as one or two bones.

I have seen, I think, Manx cats of most of the colours mentioned by you, but the most common are the grey or tabby.

I have never heard of wild cats found here, and I do not think there is any tradition about them.

A few years ago I had a very fine tom cat (bred in my own house), black all over, and with no sign of a tail. I lost it. I presume it was stolen by some tripper. Trippers are frequently on the look out for Manx cats, and I fear that many tailed kittens are deprived of their tails to meet the demand.

[LETTER II.]

Ramsey, 17th July, 1898.

Thank you for letting me see the interesting letters about Manx cats. I suppose the Society wants to have a standard by which to judge them.... I am sure we should all be interested to hear what they have to say on the subject, and we may be able to add some general information.

To take the questions in order I should say that grey tabby (barred, not spotted) is the most natural and correct, if one may so speak. I think it is certainly most common. I have known tortoiseshell, black-and-white, black, white, and perhaps others, which I now forget. The eye, so far as I know, is the same as in the common English tabby.

Certainly we have cats with tails—the rumpy being the rare form. Perhaps one in a litter, and one or two of them with half-tails.

As to what they are supposed to be, I have of course heard the Spanish Armada story. My own belief is that they have originated in _a sport_, _e.g._ as we find in dogs and fowls, and have been perpetuated as curiosities, and in modern times on account of their commercial value.

I do not know that there is any type which can be said to be more true than another with regard to size and shape of head, etc. The height at the hind legs is perhaps more apparent than real, caused by the abrupt ending, without the falling tail as in ordinary cats.

Professor Owen made a preparation, which may be seen at the British Museum, showing the bones (if any) of the tail. I think in a perfect specimen there should be no bones. Of course, there are all degrees of stumps.

It is only of recent years that any English fanciers have tried to breed true Manx cats. Miss Samuel has been very successful in establishing a strain which again and again breeds true to type. The "Golfsticks" and "Kangaroo," two noted winners, are owned by her. In former days Miss Bugden's "Gorrie," Mr. Woodiwiss's "Manx King," "Pickles," "Belle," and "Beauty," all good cats, accounted for most of the prizes. Miss Jay, whose name is more familiarly known in connection with blue Persians, has always been partial to Manx cats, and used to exhibit at the Crystal Palace. The last time I visited the Holmwood cattery I was much struck with the number of tortoiseshell Manx cats running about the stable yard. Miss Jay has quite a family of these; but, needless to say, they are all of the female sex! Mrs. Herring has not been unmindful of this breed, and has exhibited some good specimens. Miss Dresser has owned Manx cats for many years and shown some good ones. Her "Belle Mahone" and "Moonlight" were nice tabbies, free from tail, and "Bonhaki Junior" was a very fine-shaped silver tabby-and-white; but, unfortunately, he had a stump which always kept him back. Mrs. Mosely has exhibited some good blacks. Lady Alexander owned several prize-winning Manx, but these have passed into the hands of Miss Hester Cochran. The best of these are "Ballochmyle Bell Stump," a curiously spotted tabby, absolutely tailless. "Bell Spitz" and "Strathcona" are also good specimens in Miss Cochran's possession. Mr. Gambier Bolton owned and bred some fine cats. "Manx Primrose," a black, and "D-Tail," a silver tabby, won respectively first and second at the Westminster show in 1902. It is so usual to see "Breeder and pedigree unknown" after almost all the entries in the Manx classes that these two cats were distinguished by having a certified pedigree. It was a grievous loss when "D-Tail" disappeared very mysteriously from his home in St. John's Wood. "Manx Silverwing" passed from Mr. Bolton's possession to that of Mr. Foulstone's, and was later purchased by Mr. A. Ward, the well-known cat specialist. As will be seen from the illustration on page 251, this puss

is almost a spotted tabby.

[Illustration:

ORANGE MANX.

OWNED BY MRS. CLINTON LOCKE. (_Photo: S. S. Finley, Chicago._)]

Lady Marcus Beresford has lately shown a great partiality for Manx. I think I am right in stating that the first one that inhabited the Bishopsgate cattery was a beautiful white called "Mona," that I procured for her. This fine specimen was brought from the island direct, and proved herself a splendid ratter; but, alas! she did not live long to enjoy the luxuries of her new home. There are, however, no fewer than five Manx now at Bishopsgate—"Jack," a silver tabby; "Patch," a tortoiseshell; "Satanella," a black female; and "Stumps," a brown tabby male. The most recent addition is "King Clinkie," whom I have before mentioned as being owned by Mrs. H. C. Brooke. Does he ever think of his former struggling existence, now that his ways are those of pleasantness and peace? One of the latest of the specialist clubs is the Manx Club, formed by Miss Hester Cochran in 1901, with an annual subscription of 10s.; this has been reduced to 5s., and the members in the beginning of 1903 numbered about twenty. The club has, as far as possible, devoted its limited funds to guaranteeing a better classification for Manx cats at the principal shows, and when unable to afford a guarantee has given special prizes for competition. The efforts of this small body of fanciers have been substantially rewarded by the great improvement in the quantity and quality of the Manx cats exhibited during the last eighteen months. Miss H. Cochran, who has given up all other cats for Manx, is the hon. secretary, and Lady Alexander hon. treasurer. Committee: Lady Alexander, Miss H. Cochran, Mrs. Herring, and Miss White Atkins. No doubt in time the officials and members of the Manx Club will be able to add to their number.

[Illustration:

MRS. H. C. BROOKE'S MANX, "KATZENJAMMER."

(_Photo: A. R. Pickett, Bexley Heath._)]

The following is translated from a paragraph in a German weekly paper called _Mutter Erde_, and appeared in _Our Cats_ of March 1st. 1900:—

THE PROGENY OF A TAILLESS CAT OF THE ISLE OF MAN.

A cat brought from the Isle of Man (_felis catus anura_) to S. Germain en Laye, of which the pedigree is unknown, was mated with ordinary long-tailed cats, and among twenty-four kittens the four following different kinds appeared:—

I.— Kittens with ordinary long tails.

II.— Kittens with short and stump tails.

III.— Kittens without tails, like the mother.

IV.— Kittens without the least sign of a tail.

The comparison between the influence of the sire and that of the dam on the young is interesting:—

1 litter. 1 kitten like the mother. 2 „ 6 kittens, 5 like the mother, 1 like the father. 3 „ 5 „ 3 „ „ 2 „ „ 4 „ 3 „ 1 „ „ 2 „ „ 5 „ 4 „ 1 „ „ 3 „ „ 6 „ 5 „ 3 „ „ 2 „ „

It will be seen that the influence of the mother predominates.

Manx cats may be considered shy breeders, and constantly the litter will consist of one kitten only! I have been told that they are excellent mothers; but, in the words of a Manx fancier, "they only care to have one family a year, many queens won't breed at all, and heaps of males are very funny and take no notice of their wives!" Another breeder of Manx informs me that these cats seem entirely fearless with dogs, and that her canines and felines live together in perfect amity. I believe Mr. H. C. Brooke once exhibited a Manx in the same pen as a bull-dog at the South London Bull-dog Show of 1893. And now, having mentioned Mr. Brooke's name, I am pleased to say that this well-known and successful fancier of Manx, as well as foreign, cats has kindly written an article on this variety, which is his pet speciality:—

[Illustration:

"BALLOCHMYLE BELL SPITZ."

OWNED BY MISS HESTER COCHRAN.]

"On this breed I think I may claim to write with some authority, as I have kept it for a number of years, and it has always been my favourite breed of cat. I believe I may, without boasting, say that I have of late years been of some service to the breed, by constantly agitating for the Manx classes to be entrusted to judges who take some interest in the variety; for it is a lamentable fact that there are numbers of people, good judges of the more popular breeds, who are quite willing to adjudicate upon the Manx classes without possessing the slightest qualifications, and these usually merely judge the Manx as a tailless cat, which is all wrong. During the last few years I am glad to say that the National Cat Club, at almost all its shows, instead of tacking the Manx classes on to the list of any all-round judge, has appointed capable judges; and whilst, of course, no judge has ever succeeded in pleasing all concerned (except when there was only one entry in the class), the awards at these shows have always been reasonable and sound, and free from the absurdities which too often sicken fanciers and render the judge ridiculous at other shows. When we find an all-round judge openly stating that a Manx is but a tailless cat, and that he could manufacture perfect specimens, it is high time that that judge's name, however excellent a judge he may be of other breeds, should be inscribed upon the tablets of every Manx fancier's memory, and when he again officiates he should be saved the trouble of going over cats which he neither likes nor understands.

"'What is a Manx but a tailless cat?' some may ask. Well, a cat with, perhaps, an inch of tail, though in my opinion unfit to win a prize, may possibly be really a better Manx, more calculated to do good to the breed, than an absolutely tailless cat. It may possess more Manx character, and this Manx character is a thing not 'understanded of the people'; and here it is that those judges score who have taken a real interest in and studied the breed. A cat may have a couple of joints of tail, crooked or straight, and yet be a pure Manx; though, as we strive for perfection, I consider that such cats should be relegated to the stud, or at most only be placed in the money if the competition be very weak, and then never awarded any high prize.

"If breeders of Manx were more careful, there should be no difficulty in obtaining litters without any tail whatever. No cat can be a really typical Manx who is long-cast in the body. A short, cobby body is an essential in a show Manx. So also is a round, short skull. These points are usually noticeable when the kittens are young; as they grow older they disappear, frequently to return when the cat has outgrown its kittenhood. But the most important Manx property is the great length of hind leg, which absolutely marks the typical Manx as a cat quite distinct from a tailless cat; with this should be coupled a round, guinea-pig-like rump, round as an orange, which, of course, can only be obtained when there is absolutely no tail. Even a tuft of gristle or hair, as found in many of the best specimens, though in itself but a very trifling defect, detracts from this typical 'rumpy' appearance, by giving a more or less angular appearance to the hind quarters, unless, that is, it be situated so far back between the hip-bones that it in no way projects. As typical specimens showing this rumpy formation to perfection, I may mention the late 'Champion and Premier Katzenjammer,' and 'Ballochmyle Bell Stump,' probably two of the best ever seen in this respect. Had these two been mated, what glorious progeny should have resulted. Now these two cats, whilst possessing the round rumpy formation to perfection, did not excel so much in length of hind leg, and for superlative excellence in this property we must turn to another celebrated couple, the late silver tabby 'Champion and Premier Bonhaki' and 'King Clinkie,' who has just passed into the possession of Lady Marcus Beresford, and who at the age of about fifteen months has already twice won championship awards. Now, these two cats exhibited the great length of hind leg which gave them when in motion the desired comical rabbity action; but in roundness of rump they lost to the other two, being somewhat more angular.

"To gain absolute perfection we require _roundness of rump_ united to _great length of hind leg_. These are the great characteristics of the Manx, to which every Manx judge worthy of the name will attach the greatest importance. Then come other body properties—shortness of back, general cobbiness, roundness of skull, small ears, shortness of face; then, last of all, colour. And here it is that the average all-round judge goes astray, for in too many cases he attaches too much weight to colour, a good instance of which occurred when 'Ballochmyle Bell Stump,' above referred to, whose colour, though quaint, is not very pleasing, was placed below a long-cast cat of a taking colour, but in no wise a typical Manx.

"As I before remarked, colour should be considered last. I think a good black is the nicest colour for a Manx, and, of course, the eyes should be of the colour sought for in ordinary black cats. A pure blue-eyed white is very pretty, and also very scarce. Tabby-and-white I personally do not care for. Silver tabbies are uncommon and very handsome. Tortoiseshells are also pretty and

quaint.

"The fur of the Manx should be just a little longer and softer than that of the ordinary short-haired cat. Now and then we see long-haired Manx advertised, but these are, of course, mongrels or abortions, and by no means Manx cats.

"What is the origin of the Manx? That is a question which in all probability will never be answered. The theory that it originated from a cat (or cats) having lost its tail by accident I do not consider worth a moment's consideration. Such a cat might well have tailless progeny, but that would have nothing to do with the abnormal length of the hind legs, which in good specimens is patent to the most superficial observer, and which makes the gambols of a couple of Manx a comical sight calculated to excite laughter in the most mournfully disposed person.

[Illustration:

MANX CAT.

(_Photo: Gambier Bolton, F.Z.S. [Regd.]._)]

"Quaint is the old versified explanation, which I remember hearing some years ago. It ran, if I remember rightly, somewhat like this:—

Noah, sailing o'er the seas, Ran high and dry on Ararat. His dog then made a spring, and took The tail from off a pussy cat. Puss through the window quick did fly, And bravely through the waters swam, Nor ever stopped, till, high and dry, She landed on the Isle of Man. Thus tailless puss earned Mona's thanks, And ever after was called Manx.

"The most feasible explanation, in my opinion, though of course it can be but a theory, is that these cats were originally imported from the East. Asiatic cats of domestic varieties show remarkable variety in the shape of their tails, as witness the kinks often found in the tail of the Siamese cat, and the knot tails of other varieties. This subject will be referred to again in a subsequent paper.

"It is also noticeable that many Manx, like the Siamese, are very doglike in their habits, showing extreme affection for their owners. Poor old 'Katzenjammer,' for instance, would follow me to the railway station, and many a time on my return from town have I found him sitting in the middle of a field waiting for me, and on seeing me he would accompany me home just like a dog.

"To return to the question of the Manx cat's tail, this should, of course, be like snakes in Iceland—absent. What we want is for the spinal column to come to an end high up on the back, so that on placing the finger where the tail would begin a hollow or depression is felt. This is the perfection, but it is not always obtainable in even the very best specimens. Next to be desired is when only a little tuft of gristle and hair, with at most a suggestion of a twisted and withered bone, is present. Then comes a distinct caudal vertebra, if twisted or abnormal in shape so much the better; but in my opinion more than two joints should not be allowed in show specimens at all, though such cats, as I remarked above, may be valuable at stud for breeding from. But I see no reason, if Manx breeders would pay more attention, and incompetent judges were barred, why absolute taillessness should not be attained in ninety-nine kittens out of each hundred. I have bred many, but none have had the crooked stumps we often see in otherwise good specimens.

"I do not care for large Manx, which generally look coarse. Here, again, the all-rounder often goes astray, and unduly favours a large cat.

"I can heartily recommend the Manx as a pet, and the quaintness of his movements are certainly a recommendation. My cats are all house pets, so that I can watch them and enjoy their company; the 'cattery' cat is abhorrent to me. I cannot understand why so few people go in for rationally breeding this quaint variety. I had hoped that the recent purchase by his Majesty of two couples of the breed might have given it a fillip.

"To illustrate the breed, I may perhaps be accused of egotism in giving the portrait of one of our own cats, but as he is dead it is less invidious than if living specimens were selected, and as they were awarded the very highest prizes by the very greatest authorities they may safely be taken as near perfection. The silver tabby 'Champion and Premier Bonhaki' was bred by Mr. Jungbluth, one of the keepers of the monkey house at the Zoo. He made his _début_ at the Botanic Gardens as a kitten, when he was much admired by the then Princess of Wales, and Mr. Wain awarded him the championship. This success he followed up by winning four others under various judges, and died at the early age of twenty-seven months. 'Champion and Premier Katzenjammer' was bred at home; he did not commence his show career till late, and then he had to meet 'Bonhaki,' after whose

death, however, he was unbeaten, and had earned his champion title at the time of his death from gastritis last year, which robbed me of one of the most affectionate 'pals' man ever had, and I am not ashamed to own that many and bitter were the tears I shed over his grave.

[Illustration:

BROWN TABBY AND ORANGE TABBY SHORT-HAIRED CATS.

(_From a Painting by W. Luker, Jun._)]

"In conclusion, I would advise Manx fanciers to do their best to accustom their cats to seeing strangers, to being handled, and to the show pen; for when a cat is nervous and crouches in a heap it is most difficult to see whether the desired shape of hind quarters and rabbity action are present. They can best be seen when the cat holds itself fearlessly and boldly; and when a judge has a large number of classes to get through in a short space of time, in very likely an ill-lighted building, he cannot spend half an hour coaxing each cat to show its action."

[Illustration:

MR. WARD'S MANX "SILVERWING."

(_Photo: H. Glacier, Longsight._)]

[Illustration:

A LITTER BY "TACHIN."

OWNED BY LADY MARCUS BERESFORD. (_Photo: J. Fall, Baker Street._)]

CHAPTER XXIII. SIAMESE CATS.

I have often remarked at our cat shows that strangers in the fancy will inquire and ask to be directed to the Siamese class, and many and varied are the exclamations of surprise and admiration expressed by them on seeing, perhaps for the first time, a row of Siamese cats seated in their pens. Nor is it always necessary to direct visitors to the Siamese classes, for generally these animals will betray their whereabouts by the unique tone of their voice, which is distinguishable at a great distance.

There is certainly a great fascination about this peculiar breed of cats, which is yearly becoming more popular and fashionable. But fanciers are also learning a lesson in the school of experience, where frequently the fees are high, that they dare not trust their valuable specimens on the show bench. Siamese cats seem to be more sensitive than even the most delicate of long-haired breeds, and if attacked by any of the ills that catty flesh is heir to they do not appear to have any stamina to bear up against the ravages of the disease. Their recuperative powers are almost nil, and they rarely pull through a severe illness. I have never kept Siamese myself, but I have had many opportunities of observing them in sickness and in health. I have seen grown-up specimens go out like the snuffing of a candle with acute pneumonia, almost before one has realised they were even ailing. These creatures are quite human in the way they look at you with those bonnie blue eyes, and when you talk to them they seem to answer in their croaking voice. I can well understand what companionable cats these may become, and to fanciers of this unique breed other cats must appear lacking in interest and wanting in intelligence.

From time to time there have been discussions in our cat papers on Siamese cats in general, and on their kinked or kinkless tails in particular. It is certain that those cats known to us as royal Siamese are not the only species in Siam, the common cat of the country being tabby or black. So many of my friends who are fanciers and breeders of Siamese have kindly supplied me with interesting facts concerning this variety, that I do not intend to enter into any details, but will state that in 1902 a Siamese Cat Club was started by several enthusiastic admirers of this breed, and the members have certainly done much to improve the classification at shows, by offering prizes and guaranteeing classes.

The following is a list of the officials of the specialist club, with a standard of points for royal Siamese cats:—

President.—Mrs. Vary Campbell.

Vice-Presidents.—The Lady Decies, Mrs. Vyvyan, Miss Sutherland, The Hon. Mrs. McLaren Morrison, Mrs. Chapman, and Miss H. Cochran.

Committee.—Mrs. Parker Brough, Mrs. Carew Cox, Miss Derby Hyde, Mrs. C. B. Robinson, Mrs. A. Spencer, Miss Forestier-Walker, Mr. Gambier Bolton, and Mr. C. W. Cooke.

Hon. Treasurer.—Mrs. Parker Brough, Springfield, Kettering.

Hon. Secretary.—Miss Forestier-Walker.

Hon. Auditor.—Conrad W. Cooke.

STANDARD OF POINTS FOR THE "ROYAL" SIAMESE CAT.

Body Colour.—As light and even as possible, cream being most desirable, but fawn also admissible, without streaks, bars, blotches, or any other body markings.

Points, _i.e._ mask, ears, legs, feet, and tail, dark and clearly defined, of the shade known as "seal" brown.

Mask.—Complete, _i.e._ connected by tracings with the ears, neither separated by a pale ring (as in kittens) nor blurred and indistinct, the _desideratum_ being to preserve the "marten face," an impression greatly aided by a good mask.

Eyes.—Bright and decided blue.

Coat.—Glossy and close lying.

Shape.—Body rather long, legs proportionately slight.

Head.—Rather long and pointed.

[Illustration:

THE GARDEN CATTERY AT BISHOPSGATE.

(_Photo: Cassell & Company, Limited._)]

General Appearance.—With points emphasised above, a somewhat curious and striking looking cat, of medium size; if weighty, not showing bulk, as this would detract from the admired "svelte" appearance. In type, in every particular, the reverse of the ideal short-haired domestic cat, and with properly preserved contrasts of colour, a very handsome animal, often also distinguished by a kink in the tail.

Remarks.—While admitting that blues, blacks, whites, tabbies, and other coloured cats may be also cats of Siam, these being common to all parts of the world, this club recognises only as Siamese cats those cats the points of which conform to the above standard, and is, in fact, desirous of encouraging the breeding of those particular cats first made known to British fanciers as the "royal" Siamese.

The points of the "chocolate" Siamese are the same as above, with the exception of body colour.

VALUE OF POINTS.

Body colour 20 Shape 10 Coat 10 Head 10 Eyes 20 Mask 15 Density of points 15 ——— Total 100

Any cat failing to obtain 75 of the above marks shall not be eligible for the club's challenge prizes and medals.

It was shortly after the formation of the Siamese Cat Club that the following letter appeared in _Fur and Feather_:—

POINTS OF THE SIAMESE.

The committee of the Siamese Club wish to draw attention to the unfortunate diversity of opinion concerning Siamese cats expressed in articles which appear from time to time in some of the papers which devote a portion of their issue to cat news. One great object of the Siamese Club is to encourage the distinct breeding of the royal cat of Siam and also of the chocolate cat of

Siam—both beautiful in their own way, but recognised as distinct breeds. The Siamese Club is young, and not infallible; but, containing as it does most of the principal breeders and exhibitors, its committee would like to record their opinion on some few points which have appeared in the Press, in order to avoid a silence which might be construed as consent. With regard to colour, they cannot agree that a royal can be too light in body colour, nor can they endorse "we like a rich cream body, chocolate saddle, and the points glossy black, shading away to chocolate." Another paper advises the mating of royal Siamese with the chocolate variety. It is true that the young kittens are very pretty, but after six months old quickly become dark and blurred. The great beauty of royal Siamese is the contrast between the sharply defined, deepest brown markings and a body of as light a cream as possible. A third paper gives the information that an exhibitor known to it has bred prize-winning Siamese from a cross between a white cat with blue eyes and a Siamese queen. It also mentions another case where such crossing has produced good Siamese kittens, and thinks that many other people have, with more or less success, followed the same tactics. The above experiment has often been tried, purposely and accidentally, but no case is known to the writers where the result has been anything like Siamese, the kittens always favouring the English parent. All Siamese are born white, and therefore if the children of one white parent died quite young such a mistake might be natural. It certainly would be very unfair to sell such kittens, as their progeny would inherit, and might pass on, an English parentage, not even necessarily white. A white is, or may be, merely an albino variety.—(Signed) A. Forestier-Walker, Jean A. Spencer, May Robinson, L. Parker Brough, S. E. Backhouse, Constance Carew Cox.

[Illustration:

MRS. ROBERTS LOCKE, WITH "CALIF," "SIAM," AND "BANGKOK."

(_Photo: S. S. Finley, Chicago._)]

Miss Forestier-Walker and Mrs. Vyvyan were amongst the first to introduce Siamese cats into England, and they have always owned a direct descendant from the first and famous "Tiam-o-Shian," and many are the prize-winners they have reared and shown from this celebrated strain. Miss Forestier-Walker has frequently acted as judge of Siamese, and took a very active part in the formation of the specialist club for this breed. She has kindly furnished me with the following notes, and given me some photographs of Mrs. Vyvyan's cats:—

[Illustration:

"SI."

THE PROPERTY OF W. MARGETSON, ESQ. (_Photo: H. J. Comley, Stroud._)]

"Siamese cats were first introduced into England about twenty-five years ago, but were not often seen until a few years later. Among the earliest were those belonging to Sir Robert Herbert, Lady Dorothy Nevill, the Rev. S. Baring-Gould, Mrs. Cunliffe Lee, Mrs. Vyvyan, and myself. Since then they have become fairly common.

"There are two distinct varieties in the present day. (1) The royal cat of Siam, cream-coloured in body, with sharply defined seal-brown markings on head, ears, legs, feet, and tail; eyes a decided blue. The cats generally become darker after two years old, but where great care has been taken in breeding the true royal cats keep the light colour longer. In any case the body colouring should be even, not blotched or striped. The larger, lighter-coloured cats have china or ultramarine blue eyes; the more slender, darker cats have deeper-coloured eyes. (2) The chocolate cats are deep brown in colour, showing hardly any markings, and have blue eyes.

"All Siamese kittens are white when born, but in a few days slight markings appear on tail, ears, and paws, and by four months old the markings are dark and complete, excepting those which connect the face and head; these are seldom perfect before eight months old.

"The tails are sometimes straight, which is not a fault; but a knot or kink in the tail is a peculiarity of the breed, and therefore desirable. In England it has been asserted that this is a defect, but in Siam it is highly prized, and cats from the royal palace which have been given by the King as presents of value to important people have had this distinction. In the East a cat with a kinked tail fetches a higher price.

[Illustration:

"TIAM-O-SHIAN IV."

OWNED BY MRS. VYVYAN. (_Photo: Speight, Kettering._)]

"The Siamese have a great affection for animals, and there is no doubt that the cats are much valued, those in the royal palace having been kept exceptionally pure.

"There is a legend that the light-coloured cats, with blue eyes, represent silver; the dark cats, with yellow eyes, gold; and that the possessor of both will always have plenty. This rather gives the idea that originally the eyes of the pure chocolate cat were yellow, and that the present variety has been crossed with the royal cat.

"Mr. Young, of Harrogate, had some years ago a chocolate cat with yellow eyes.

"Another belief is that they receive the souls of their owners at death, and it is well known that the King of Siam had one on board his yacht when visiting Europe a few years ago.

[Illustration:

"IT."

OWNED BY LADY MARCUS BERESFORD. (_Photo: Russell & Sons, Windsor._)]

"It is a great mistake to mix the varieties, as the result after they become adult is a blurring of the markings and a patchy coat.

"The males are extremely powerful, and will kill strange cats and fight dogs. They are devoted to their wives and children, and to their owners. They are exceedingly intelligent. With the dogs of the house they will be on excellent terms.

"The litters vary in size, but four to five is the usual number. The kittens are difficult to rear, as they suffer from worms and teething, but after seven or eight months old there is little danger. Some people think a meat diet best, but I find it satisfactory to bring them up on lighter food, such as Ridge's food, milk, gravy, and fish, until they begin to cut their teeth, when meat is required.

"A pair from the Palace were given to Mrs. Vyvyan and myself in 1884–5, and we have been very careful in breeding, mating when possible with such good cats as Mrs. Lee's celebrated 'Meo,' Miss Moore's 'Siam,' Mrs. Harrington's 'Mechi,' etc, and have bred in consequence the famous 'Tiam-o-Shians' II., III., and IV., 'Polyphema,' 'Susa,' 'Kitya Kara,' 'Goblin,' 'Champion Eve,' 'Mafeking,' 'Vishuddha,' 'Ah Choo,' 'Suzanne,' and many others."

Among fanciers and importers of Siamese cats in the past, I may mention the Hon. Mrs. McLaren Morrison, Lady O'Malley, Lady Decies, Mrs. Brodie, Mr. Temple, Mr. Gambier Bolton, Miss Moore, Mrs. Elliott Hill, Mrs. Cunliffe Lee (owner of the celebrated "Meo"), and Mrs. Carew Cox, who later in this article will give some account of her "King Kesho" and the breed with which her name is still associated. Mrs. Herring has exhibited good specimens from time to time. Mrs. Chapman's "Wally Pug" used to cross the Irish Channel to visit English cat shows. Mr. Young and Mr. Inman, both of Harrogate, favoured this breed, and had some lovely cats. Mrs. Nield owned a charming little female named "Mintha-mee"; and Miss Sutherland, who lives in the south of France, used to breed a lot of good Siamese from her imported "Prince of Siam." Several of her breeding have been sold in England, and have won at shows. Mrs. Patton Bethune has often exhibited, and is an ardent admirer of the breed. Mrs. Parker Brough, in whose care "Tiam-o-Shian IV." is placed by Mrs. Vyvyan, is well known as a Siamese breeder, as is also Mrs. Spencer, of Eye Vicarage, who exports quite a number of cats; one of her breed—owned by Mr. E. Ratcliffe—is a beautiful animal. Mrs. Vary Campbell, the president of the Siamese Club, is a generous supporter of the breed. Mr. and Mrs. W. R. Hawkins have always had some fine specimens; and Mrs. Hankey, Miss H. Cochran, Miss Derby Hyde, and Miss Armitage are among others who owned some notable Siamese cats. Mrs. Backhouse's "Champion Eve" was a distinguished prize-winner, and Mrs. Robinson's "Ah Choo" was chosen as a model for the medal of the Siamese Club. But it is chiefly as the owner of the celebrated "Champion Wankee" that Mrs. Robinson is known in the cat fancy in general, and among Siamese breeders in particular. "Wankee" was the first Siamese to win the title of "Champion." He was bred in Hong-Kong, his mother—"Nims"—being a stolen palace kitten. "Wankee" was six months old when he arrived in England: and was born in September, 1895. He has won over thirty prizes, but was never shown till June, 1898, therefore losing the time in which most Siamese cats gain their honours—namely, between six months and two years, when they are pale in colour of coat.

[Illustration:

MR. RATCLIFFE'S SIAMESE.

(_Photo: Hartley, Burnley._)]

Many are the prize kittens he has sired, too numerous to mention. Mrs. Robinson, who is a member of the National Cat Club committee, has frequently acted as a judge of Siamese, and has kindly written the following account for this chapter:—

"One of the most beautiful of the short-haired cats is undoubtedly the royal cat of Siam, and the breed is greatly increasing in popularity; but is never likely to be common, as the cats are delicate in this country. The best description is that drawn up by the Siamese Cat Club in their standard of points. The points of the chocolate Siamese are the same as the royal, with the exception of body colour, which is a dark rich brown all over, thus making the markings less noticeable. All Siamese cats darken with age, and when they get dark there is a tendency to call them chocolates. I know of only one real chocolate—Mr. C. Cooke's 'Zetland Wanzies'—so consider them more likely to be a freak than a distinct variety.

"Of the royals there seem to be two types in England: the one—rather a small, long-headed cat, with glossy, close-lying coat and deep blue eyes, and with a decided tendency to darken with age—is generally the imported cat or having imported parents; the other is a larger cat, with a rounder head, a much thicker, longer, and less close-lying coat, and the eyes a paler blue (these cats do not darken as much or as soon as the other type, and have generally been bred for several generations in England).

"The kittens are born absolutely white, and in about a week a faint pencilling comes round the ears, and gradually all the points come. At four or five months they are lovely, as generally they retain their baby whiteness, which contrasts well with their almost black ears, deep brown markings, and blue eyes. Some kittens are much longer than others in getting dense, these making the lightest cats.

"This breed is said to be kept very carefully in the palace in Bangkok—hence the title 'royal'—and is by no means the common cat of Siam. One gentleman (a missionary), who had lived there fifteen years, had during that time seen only three. A few years ago there was a pair of these cats in the Zoological Gardens at Bangkok, but they were very poor specimens.

"They have occasionally been given by the King as presents of great value, and several pairs have come to England in this way; also kittens have undoubtedly been stolen from the palace from time to time.

"There is a legend that these cats were kept exclusively and with great care in the King's palace, as resting places for royal souls. The Siamese are Buddhists, and consequently believe in the transmigration of souls; but with the growth of Western ideas and Western scepticism I doubt this being admitted.

"They are very intelligent, almost doggy in their ways, and very affectionate, but not universally friendly. The males are great fighters, and freely use their terrible voices; but they are well suited for house pets, as they seem happiest with their human friends.

"The first specimens were brought to England about twenty-five or thirty years ago, and Mr. Harrison Weir says that among those who possessed them were Lady Dorothy Nevill, whose cats were 'imported and presented by Sir R. Herbert of the Colonial Office. The late Duke of Wellington imported the breed, also Mr. Scott of Rotherfield.'"

[Illustration:

LADY MARCUS BERESFORD'S "URSULA."

(_Photo: E. Landor, Ealing._)]

Miss Armitage, of Chaseleyfield, Pendleton, has sent me some charming photographs of her pets. She writes:—

"I have very few cats at present; I lost so many beautiful Siamese last year, and I think I made rather a mistake in having their skins made into mats! 'Cora,' the mother of my Siamese cats and kits, is still a beauty, and I really think she improves with age; and though her eyes are not all I could wish for in colour, yet her kittens have always had the desired tone of blue. I have now a lovely daughter of 'Cora' and 'Champion Wankee,' aged nine months. When she was a few hours old I put her to be fostered by our old English garden tabby, who makes her headquarters in the greenhouse. This kitten has never had a day's illness. She leads a wild life, catching birds and mice, and nibbling the tips off the ferns—much to the gardener's annoyance. I am hoping to send her to our next National Cat Club show, if I can catch her that day, but she is generally up a tree when wanted!

"I find the way to succeed in breeding and rearing Siamese kittens is to only keep a few. I strongly believe in putting them forth into cottage homes. Distemper spreads like wildfire amongst this breed, and it is heartrending to lose whole litters at once. It is strange

how much stronger the females are than the males. I have never lost a female kitten yet; but, alas! many a promising male."

I remember a beautiful male bred by Miss Armitage that she exhibited at one of the Manchester shows. "Sam Sly" was as near perfection as possible, and after taking everything in the way of prizes, medals, and championships this fine fellow came home and died! Mrs. Spencer, of Eye Vicarage, to whom I have alluded as a Siamese fancier, has bred so many large litters of kits that I wrote to ask if she would kindly give me and my readers the benefit of some of her experience in rearing young Siamese. She writes in reply:—

"My 'Royal Siam' came from the royal palace, and I consider him a splendid specimen. I did not breed from him until he was between three and four years old, which may be one of the reasons why all the kittens by him are so wonderfully strong and healthy. He has never ailed anything since I have had him. I have never placed him at stud, but have allowed a few friends to send their queens to visit him. Neither have I ever exhibited him, for he is far too precious a pet to be allowed to run any risks. My queen 'Princess Maimowne' is also a fine strong cat, a daughter of Mrs. Carew Cox's 'King Kesho'; and many are the prize-winners bred from these two. I heat my catteries during the day in winter, and at night in cold weather I give the cats a hot stone bottle in their sleeping boxes, for it is the damp and cold of our English winter nights which are so dangerous. The windows of my catteries face south, and this is important in rearing Siamese. I always allow my cats an abundance of fish; this I give—mixed with bread soaked in water—twice a day, with another meal of something different, thus making three meals a day. I boil all the milk. Sometimes I give a little cod-liver oil over their food—with very beneficial results. If the kittens have bad colds or any trifling ailment, I indulge them with a little finely cut up raw beef. I have been breeding Siamese for over five years, and I have only lost one kitten of my own rearing. I think the reason of my success is that I never pass over the most trifling symptom of illness, and it is very necessary to take the temperature of Siamese at the slightest sign of sickness. I send a great number of kittens away to purchasers, and I am most particular in the way I pack the kits for their journey. The basket outside should be covered with thick brown paper, leaving just a square piece in the lid for ventilation. Inside I line with new house flannel, and place a soft cushion at the bottom, and if very cold weather I put an indiarubber hot-water bottle under the cushion. If the cats have to pass through London, I arrange with the District Messengers Company to meet the cat and convey it to its destination or to another station. Thus dangerous delays are avoided at a very little cost."

As everyone knows, Lady Marcus Beresford has always been especially fond of Siamese cats, and many splendid specimens have inhabited the Bishopsgate cat cottage. At present "King of Siam" and "Khoula," and a quaint little female called "It," represent this breed. In the days gone by "Tachin" and "Cambodia" were the admired of all admirers, and I doubt if ever a more perfect pair has landed on these shores. These cats were given to Lady Marcus Beresford twelve years ago by the late Lord William Beresford, who brought them straight from the palace at Bangkok. Lady Marcus writes:—

"I never once had any trouble or anxiety with them—dear, gentle, friendly little people, so clever and attractive. I have never seen any I have so admired. They had many fine, healthy litters, scattered about now amongst various friends. My success all round was great with them—no illness of any kind, till one day a fiend poisoned both 'Tachin' and 'Cambodia,' and some of their six months kittens. I have replaced them with some bred in England; and my opinion is that, as a rule, the imported ones are much the stronger. A pair of Siamese imported from the temple at Bangkok I purchased from Mrs. Vary Campbell, and had the great misfortune to lose them. They differed from the royal Siamese, being darker and having a more pointed head and face, and their eyes were larger and fuller.

"I consider that Siamese cats are much cleverer than other breeds, and with patience can be taught several clever tricks. I intend to go in more largely for them in the future."

[Illustration:

MISS ARMITAGE'S "CORA."

(_Photo: Salmon & Batchan, New Bond Street, W._)]

Several of Lady Marcus Beresford's Siamese found their way into Mr. and Mrs. Hawkins' possession, and were exhibited from time to time, always gaining great distinction. Mrs. Hawkins possesses a daughter of "Tachin," and so hopes to keep up this unique strain. Mrs. Hawkins has some of the best arranged and very solidly built catteries at Brighton, of which I give an illustration. These are specially adapted for the breeding of Siamese and silvers, the two varieties which find favour at Shalimar. A long experience with Siamese enables Mrs. Hawkins to write with authority, and I give her notes as given to me for the benefit of my readers:—

"The first thing you have to consider with regard to these animals is that when newly imported they are naturally delicate, and must be hardened off, so to speak, just as our delicate foreign birds have to be; that is to say, you cannot treat them at first as you would our ordinary fireside cats. If you are fortunate enough to pick up newly imported ones, even if you have to pay a good price for them, they will prove a good investment; and perhaps you may be able to get some from one of our numerous cat fanciers, though they are very scarce at present and difficult to obtain. My advice is to get the best possible pair, and let them breed in the spring in the house, if you can let them have a spare room, which need not be warmed in any way. Leave the mother quietly with the kittens; and, having provided a warm bed and bedding for them previously, leave them to nature as much as possible, just going in now and then to see that all is going on all right, and giving the mother warm milk, etc., and coaxing her to get used to you.

"Siamese cats are particularly gentle and affectionate, and if you are kind to them they soon get to know and love you. It is a pity their nature is not more copied by human beings—then we should not have so much dissension and wrangling in our cat fancy. But this is a digression! As the kittens get on it is as well to have a warm place outside prepared ready for them; but do not put them out too soon, and if any show the slightest suspicion of cold they must be brought in and allowed to get over it completely before being turned out in the garden or outhouses, with the others.

"My own Siamese kittens were born in a cat house in my garden at Brighton, but they were June kittens, so by that time we were having very nice weather. The father and mother I had as kittens; I pulled them through their baby ailments successfully, and as soon as the weather was propitious and sunny I put them in their outside houses. Siamese and chinchilla kittens (both of which I go in for) must be hardened off gradually. They are just like English children brought from abroad, who have to be carefully nurtured at first and trained to get used to our English climate.

"What we want is to establish a really healthy, strong strain of Siamese in England, and by following the above suggestions I think it is possible to do it—not without difficulty, as, of course, it takes a little time and trouble (like everything else), but what is worth having is worth trying for.

"I may say I won with my Siamese at Brighton shows every time I exhibited them, and am now starting breeding them again; and I think that everyone who will have the patience to go in for this charming variety will find themselves well repaid, as the kittens command £5 to £10 each if successfully reared, and sometimes more. Of course, one must keep a careful watch over their diet, and not over-feed (this is a great point, as they will contract skin diseases if you do); but all these things apply as much to all cats, and I cannot see why Siamese should be more difficult to breed and establish thoroughly in England than other cats. One of mine, a female, is out now (and has been all the winter) in a brick cat house, and is perfectly well. I have been told Siamese are so delicate that people cannot rear them. This is often the fault of the people themselves, for if they will not take a little trouble over animals they cannot expect to make money by them. By this I do not mean fussing and worrying your servants over them. Look after them yourselves, see that they are all right every day (a good feed twice a day is quite sufficient), and then your Siamese will soon be as healthy and strong as your other cats. All the points of a good Siamese are so well known that I need not touch upon them here. Start with a good strain, be careful, be patient, and you will be rewarded in the end."

[Illustration:

PAIR OF SIAMESE BELONGING TO MRS. ARMITAGE.

(_Photo: Salmon & Batchan, New Bond Street, W._)]

I have mentioned Mrs. Parker Brough as a breeder of Siamese cats, and I am indebted to her for the following account of her favourite breed:—

"A peculiarity of royal Siamese is that the kittens are born quite white, and at about fourteen days the points begin to look rather grey, turning at two months to a deep seal-brown, while the rest of the body usually remains white or cream for at least a couple of years (the whiskers and claws remain white). The colouring process resembles nothing so much as that of a meerschaum pipe. There are distinct varieties of Siamese known to fanciers—the palace or royal cat, the temple cat (chocolate), and there is likewise the common cat of the country, which is also found within the palace. The points of the chocolate cat are identical for shows with those of the royal except body colour, but the imported chocolate is often dark chocolate, with blue eyes, stumpy tail with a marked kink, short legs, and heavy, thick body. There are not many chocolates exhibited, owing to the preference given to the royal variety.

"It must be understood that there is no definite royal breed as such, but the palace breed seems to have originated by selection. The Siamese as a nation are lovers of anything quaint or uncommon, and the white-bodied cats in Bangkok seem to have been

given to, or bought by, the inhabitants of the palace, until they have established a breed of their own, and reproduced the cat that fanciers know to-day as the royal cat of Siam. This should explain a point which has given rise to much controversy, as travellers agree that other cats than royal Siamese are to be found inside the palace, yet the King and Prince Damurong have given from time to time royal Siamese to friends, naturally choosing for a present the cat that has the most value in their eyes. That is to say, that the term 'royal Siamese' or 'royal cat of Siam' is a descriptive term applied to a particular variety of cat, and should imply no more than this. We have a parallel case in 'King Charles spaniels.' The temple cat is under the care of the Jan priests, who have the greatest reverence for animal life, and whose temple is a sanctuary for all animals.

"Those who have kept Siamese will readily understand that, given a climate to suit them, only one breed of cat would be left in the temple—_i.e._ the Siamese, for this breed is distinguished as much by its pluck and activity as by hatred for any other breed of cat. The common cat of Siam is very much the same as anywhere else, except that the Malay kink in the tail is to be found in many of them. Until recently the Siamese was but little known in Europe, but occasionally was to be found in the various zoological gardens. At present there is a fine female specimen to be seen at the Zoo at Frankfort-on-the-Main, having been purchased from the King of Roumania. One or two are to be seen at Berlin, and we understand some are to be seen at the Hague. London has the first one it has had for six years, but it is not shown owing to its want of condition.

"A point on which the Siamese fancy is divided is whether the ideal cat should have a kink in the tail or not. The Club remains neutral. 'Champion Wankee' has a decided kink, looking, in fact, as though the tail had been caught in a door in his early youth. 'Tiam-o-Shian IV.,' on the contrary, has none. This kink is a peculiarity of the animals of the Malay Peninsula, and sometimes is so marked, as to make the tail appear like a corkscrew, though others of the same litter may have quite straight tails. There is a peculiarity in breeding Siamese—_i.e._ the rarity of female kittens in a litter, the average seeming to be five males to two females. This may be due to the artificial lives so often led by these cats; and, if so, corroborates the theory of Herr Schenk, the Austrian doctor, of the probabilities of sex at birth. Three of the most noted male cats exhibited in England have been Mrs. Robinson's 'Champion Wankee,' Mrs. Vyvyan's 'Tiam-o-Shian IV.,' and Mrs. Parker Brough's 'Koschka.' Probably Mrs. Backhouse's 'Champion Eve' and Mrs. Vyvyan's 'Polyphema' were the best females exhibited. 'Koschka' was, perhaps, the finest cat we ever saw, having eyes of the most glorious blue imaginable. 'Koschka' died after the Westminster show of 1900. Owners run a great risk in sending their Siamese (especially kittens) to shows, as in addition to being more liable to take cold, are apt to fret themselves ill at being separated from their mistresses. Many fanciers are leaving off showing Siamese for that reason—for instance, the Siamese classes were cancelled at the Westminster show of 1903 owing to lack of entries.

"It is hard to say how they should be kept and how they should be fed. Some Siamese thrive by being treated just the same as ordinary cats, but they are few and far between. We have known cats which have been allowed to run about in the snow, and in and out of draughts, and remain perfectly healthy; and others, who seem quite strong as long as they are taken care of, catch cold and die if they get their feet wet. However, if their cattery is kept constantly at a temperature of 50 degrees, and they are fed on scraped beef, milk (without boracic acid or preservative), water, and vegetables they seem to do better than under any other conditions. Personally, we have two catteries—indoor and outdoor. The indoor one is fitted up with 'foster mothers,' as used for chickens, on legs about three feet from the ground. We find this very necessary owing to the draughts on the floor. The rooms can be quickly warmed to any temperature required, even in the depth of winter. We like our grown-up cats loose about the house, but it is impossible to allow kittens their full liberty when there are many of them, as they are bound to get into mischief and do much damage to the furniture, climbing up curtains and breaking ornaments on mantelpieces and scratching leather, etc. Of course, they are allowed downstairs a portion of every day when their mistress is able to look after them. They are most fascinating, frolicsome little creatures. The outdoor catteries—for use in summer—consist of a house and greenhouse, with covered runs leading from them, and so arranged that any or every cat can be isolated at will. These arrangements have taken a great deal of anxiety off our shoulders.

"This breed is certainly the noisiest, least dignified, most intelligent, and most active of all the cats. They are doglike in their nature, and can be easily taught to turn back somersaults, and to retrieve, and in the country take long walks like a terrier.

[Illustration:

MRS. ROBINSON'S "AH CHOO."

BRED BY MRS. VYVYAN. (_Photo: E. Landor, Ealing._)]

"If they think it is meal-time and they fancy themselves neglected, they cry like children. The points of the perfect royal Siamese lie in the eyes, which should be a most perfect blue, and the contrast between the seal-brown of the paws, mask, and tail and the white or cream of the rest of the body, which should _not_ be disfigured by bars or blotches. Age should be taken into consideration in judging this contrast. There are many beautiful kittens shown that we never hear of again after they have grown up, age having blurred their coats, thereby making the contrast less defined.

[Illustration:

MRS. ROBINSON'S "CHAMPION WANKEE."

(_Photo: E. Landor, Ealing._)]

"For travelling short distances there are few better travelling cases than a Canadian cheese box, with holes bored in the side. They are cheap (say 4d.), light, and damp and draught proof, and can be burnt after once using."

It will be gathered from the accounts given by Siamese fanciers that these cats, though delicate, with the exercise of care may be reared like ordinary ones of other breeds. Miss Cochran is very emphatic on this point. She says:—

"If Siamese are treated like common English cats, given plenty of fresh air and proper food, they are hardy and healthy; and by proper food I mean a meat diet—raw shin of beef, and as often as possible any kind of bird with the feathers on, or fowls' heads and mice. The fur and feathers act as a mechanical vermifuge. If the Siamese cats are coddled, they will certainly die. They have naturally rather delicate lungs, and for these fresh air is absolutely necessary; a close, hot atmosphere and heated rooms are fatal."

[Illustration:

"MAFEKING."

THE PROPERTY OF MRS. VYVYAN. (_Photo: E. Landor, Ealing._)]

Mrs. Carew Cox I have alluded to as one of the pioneers of the Siamese fancy, and she still remains an ardent admirer of this breed, and often acts as judge. She has kindly written a very valuable article specially for this work, and I have therefore great pleasure in giving her interesting experience in this chapter on Siamese:—

"Only those who possess Siamese can understand how reluctantly a lover of this breed takes up a pen to endeavour to do justice to its characteristics—it is like attempting the impossible. One feels one must step softly—so to speak—in the presence of these wonderfully fascinating creatures, whose thoughtful yet penetrating eyes appear to see so far and so much, whose intelligence seems almost human, and who seldom stay with us for long. Unfortunately, these cats are difficult to rear, the constant damp of our climate affecting their lungs and producing frequent colds and coughs, lowering vitality and causing debility.

"There are two recognised varieties of this breed—the royal and the chocolate. The former is certainly the most beautiful in appearance, the seal-brown points—sometimes black in adults—relieving the pale but rich cream colour of the rest of the body, and the brown mask forming a grand setting for the superbly blue eyes. The mask on the face should circle well above the eyes, but should not extend into the ear space; the cream colour should be in evidence beyond the circle; the ears should be seal and well and distinctly put on—_i.e._ the seal or brown should not merge into the cream; the legs, feet, and tail should be of the same shade of seal, the darker the better. The tail of a Siamese cat has been the subject of considerable discussion and argument, some preferring the straight tail and some the kinked. The former is surely the most to be desired for appearance sake; but the latter undeniably adds to the quaint and foreign appearance of the cat, and in Hong-Kong preference is given to them and higher prices paid for 'kinks.' The eyes should be large and luminous, of a bright shade of true blue, appearing flame-coloured at night or by artificial light; good specimens are often spoilt by small eyes, pale in colour. There appear to be two distinct types—the compactly built, short in body, short on legs, and round in head; and the long-bodied, long-faced, lithe, sinuous, and peculiarly foreign-looking variety. I am informed that the small cats are held in great esteem in Siam, some of the females being quite liliputian. It is a matter for regret that as the cat ages the beautiful clear cream colouring becomes cloudy and dark. There have been exceptions to this rule: the late 'Polyphema,' owned by Mrs. Vyvyan, retained her pale colouring and her well defined points to the last, and was the mother of many very beautiful kittens. Male cats are generally larger than females, and possess voices, which demand instant attention.

[Illustration:

THE LATE "KING KESHO."

(_Photo: Phillips, Croydon._)]

"The chocolate Siamese are of a rich chocolate or dark seal, with still more intense points. These cats usually possess eyes of rich amber. I have Miss Forestier-Walker's kind permission to utilise the following most interesting—and hitherto unpublished—extract from a letter received by her in October, 1902:—'I am very pleased to write and give you the following information _re_ Siamese cats. During a stay of some thirteen years in the Straits Settlements I have visited Siam on several occasions, and on one of these visits the present King of Siam gave a friend of mine a pair of cats. These cats were what the King called palace cats, were very valuable and perfect specimens, with short twisted tails. It may also interest you to know that the Siamese have a superstition about their cats, and like to have both breeds in their houses—_i.e._ the dark, coffee-coloured ones with yellow or golden-coloured eyes, and the cream-coloured with blue or silver eyes. The idea is that the yellow-eyed cats will bring gold and the blue-eyed silver, hence if you have both breeds there will always be plenty in the house.'

[Illustration:

LADY MARCUS BERESFORD'S "CAMBODIA."

(_Photo: E. Landor, Ealing._)]

"I advocate that all kittens should be reared by healthy English foster-mothers, and am convinced that if breeders would adopt this plan we should in time succeed in establishing a far stronger breed of cats. As matters now stand, the kittens inherit and develop any ailment or weakness to which their mothers may be subject, so that from the very commencement of their existence they have but little chance of becoming strong and healthy enough to withstand our climate of many moods.

"Plenty of sun and air they require, but damp and draughts are fatal. All young kittens should be encouraged to take exercise; empty cotton reels cause hours of amusement, also a rabbit's foot tied on to string or otherwise; corks of any description must be avoided. Large bones should be given when the kittens are two months old—they assist the growth of teeth; small ones, such as of game, chicken, or fish, are dangerous. The best and safest of all is a bullock's foot boiled down and pulled apart; these bones will occupy kittens for a considerable time.

"Worms cause an enormous mortality amongst Siamese, and are, I feel convinced, at the root of nearly every ailment from which cats or kittens suffer; therefore, however reluctant one may feel as to giving medicine to youngsters of tender age, it is better to do this than to run the risk of these odious parasites establishing themselves, for they are most difficult to dislodge permanently. I have used Saunder's worm powders with considerable success. Of course, the dose for kittens must be administered in minute quantity—just a small pinch given in warm olive oil early in the morning after an all-night fast. In giving the powder to adults I always enclose it in capsules. In cases of weakness or exhaustion a few drops of brandy or whisky in a teaspoonful of warm milk works wonders. It is often necessary to give some sort of tonic after medicine of this description.

"Siamese kittens should be well fed; not much at a time, but little and often—lean scraped beef or mutton, vegetables, stale bread and gravy, boiled fish, rabbit, raw eggs, milk (previously boiled); in fact, anything light and nourishing. The remains of a meal should never be left on the floor. These kittens' digestions are not strong, and their intestines are most delicately formed.

"The colour of the eyes of Siamese kittens should be well determined at eight weeks. They are most interesting and playful at this age; a tunnel made of newspapers will afford endless amusement, and after a long and energetic game of play they will sleep for hours. It is not desirable to lift or handle them more than can be avoided whilst they are very young. In cases of bad colds or coughs, a simple but usually effective remedy is a mixture of three pennyworth of oil of almonds and three pennyworth of syrup of violets, mixed by a chemist—a quarter of a teaspoonful thrice daily (it is absolutely necessary to shake the bottle thoroughly before administering the medicine). For an adult an eggspoonful three times daily may be given. Cod-liver oil is always safe (also the best olive oil), and helps to build up the constitution. As a tonic I know of nothing to equal half-grain (coated) quinine pills, given early each morning for a few days now and again. In cases of bronchitis, Carvill's Air Purifier (about a teaspoonful) should be placed in boiling water, and the cat or kitten made to inhale the steam several times daily, and particularly the first thing in the morning and the last at night.

[Illustration:

PUGS PAYING A VISIT TO THE SIAMESE.]

“For adults suffering from bad throat complaint and total refusal of all food I have found no remedy to equal the following prescription, if given in time. I have administered it with great success to numberless cats: Forty drops Calvert’s pure carbolic acid, two drachms spirits of wine, six ounces pure water. Not quite half a teaspoonful to be mixed with a teaspoonful of warm milk, poured down the throat three times daily; for very young cats a smaller quantity of the mixture should be given. I doubt if it would be advisable to give it to young kittens. Even if the cat does not swallow the whole dose, it acts beneficially as a mouth-wash and disinfectant, apparently removing an unpleasant taste and re-establishing the power to smell—the loss of this sense often preventing a sick cat from eating. Weak eyes, sickness, and diarrhœa are tedious ailments to which all kittens are very subject, and to effect a permanent cure the treatment must be very persistent.

[Illustration:

MRS. HAWKINS’ CATTERY.]

“I do not know when Siamese were first introduced into England, but Lady Dorothy Nevill possessed some several years ago. Sir Robert Herbert imported some; and Miss Forestier-Walker and her sister (Mrs. Vyvyan), who have owned and bred many beautiful specimens, first made acquaintance with this breed in 1883, and soon afterwards were presented with ‘Susan’ and ‘Samuel’ direct from t

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Genius rewarded

John Scott

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[Illustration: _Works at Elizabeth, N.J. The Singer Manufacturing Company_]

Genius Rewarded; OR, The Story of the Sewing Machine

[Illustration: The Story of the Sewing Machine]

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THE

STORY OF THE SEWING MACHINE.

CHAPTER I. THE SEWING MACHINE'S RIVALS.

"With fingers weary and worn, With eyelids heavy and red, A woman sat, in unwomanly rags, Plying her needle and thread— Stitch! stitch! stitch! In poverty, hunger and dirt, And still, with a voice of dolorous pitch— Would that its tone could reach the Rich!— She sang the 'Song of the Shirt.'"

[Illustration:

THE SONG OF THE SHIRT.]

In a back street of Boston two men sat one sultry August midnight upon a pile of boards. They were penniless and friendless; they were smarting under failure and keen and bitter disappointment. Actual want stared them in the face and made them desperate. And yet, upon the outcome of that midnight scene mighty issues hung quivering. All the world had a stake in the thoughts of those poor, friendless, desperate men. One of them had heard from across the seas the "Song of the Shirt;" he had heard its sad echo even from the more prosperous homes of our own land, and its dismal chords had awakened in his breast a burning desire to still its horrible refrain, and carry relief and help to the weary seamstress. Golden visions, too, had floated before him of the princely reward the world would offer for such service to its great sisterhood.

With great difficulty he had persuaded two other men to join him. One furnished the scanty capital of _forty dollars_; the other gave the use of his machine shop, workmen and tools. Day and night he had worked to produce a SEWING MACHINE, sleeping but three or four hours out of the twenty-four, and eating, generally, but once a day, as he knew the machine must be built for forty dollars or not be built at all. The hour of trial had come that very day. The machine had been completed and put together, and _did not work_! One by one the workmen left him in disgust, but still the inventor clung tenaciously to his purpose, and refused to yield to defeat. All were gone but this companion, who held the lamp while the inventor worked. Loss of sleep, insufficient food, and incessant work and anxiety made him weak and nervous, and he could not get tight stitches. Sick at heart, the task was abandoned at last, and at midnight the worn and wearied men turned their backs upon their golden dreams and started for their lodgings. On their way they sat down upon the pile of boards, and were gloomily discussing the sad fate of the project, when his companion mentioned to the inventor that "the loose loops of thread were all upon the upper side of the cloth." Instantly it flashed upon the inventor what the trouble was, and back through the night the men trudged to the shop, re-lighted the lamp, tightened a little tension screw, and in a few minutes ISAAC MERRITT SINGER had produced the first Sewing Machine that ever was practically successful.

[Illustration:

THE CRITICAL MOMENT.]

It _was_ a great stake which the world had in the gloomy midnight reflections of two desperately poor men, seated upon that pile of boards, thirty years ago! Rarely has so much hung upon the thoughts of two humble men. That midnight scene settled the question whether woman should have a tireless helper in her weary task of stitching—whether or not the world should thenceforward have a machine for sewing. Out of that lumber-pile conference came the Sewing Machine and all the mighty interests involved in its manufacture, sale, and use. It was the answer to the "Song of the Shirt;" its dolorous tone had reached—not the rich—but a poor, struggling mechanic; and his invention has done for woman and for the home-circle what no other invention ever has done. We look back upon James Watt, sitting before the open fireplace, watching the pot lid rise and fall with the then undiscovered power of steam, as the scene whence issued all the blessings which followed the Steam-engine. We think of Franklin flying his storm-riding kite and drawing down the lightning, as thereby bringing to us all the civilizing influences of the Telegraph. But neither of these men, if they could have looked down the dim vista of the coming centuries, and foreseen what their inventions should do for humanity, could have contemplated results more surprising than those which Isaac Merritt Singer lived to see crowning the invention which hung trembling upon the results of that talk upon that pile of boards!

The Telegraph and Steam-engine live daily in the broad blaze of public view; the Sewing Machine modestly hides itself away beneath three million of the nine million roofs of America. They are public blessings; the Sewing Machine is a purely domestic one. It earns a woman's dime; they earn a railroad king's millions. They deal with the great arteries of trade and commerce; it deals with the fireside circle. The Telegraph and Steam-engine proudly boast their alliance and familiarity with Capital; the Sewing Machine contentedly takes up its humble quarters mainly with people who never drew a dividend in all their lives. Capital and wealth must run the former; slender and humble feet most often run the latter. The Locomotive puffs defiantly in nearly every legislative hall; the Sewing Machine sings its tireless tune to ears that would not know what "_lobby_" meant. The former haughtily issues its dictum to primaries and conventions; the latter could not control a solitary vote. Steam and the Telegraph deal mainly with creation's lord; the Sewing Machine with his lowlier sister.

A certain class of people are apt to underrate domestic affairs, simply because they are domestic, forgetting that the real progress of the world is always made beneath the shelter of the homestead roof, not under the resounding domes of Senate Chambers; and that a Nation's surest hope for greatness and for safety is found in the character of its _homes_, rather than in the shrewdness of its merchants or the skill of its artisans. It is the atmosphere of the boy's early home which clings like an indestructible and exhaustless aroma to his entire life; it is the influence and memory of what his home and his mother were which mould his after life, control his habits of thought, and make him a power for good or for evil in the world. And for the most part he remains unconscious of any such influence. He has imbibed it with his daily sustenance and inhaled it with every breath of his native air, until he involuntarily weighs everything, measures all affairs, and judges all men according to the standards and traditions that prevailed in the now hallowed precincts of his early home.

Whatever, therefore, brings added comfort to the matron and the maiden; whatever saves the busy housewife's time and increases her opportunities for culture; whatever lifts any of the heavy household burdens, and disenthralls to any degree the WOMEN of our day, contributes an ever-augmenting influence towards the highest and best progress of the world.

[Illustration:

"HAPPY HOMES"—EFFECTS OF THE ANSWER.]

And so the importance of the Sewing Machine in its influence upon the home; in the countless hours it has added to woman's leisure for rest and refinement; in the increase of time and opportunity for that early training of children, for lack of which so many pitiful wrecks are strewed along the shores of life; in the numberless avenues it has opened for female labor; and in the comforts it has brought within the reach of all, which once could be attained only by the wealthy few, becomes so apparent that few, if any, will dispute its right to stand at least beside its powerful rivals, the Steam-engine and Telegraph.

CHAPTER II. GROWTH OF THE IDEA.

The idea of sewing by machinery had been cherished for a hundred years before the first successful machine was built.

The earliest attempt at sewing by machinery of which any authentic account exists was made as early as July 24th, 1755, when a machine was patented in England by Charles F. Weisenthal, having a needle with two points and an eye at mid-length.

The next sewing machine was that of Thomas Saint, of England, who obtained a patent July 17, 1790. This man seems to have understood, with remarkable clearness, the main essential features of the invention, for his machine had a horizontal cloth-plate, an overhanging arm, at the end of which was a needle working vertically, and a "feed" working automatically between the stitches. These features have been preserved in every successful machine ever made. The needle was notched at the lower end, to push the thread through the goods, which had been previously punctured by an awl. As the needle passed upwards, leaving a loop in the thread, a loop-check caught the loop and held it until the needle descended again, enchaining the thread of the new loop in the former one.

In 1804 an Englishman, named Duncan, made a chain-stitch machine, having a number of hooked needles, which passed through the cloth and were supplied with thread beneath the goods by a feeding needle, whereupon the needles receded, each drawing a loop through the loop previously drawn by itself through the cloth.

In 1818 Rev. John A. Dodge, of Monkton, Vt., invented, and, with the assistance of John Knowles, an ingenious mechanic, constructed a machine having the double-pointed needle and eye at mid-length. It made a stitch identical with the ordinary "back-stitch," and was furnished with an automatic device for "feeding" the work. Mr. Dodge never applied for a patent, nor attempted to manufacture any more machines, because of the great pressure upon his time as a pastor, and further on account of the bitter opposition of journeymen tailors, who denounced the machine as an invasion of their rights.

The first patent issued in America for a sewing machine was that of a man named Lye, in the year 1826. Lye's device could hardly have contained any useful or striking features, for when the fire of 1836 destroyed all the Patent Office Records, it consumed all that remained of this machine.

In the year 1830 Barthlemy Thimmonnier, a Parisian, invented a machine which operated much as Saint's did, except that the needle was crocheted, and, descending through the goods, pulled up a lower thread and formed a series of loops upon the upper side of the goods. Eighty of these machines, made of wood, are said to have been used at one time in Paris, making army clothing; but though patented in France in August, 1848, and in the United States September 3, 1850, it had too many defects to become anything more than an important step in the onward march of this great invention.

[Illustration:

BIRD'S EYE VIEW OF THE GREAT SINGER FACTORY.]

Many other machines, of more or less merit, were constructed before Mr. Singer made his machine, but all fell short of being practical and useful. The nearest approach to success prior to 1850 was made by Walter Hunt, of New York City, in the years 1832–3–4. His machine had a curved needle, with an eye near the needle-point, which was operated on the end of a vibrating arm. A loop was formed beneath the cloth by the needle-thread, through which a shuttle, reeling off another thread, was forced back and forth with each stitch, making an interlocked stitch like that now made by the best machines. George A. Arrowsmith, a blacksmith, of Woodbridge, N. J., being of a speculative turn, bought one-half of Walter Hunt's invention in 1834, and afterwards acquired the remainder. Soon afterwards, Adoniram F. Hunt, a brother of Walter, was employed by Arrowsmith to construct some sewing machines upon the same principle, but differing somewhat in arrangement of details from the original. These machines were made and operated at a machine shop in Amos Street, New York City. Arrowsmith neglected to obtain a patent upon the machine for reasons which, in the light of events now past, make singularly interesting reading. He assigned three reasons for not procuring a patent: (1) He had other business; (2) the expense of patenting; (3) the supposed difficulty of introducing them into use, saying, it "would have cost two or three thousand dollars to start the business." There appeared also a prejudice against any machine which had a tendency to dispense with female labor. A proposition made by Walter Hunt to his daughter to engage in the corset-making business with a sewing machine was declined, after consultation with her female friends, principally, if not altogether, as she afterwards testified, "on the ground that the introduction of such a machine into use would be injurious to the interests of hand-sewers. I found that the machine would at that time be very unpopular, and, therefore, refused to use it."

The neglect of Hunt and Arrowsmith to procure a patent upon this sewing machine was fraught with momentous consequences a few years later, not only to them but to the entire sewing machine trade and the world at large.

John J. Greenough, on February 21, 1842, procured the first sewing machine patent in America of which any official record now exists. His machine sewed with two threads, both of which were entirely passed through the cloth at every stitch, the needles being pulled by pincers through holes previously bored with an awl. It was designed principally for leather work.

R. W. Bean, of New York City, patented a machine, March 4, 1843, for making a "running" or basting stitch.

Another machine, having two threads and generally like Greenough's, was patented December 27, 1843, by George R. Corliss, of Greenwich, N. Y. It had eye-pointed needles reciprocated in horizontal paths, through holes previously made by awls, the goods being fastened between clamps and fed in front of the needles.

[Illustration: [Furnace]]

Another form of sewing machine, of which several varieties were patented between 1844 and 1850, adopted the somewhat primitive method of first crimping the cloth and then forcing it upon the needle, which was driven through a number of thicknesses at the same time, making a running stitch.

In the year 1846, or over twelve years after Walter Hunt's machine was built, Elias Howe, Jr., having probably ascertained that Hunt had never patented his machine, built a sewing machine upon the Hunt plan, adding two puerile devices (both of which were subsequently abandoned as useless), and procured a patent thereon in his own name. These devices were a "clipping piece" to control the unwinding of the shuttle-thread, and a "baster-plate," to which the work was basted, and thus hung vertically in front of the machine. This machine never became of real utility until the inventions of Mr. Singer, five years later, had been added to the principles of action applied originally by Hunt and appropriated by Howe. After Singer's inventions had been recognized as giving to the sewing machine a practical and immense value, Walter Hunt testified, under oath, as follows: "ELIAS HOWE _has several times stated to me that he was satisfied that I was the first inventor of the machine for sewing a seam by means of the eye-pointed needle, the shuttle and two threads, but said that he had the prior right to the invention because of my delay in applying for letters-patent._" In the year 1853, Hunt applied for a patent upon his invention, but was refused upon the ground of abandonment.

Judge Charles Mason, Commissioner of Patents, in delivering his decision in May, 1854, upon the evidence in Hunt's application, used the following language: "Hunt claims priority upon the ground that he invented the Sewing Machine previous to the invention of Howe. He _proves_ that in 1834 or 1835 he contrived a machine by which he actually effected his purpose of sewing cloth with considerable success. Upon a careful consideration of the testimony, I am disposed to think that he had then carried his invention to the point of patentability. I understand from the evidence that HUNT actually made a working machine in 1834 or 1835. The papers in this case show that _Howe_ obtained a patent for substantially _this same invention_ in 1846."

Notwithstanding this, the Commissioner was forced to refuse Hunt's belated application, for the reason that an Act of Congress in 1839 had provided that inventors could not pursue their claims to priority in patents unless application was made within two years from the date when the first sale of the invention was made. Hunt had sold a machine in 1834, and had neglected to make application for his patent till 1853.

[Illustration:

THE SINGER COMPANY'S STEAMER, "EDWARD CLARK."]

Thus it was that one of the grandest opportunities of the century was missed by the man who should rightfully have enjoyed it; the honors and emoluments of the great sewing machine invention passed to a man who neither had invented a single principle of action, nor applied a practical improvement to principles already recognized; and Elias Howe, Jr., acquired the power, by simply patenting another man's invention, to obstruct every subsequent inventor, and finally to dictate the terms which gave rise to the great Sewing Machine Combination about which the world has heard—and scolded—so much.

Howe's machine was not, even in 1851, of practical utility. From 1846 to 1851 he had the field to himself, but the invention lay dormant in his hands. He held control of the cardinal principles upon which the coming machine must needs be built, and planted himself squarely across the path of improvement—an obstructionist, not an inventor—and when, in 1851, Isaac M. Singer perfected the improvements necessary to make Hunt's principles of real utility, Howe, after long and expensive litigation, laid Singer and all subsequent improvers under heavy contribution for using the principles of Hunt, patented by himself.

Morey & Johnson procured a patent February 6, 1849, for a single-thread machine, making a stitch by a hook acting in combination with a needle.

Lerow & Blodgett patented a machine October 2, 1849, the peculiar feature of which was that the shuttle was driven entirely around a circle at each stitch. This took a twist out of the thread at every revolution, and was soon abandoned, but not before Howe had sued the proprietors and laid them under tribute.

Allen B. Wilson invented a double-pointed shuttle, making a stitch at each passage of the shuttle, which he patented November 12, 1850.

Grover & Baker, February 11, 1851, obtained a patent for a machine using two needles, one passing through the goods and the other operating beneath the cloth.

[Illustration:

THE OLD AND THE NEW.]

Other patents, of more or less value, were obtained, but not yet had a sewing machine of any practical working value been produced. Machines had been made by hundreds, factories had been built for their manufacture, territorial rights had been sold for machines that contained more or less merit, but which would not and could not do continuous stitching. The idea of a successful substitute for woman's deft fingers at sewing had come to be regarded much as the member of Parliament viewed the project of an ocean steamship, when he offered to "_eat_ the first ship that should cross the Atlantic by steam!" The sewing machine had bitterly disappointed those who purchased it for use in the household; it had bankrupted those who sought to manufacture; it had turned to ashes upon the lips of those who bought territorial rights. If any one had profited by it, it was the vendor of territorial rights. Indeed, a sewing machine patentee named Blodgett told Singer he was an idiot for presuming to make sewing machines to _sell_. They would not work, and the only money to be made out of the business was in "selling territorial rights." Deep-seated distrust pervaded the public mind, and well-deserved odium had settled upon the entire invention. Such was the state of affairs when Isaac M. Singer turned his versatile mind towards the Sewing Machine.

CHAPTER III. THE FIRST SINGER MACHINE.

The humble origin of the first practically successful sewing machine was told by Mr. Singer himself a few years before his death. We reproduce the interesting narrative in his own language:

"My attention was first directed to sewing machines late in August, 1850. I then saw in Boston some Blodgett sewing machines, which Mr. Orson C. Phelps was employed to keep in running order. I had then patented a carving machine, and Phelps, I think, suggested that if I could make the sewing machine practical I should make money.

"Considering the matter over night, I became satisfied I could make them practically applicable to all kinds of work, and the next day showed Phelps and George B. Zeiber a rough sketch of the machine I proposed to build. It contained a table to support the cloth horizontally, instead of a feed-bar from which it was suspended vertically in the Blodgett machine, a vertical presser-foot to hold the cloth, and an arm to hold the presser-foot and needle bar over the table.

"I explained to them how the work was to be fed over the table and under the presser-foot, by a wheel having short pins on its periphery, projecting through a slot in the table, so that the work would be automatically caught, fed, and freed from the pins, in place of attaching and detaching the work to and from the baster-plate by hand, as was necessary in the Blodgett machine.

"Phelps and Zieber were satisfied that it would work. I had no money. Zieber offered forty dollars to build a model machine. Phelps offered his best endeavors to carry out my plan and make the model in his shop. If successful we were to share equally. I worked at it day and night, sleeping but three or four hours out of the twenty-four, and eating generally but once a day, as I knew I must make it for the forty dollars, or not get it at all.

"The machine was completed in eleven days. About nine o'clock in the evening we got the parts together, and tried it. It did not sew. The workmen, exhausted with almost unremitting work, pronounced it a failure, and left me one by one.

[Illustration:

DESERTED BUT DETERMINED.]

"Zieber held the lamp, and I continued to try the machine; but anxiety and incessant work had made me nervous, and I could not get tight stitches. Sick at heart, about midnight we started for our hotel. On the way we sat down on a pile of boards, and Zieber mentioned that the loose loops of thread were on the upper side of the cloth. It flashed upon me that we had forgotten to adjust the tension on the needle-thread. We went back, adjusted the tension, tried the machine, sewed five stitches perfectly, and the thread

snapped. But that was enough."

Persistent efforts have been made by interested parties to create an impression upon the public mind that it was Mr. Howe who first evolved order out of the chaotic essentials of the sewing machine and brought it into practical use. Of this let the reader judge for himself, after comparing the features of each machine set forth below. Let him note the features that are still preserved in every successful sewing machine and those which have been abandoned as practically worthless, and he will find little difficulty in settling for himself the merits of the respective claims of Howe and Singer.

HOWE'S MACHINE HAD ■ _SINGER'S MACHINE HAD_ ■■■■■■■■■■■1■■■■■■■■■■■ _A curved needle. (Now obsolete in ■_A straight needle. (Now in general machines of this class.)_ ■ use.)_ ■■■■■■■■■■■2■■■■■■■■■■■ _A needle arm swinging like a ■_A needle bar moving vertically. pendulum in an arc of a circle. ■ (Now in general use.)_ (Now obsolete.)_ ■ ■■■■■■■■■■■3■■■■■■■■■■■ _A clamp, or "baster-plate," from ■_A horizontal table, upon which the which the work was hung ■ work was laid flat, by means of vertically in front of the ■ which it could be instantly and machine. In order to make a turn ■ readily turned in any direction. in the seam, the machine had to ■ (Now in general use.)_ be stopped, the goods taken off ■ from the plate, and then ■ readjusted to it. (Now ■ obsolete.)_ ■ ■■■■■■■■■■■4■■■■■■■■■■■ _A feed motion imparted to the ■_A feed motion imparted by means of baster-plate by the teeth of an ■ a roughened feed wheel extending intermittently moving pinion, ■ through a slot in the top of the working into the holes of the ■ table. (Replaced by the present baster-plate, from which the work■ feed, similar in principle but was suspended, which had to be ■ improved in action.)_ readjusted every time a seam had ■ been sewed the length of the ■ plate. (Now obsolete.)_ ■ ■■■■■■■■■■■5■■■■■■■■■■■ _Two shuttle drivers, entirely ■_Two shuttle carriers attached to distinct from each other, which ■ the same bar, sliding steadily "threw" the shuttle from side to ■ and regularly in a horizontal side, producing violent ■ groove. (Now in general use.)_ concussions, and liable to throw ■ the shuttle drivers out of place.■ (Now obsolete.)_ ■ ■■■■■■■■■■■6■■■■■■■■■■■ ■_A spring presser-foot by the side ■ of the needle, to hold the work ■ down. (Now in general use.)_ ■■■■■■■■■■■7■■■■■■■■■■■ ■_An adjustable arm for holding the ■ bobbin containing the ■ needle-thread. (Now obsolete.)_ ■■■■■■■■■■■8■■■■■■■■■■■ _A single acting treadle. (Now ■_A double acting treadle. (Now in obsolete.)_ ■ universal use._) ■■■■■■■■■■■9■■■■■■■■■■■ _An eye-pointed needle._ (INVENTED ■_An eye-pointed needle._ (INVENTED BY WALTER HUNT.) ■ BY WALTER HUNT.)

The tests of time and actual service have been applied to the original features of both machines, and these, at least, know no favoritism. It matters not in these tests how broad or loud is the claim of any man; history may be blinded for a time, but the "survival of the fittest" is the inexorable law in useful inventions.

None of the devices used by the man who claims to have "invented the sewing machine" can be found in any successful shuttle machine to-day. Thirty years of actual service have swept away every vestige of Howe's original machine except the eye-pointed needle, invented twelve years before by Walter Hunt, and used by both Singer and Howe. Meanwhile every feature of Singer's original machine has been adopted by every successful machine builder of the class to which these machines belonged, with the single and unimportant exception of the adjustable arm; and in nearly every case when a device of Howe's has been found worthless, and been abandoned, it was Singer's device which was substituted, as the foregoing table explicitly shows. In the clear light of such facts it is not difficult to understand to whom the world is really indebted for the inestimable boon of the sewing machine.

CHAPTER IV. GREAT OAKS FROM LITTLE ACORNS.

Starting with a capital of _forty dollars_, and that borrowed from another man, this poor mechanic launched upon the stormy sea of commercial life. Discouragements and disappointments met him at every turn. People had learned to look upon the Sewing Machine very much as we look upon the "Keely Motor." Every man who pretended to have a working machine was considered an impostor. Thousands had bought machines on the faith of inventors' statements, which they were obliged to throw aside as useless. Whoever now attempted to introduce the Sewing Machine must face all the consequences of previous failures, and this Mr. Singer quickly learned to his sorrow. Everywhere he found people unwilling to believe that a successful sewing machine had actually been built, and repeatedly he was shown to the door the moment he had stated his business.

Mr. Blodgett advised him to give up manufacturing, and sell territorial rights. He said he was a tailor by trade and knew more about sewing than Singer possibly could; that the Blodgett machine had been the leading machine in the market, and he could rest assured that "sewing machines would never come into use."

Still the undaunted mechanic struggled on in poverty, bearing up under reverses and disappointments, resolved to _force_ an unwilling public to recognize the fact that a successful sewing machine could and actually had been made. Slowly he gained ground; gradually he obtained access to the public ear; by degrees he induced people to at least give his machines a test. A few hundred dollars borrowed from friends expedited the work of introduction, and just as the skies seemed to brighten, a new and formidable trouble appeared. The news that Singer had made a machine which would actually do continuous stitching brought Elias Howe, Jr., to his door with the patent he had obtained upon another man's invention (as before stated), who claimed that Singer infringed his patent, and must pay him the modest sum of $25,000 or quit the business. It did not take long for a man who had recently borrowed forty dollars to begin business, to decline paying twenty-five thousand dollars tribute-money, and the consequence was that Singer found himself burdened with litigation that threatened to swamp him.

[Illustration:

YARD OF THE GREAT SINGER FACTORY.]

At this juncture he called in the aid of Mr. Edward Clark, whose recognized legal and financial skill were taxed to the utmost to prevent the utter ruin of the inventor. Mr. Clark became an equal partner, and business was thenceforward conducted under the firm name of "I. M. Singer & Co."

Other inventors were stimulated by Singer's success to vigorous efforts at making machines of practical utility, and the consequence was a series of infringements upon existing patents, resulting in a perfect epidemic of litigation. Principal among the litigants was Elias Howe, Jr., whose patent enabled him to bring all the rest under contribution, and this he did, sueing right and left for several years. The patent of 1846 had made Howe complete master of the situation, and enabled him to dictate the formation of a combination, by the terms of which licenses were issued to manufacturers upon the payment of a heavy royalty for each machine manufactured. From this royalty Howe received the monstrous stipend of over two millions of dollars, not because he had invented anything useful to the world, but simply because he had obtained a patent upon the inventions of another man!

From the outset, Singer & Co. resisted, at great expense, the demands and pretensions of Howe, fighting single-handed the battle of the inventors and the great world which was waiting for cheap machines. Howe was endeavoring to establish a monopoly, strong and compact, which meant dear machines to the weary-fingered women who were still singing the dreary "Song of the Shirt;" Singer & Co. were struggling to throw the business open to fair and honest competition at moderate prices. For three years the unequal contest was continued against the monopoly. All the other manufacturers had yielded to Howe at the first, and were conducting their business without interruption under his licenses. They viewed the contest between Howe and Singer & Co. much as the traditional frontiersman's wife regarded a terrible struggle between her husband and a grizzly, merely remarking that "it didn't make much odds to her which won, but she allers loved to see a right lively fight." If Singer & Co. won, all the others would reap the full benefit of the victory without cost to themselves; if Howe should win, they would be no worse off than they were before, and he would probably cripple their most formidable competitor. Meanwhile the business of Singer & Co. was suffering every possible obstruction, while that of their competitors, now wholly uninterrupted, was making great strides.

[Illustration:

SCREW DEPARTMENT.]

At last, in May, 1854, self-preservation dictated a withdrawal from such a contest, and an agreement was made by which Singer & Co. were to pay Howe a royalty upon each machine manufactured by them. Thus was taken the last and most important step towards the great Sewing Machine Combination, into which Singer & Co. were the last to enter, and then only when driven into it for self-preservation, after a long and exhaustive drain upon their means. In settlement of this suit, Howe received $15,000 royalty, and the total sum paid to Howe by Mr. Singer and his associates, up to 1877, was over a quarter of a million dollars.

By the year 1863, the annual sales of Singer machines amounted to 21,000, and agencies were established in the principal cities of the United States. In that year the firm was merged into an incorporated company, bearing the title of "The Singer Manufacturing Company," and both the original partners retired from the active management of the business, though they remained the heaviest stockholders, and had seats in the Board of Directors.

In four years' time the yearly sale of machines had more than doubled. In two years more even this large figure had been doubled. Two years more and the annual sales had again doubled, the sales of that year (1871), amounting to 181,260 machines. In seven years more even this amount of business was doubled, the number of Singer machines sold in the year 1878 being 356,432. It

would seem as if the extreme limit of business must now have been reached. But still the yearly sale increased, and, in the single year, 1879, the world bought the immense number of 431,167 Singer Sewing Machines, and, at the time of writing, it appears as though even this figure might be surpassed for the year 1880. Three-fourths of all the sewing machines sold throughout the world in 1879 were "Singers."

Perhaps no company ever before was officered as the Singer Manufacturing Company was at its organization in 1863. The business had been originally started by a penniless man upon a borrowed capital of forty dollars, and had brought to him and his partner a golden harvest. Both were now rich, and in stepping out they placed the control of the new Company in the hands of men who had risen to notice solely by their own merits and exertions. The new President, Mr. Inslee A. Hopper, had been an entry clerk with I. M. Singer & Co.; the Vice-President and General Manager was found in the person of Mr. George R. McKenzie, who had been a joiner and cabinet maker for the old firm at eleven and a half dollars a week. He was a hard-working mechanic, whose solid business worth and prodigious ability as an organizer and an executive took him by degrees to the post of General Manager of a business giving employment to forty thousand men, which post he fills to-day with eminent and acknowledged skill. The Secretary was Dr. Alexander F. Sterling, a physician of New York City, who possessed an unusual tact for business; and the Treasurer's post was assigned to Mr. William F. Proctor, who had spent years at a machinist's bench, and whose practical judgment and skill in mechanics are important elements to this day in the management of the business.

In 1876 Mr. Hopper resigned, and Mr. Edward Clark was unanimously called to the Presidency of the Company, and the active management of the business to whose early days he had devoted his abilities with such signal success.

Nor are these the only instances where men have risen from the ranks to high position in the Singer Company. Many years ago, when the old firm was battling with poverty, Mr. Singer sent a bright, energetic, but poor young man, to New Haven, Conn., to open an office and try to establish a business in Singer machines, saying to him, "Jim, we will send you all the machines you want, but not a cent of money." It was the practical application of the polite Southern phrase, "Root, hog, or die." The young man fought his way to business with desperate energy, and to-day is manager of the Central Office at Chicago, having a district covering several States and Territories, and has, within a single year, sold over two million dollars worth of Singer Sewing Machines.

Another young man, who worked as a clerk at six dollars a week in this same New Haven office, is now manager of the immense office at London, which manages the Company's business in Great Britain and Ireland, France, Spain, and Western Europe generally, also Africa, Australia, South America and the British Possessions of Asia.

Not many years since, a bright German boy was employed in the factory, carrying water for the men and doing odd jobs. He did his trivial duties well, however; so well that he was rapidly pushed forward. Step by step he was promoted, and now is manager of the great Singer office at Hamburg, Germany, which does a vast business throughout Central and Eastern Europe, and is pushing its way into Western Asia. Like the others, he began without friends or influence, and has won his present proud position by faithful adhesion to duty in the humblest post, by modest energy and strict integrity.

[Illustration:

ASSEMBLING ROOM.]

The Central Office managers at Cincinnati and St. Louis, each doing a large business and entrusted with great interests and responsibilities, began at the lowest round of the ladder, and have climbed unaided to their present positions. Surely there has been no royal road to position in this remarkable company.

It is doubtful if the history of the entire world can furnish an instance in which any single house, doing a legitimate business, has had a growth so stupendous within an equal length of time. The reader will remember that Arrowsmith, the purchaser of Hunt's first machine, failed to patent the invention because, among other reasons, it would require "at least three thousand dollars" to begin the business of manufacturing and selling sewing machines. Little did he dream that within thirty years a single company would have millions of dollars invested in the manufacture of one form of sewing machine! Arrowsmith urged for his fatal delay in procuring the patent to which he was then entitled, that the fees were so heavy—some $60! And now one company spends thousands of dollars annually in the various forms of advertising!

Still another reason urged by this enterprising smithy was that he "had other business." Yet, within thirty years a single company finds itself with over ten thousand employés under regular salaries or wages, and thirty thousand more working the whole or part of the time on commission. And this Company, investing many millions of money in its business, spending thousands every year in

advertising, employing some forty thousand persons, eight thousand horses, and having its own locomotive and steamboat busy in transporting its machines and materials between New York and its great factory at Elizabeth, is, as the reader may have surmised, The Singer Manufacturing Company.

[Illustration:

JAPANNING FURNACES.]

Its system of agencies embraces the entire civilized world, and even pushes its outposts across the boundaries into semi-civilized lands. All of the United States and Canada are covered with this grand network of agencies; Mexico, the West Indies, and South America are familiar with the name "Singer." Every nook and corner of Europe knows the song of this tireless Singer, too, and so do the colonized portions of Africa, Asia, and Australasia. An immense business is done in Singer machines in Australia; thriving agencies and sub-agencies may be found throughout China, Japan, and the Islands of the Indian Ocean. Calcutta has a large business in Singer machines, and even Cape Town and Transvaal, in South Africa, are giving the Singer agents an increasingly large patronage.

On every sea are floating the Singer Machines; along every road pressed by the foot of civilized man this tireless ally of the world's great sisterhood is going upon its errand of helpfulness. Its cheering tune is understood no less by the sturdy German matron than by the slender Japanese maiden; it sings as intelligibly to the flaxen-haired Russian peasant-girl as to the dark-eyed Mexican Señorita. It needs no interpreter, whether it sings amid the snows of Canada or upon the pampas of Paraguay; the Hindoo mother and the Chicago maiden are to-night making the self-same stitch; the untiring feet of Ireland's fair-skinned Nora are driving the same treadle with the tiny understandings of China's tawny daughter; and thus American machines, American brains, and American money are bringing the women of the whole world into one universal kinship and sisterhood.

[Illustration:

CASTING IN THE FOUNDRY.]

The Principal Office of the Company is finely located in New York City, overlooking Union Square. From this office the general business of the Company is directed all over the world. The American business is transacted from twenty-five centres, located in the larger cities, such as Philadelphia, Chicago, San Francisco, Boston, Pittsburgh, New Orleans, Richmond, Cincinnati, St. Louis, etc. Each Central Office is controlled by a manager, under whose direction Branch Offices are located throughout the territory assigned to his care. Under the Branch Office agent, again, are located subordinate offices in every town or village within his district where business seems to warrant it. The territory controlled by a Central Office often embraces an entire State, and, in some cases, several States. In other instances two or more Central Offices are located within the same State. While the Central Office manager is charged with the general direction of all his Branches, and the Branch Office agent with the care and management of all his subordinate offices, yet the reader should not suppose these superior offices to be nothing but a sort of head-quarters for the officers of higher rank. Every Central Office is equipped with its force of canvassers, collectors, etc., and is expected to accomplish as much of the actual work of canvassing and selling as though it were the only office the Company ever opened. The same is expected of the Branch Office, and woe to that manager who cannot do duty as a private soldier, and make his own office an example in all respects to the smallest "sub!" It were better for him that the General Manager had never been born! The Canadian business is similarly managed from two Central Offices: one at Montreal, the other at Toronto. All these twenty-seven Central Offices report to New York, and receive their instructions direct from the officers of the Company.

The London office has immense interests confided to its care, as before stated. The South American business is managed from London, principally because England enjoys facilities of communication with that continent which even Yankee enterprise has thus far neglected to secure for our own country.

[Illustration:

NEEDLE DEPARTMENT.]

The business of Middle and Northern Europe and of Western Asia is managed from the Hamburg office, which, like the London office, makes a consolidated report to the principal office in New York. The total number of the Company's offices throughout the world is over 4,500, of which over one-third are in the United States.

The foregoing are but a few of the interesting details of the organization and management of this remarkable Company. It is doubtful if any public or private corporation in the world can show so complete an organization. No bank is more scrupulously exact in every detail; no army has a more systematic discipline. And while such a complete system is necessary to prevent so enormous a business, covering so much ground, from falling to pieces by its own weight, yet it is also true that the very completeness and compactness of this organization are themselves the best possible guarantees for the permanence and indefinite prosperity of this gigantic corporation.

CHAPTER V. THE GREAT FACTORY.

Our lady friends may like to know how and where the "Singer" was made which has done such valued service in their homes, and as it is a most natural desire, we are glad to be able to gratify the same. We, therefore, cordially invite all who feel disposed to come along while we take a hurried, but, we hope, interesting glance at the various parts of this mammoth workshop.

[Illustration:

FORGING SHOP.]

[Illustration:

CLOCK TOWER.]

Leaving the City of New York by the New Jersey Central Railroad, we dash through a dozen pretty Jersey villages, cross Newark Bay upon a bridge which lacks but a few feet of being two miles long, rush past the walls of the great Singer Factory, and alight at the Elizabethport Station, just beyond. This is one of the seven railroad depots of the beautiful City of Elizabeth, New Jersey. Looking back down the track, we see a finely laid-out park, with well-kept walks, handsome shrubbery and trees, and a profusion of flowers, in the centre of which stands a large fountain. This is the private park of the Factory, and is by far the handsomest in the city. The Singer Company bought an entire block in front of the Factory, and transformed it into a park which they maintain at their own expense. Beyond "Singer Park" loom up the massive proportions of the Singer Factory, four floors high, the upper story having a massive Mansard roof. The building is built of brick, iron and slate, with iron beams and girders, and is proof against those conflagrations which so often destroy human life in large manufactories. The front is constructed of handsome pressed brick, and the structure is adorned with a tower in which a large clock shows the "hours as they fly" to all the neighborhood.

[Illustration:

SHIPPING SHEDS.]

Passing through the light and handsome offices, we find ourselves in what at first sight appears to be another park, shut in on three sides by long lines of high buildings. This is, however, not designed for a park, but is nothing more than the superbly-kept Factory Yard, embracing ten or twelve acres. Asphalt walks run down and across, connecting the various buildings that skirt the yard with each other, and with the dock at its foot. Beside and between the walks, every square foot of ground in this immense yard has been seeded with grass, whose green and well-kept borders are here and there fringed with shrubs and flowers. The walks are neatly kept, and though over two thousand workmen tramp daily through the yard, we will not see a bit of dirt as big as a filbert anywhere.[1] Up and down run railroad tracks from the main gate to the dock, with branch tracks to each shop door. These tracks aggregate over five miles in length, and are in constant use in bringing coal, iron, and lumber from the Central Railroad track outside, or the dock at the foot of the yard, or carrying car loads of machines to one or the other outlet. For this purpose the Company owns a locomotive, the "I. M. Singer," which puffs away busily at its work from morning till night. Here are long sheds, beneath which cars are being loaded with Singer machines for Chicago, St. Louis, or San Francisco. There are long trestles opposite the foundry doors, upon which coal cars, direct from Pennsylvania mines, are pushed by the "I. M. Singer," and their contents deposited "where they will do the most good." Iron, sand, and lumber cars are sent similarly to the exact spot where they are to be worked up, and so an immense cost of handling is saved. At the dock, which lies along Staten Island Sound nearly a thousand feet, the Company's steamer "Edward Clark," is taking on board a cargo of machines for New York City, or perhaps for some European steamship lying in New York Bay.

Footnote 1:

An amusing instance recently occurred in a Southern State of the use to which these grass plats could be put by persons whose tender consciences would not permit outright lying. A man interested in selling a cheap imitation "Singer," sent a letter to a Southern paper, enclosing a spear of grass which, he said, he "had plucked in the yard of the Singer Factory," as evidence that the Singer Company was falling into decay, and its great factory being overgrown with grass and weeds.

Taking it for granted that all women are methodical, we must ask our fair visitors to go with us to the foot of the yard, and begin studying the manufacture of sewing machines just where the manufacturer is obliged to begin making them—at the foundry.

[Illustration: [Furnace]]

[Illustration:

BRASS FURNACE.]

Passing the great piles of pig-iron and the greater heaps of coal, we enter the foundries. Upon yonder high platform two men are throwing great lumps of coal into the blazing, roaring mouth of a fiery furnace; and presently they stop throwing in coal, and begin to pitch in heavy bars of pig-iron, while the furnace hisses aloud with its fervent heat till it reminds us of Nebuchadnezzar's. At the foot of this furnace or "cupola" two or three men are catching the molten iron in a huge pot on wheels which, when full, is drawn to another part of the foundry, and there another lot of men surround it, their hand ladles are poured full, and away they hurry with their hot and heavy burden to fill the long rows of moulds which cover the floor. Four such cupolas are breathing out great blasts of fire at their tops, and running streams of fiery liquid iron at their bases. Three of them have a capacity for melting eight tons of iron each per hour, and the other converts six tons of pig-iron into liquid each hour. The morning hours are occupied by the moulders in making moulds in sand of the various parts to be cast; and for about two hours in the afternoon the cupolas send out their sparkling streams, and the men fill the moulds with molten iron. When sufficiently cooled, the moulds of sand are knocked to pieces and the iron taken out and thrown into piles about the floor, while the sand is shoveled up and moistened for another day's moulding. Four hundred men are employed in this immense foundry, which melts up sixty-five tons of iron every day in the week. The ground floor of the foundry has an area of over _two acres_. Imagine a two-acre field filled every day with iron castings of Singer sewing machines!

And this is only a part of the iron work composing the machine. Much of the machine is composed of steel and wrought iron, which starts on its trip from the Forging Shop, instead of the Foundry. The portions cast in the foundry embrace the machine legs or "stands," the "arm" and "bed," the balance-wheel, band-wheel and a few minor parts. These parts, after cooling and being removed from the moulds, are taken to the Rumbling Room, 50 feet wide and 200 feet long, and put into revolving barrels filled with small five-pointed cast iron stars, which tumble about the barrels among the castings for hours together, and by the constant friction wear off all the sand and roughness.

The machine legs or stands then go to the Drilling Room, where the screw-holes are drilled out, and thence to the Japanning Room, where a set of grimy men, in half undress costume, souse them into a vat of liquid japan, after which they are put into great brick ovens, and left for several days for the japan to thoroughly bake and harden. This gives them a handsome, black, glossy finish and prevents rust. The other cast iron parts are similarly treated, except the "arm" and "bed;" these, after being firmly secured together, are japanned and scoured down; then japanned again, and again scoured down. A third japanning and scouring is then given and they go to the Ornamenting Room, of which we shall see something shortly. The wheels, and other parts which work against other portions of the machine, go before japanning to the Milling Department, an immense shop 1,250 feet long, upon two floors, and 50 feet wide, where they are put upon a lathe and shaved off with steel knives to the exactness of a hair.

Next above the Rumbling Room we come to the Forging Shop. Here numbers of great drop hammers are stamping out, at a single blow, the steel and wrought iron parts of the machines. These hammers weigh from three hundred to fifteen hundred pounds each. They are made with a "die" on their face, and the bed or anvil on which they drop has a corresponding die, so that a bar of hot iron held on the anvil is, by a single blow of the falling hammer, converted into a shuttle, a feed driver or a completely formed lever. Even the shuttle, which looks so much like a little boat, is made with a single blow of a huge drop hammer, which converts a square bar of iron in an instant of time into a perfectly formed shuttle. It is afterwards taken to another room, where another machine, with just one vigorous _push_, forces the shuttle through a sharp-edged aperture in a steel die, which trims off all unevenness and every bit of steel that may have projected beyond the edges of the die in the drop hammer. In another room the shuttle is drilled with holes for the thread; in another it is polished on an emery wheel, and in yet another is fitted with the little check spring, and then, after receiving the bobbin, it is ready for service in _your_ Singer machine. The Forging Shop is 423 feet long and 50 feet wide.

[Illustration:

STOCK ROOM.]

Leaving the Milling Department, each article is passed to the Inspection Department for "Parts," where every piece or "part" is examined and measured with an accurately made steel gauge, and only such as are found to be exact and true to the thousandth part of an inch, are permitted to go on to the Stock Room. The rejected parts (and such is the accuracy of the machinery that these are comparatively few) go again into the furnace to be made over from the beginning. It is largely owing to the impartial rigidity of these inspections that the Singer machine has become so famous for evenness of work and for immunity from the periodical "fits" of misbehaving which so often afflict machines of other makes.

And so the Singer Company makes no second grade articles, and puts nothing but the very best material and workmanship into any of its machines, finding, by practical experience, that it pays to put just as good parts into its cheapest as into the highest priced pearled and ornamented cabinet machine. Indeed, the only difference between the cheapest genuine Singer and the most costly machine is in the finish, decorations and cabinet work. All the working parts are exactly the same.

The carefully inspected parts, after passing muster, are sent to the General Stock Room, where long rows of cases, extending nearly to the high ceiling, receive each sort into its appropriate box or shelf. Thence they are distributed in due proportions to the Assembling Department when called for. The Stock Room is 50 feet wide and 180 feet long.

Our fair friends will remember that we left the machine heads and bed plates in the Japanning Room, being scoured down after japanning. We must go back to them in order to keep up the connection. After being carefully scoured, the heads are sent to the Ornamenting Department, where skillful workmen pencil out, with a fine camel's hair brush, the designs of flowers and scroll work which ornament that portion of the machine which rests upon the table. The rapidity with which these pretty and often intricate designs are traced is wonderful. Look at your machine at home; observe all the gilded ornamentation and design, and then fancy a man doing such a machine head "offhand," without the least guide for hand or brush, at the rate of 100 machines a day! As quickly as the penciling is done the machine is seized by another man, holding in his hand a book of gold leaf, which he deftly lays over every pencil-line. The gold leaf firmly adheres to the "sizing" laid on by the brush and the rest is rubbed off by a single touch of another man who passes a piece of soft cotton batting over it. The whole is then varnished with the best quality of white varnish and placed in a huge oven, where it bakes till it has become perfectly dry, hard and glossy. The Ornamenting Room is 125 feet long and 75 feet wide.

[Illustration:

ORNAMENTING THE MACHINE.]

The larger parts of the machine having now been japanned and ornamented, are brought to the "Assembling Room," and at the same time the small working parts are brought from the Stock Room, and here all these parts are "assembled," or brought together, and each placed in its proper position within or upon the machine head. Each of these parts has been so nicely fitted, and so accurately worked by the machinery which made it, that when the numerous and varying pieces come together in the assembling process, it requires little and often no adjustment whatever, and each fits in the place made for it, resulting in a complete and harmonious whole. Connecting with this Department is the Adjusting Department, where long rows of machines on benches are being run by steam at a very high rate of speed. This is yet another of the many testing processes through which your family "Singer" has gone in order to insure the absolute perfection of its working parts. Up and down these long rows of humming machines, skillful and patient mechanics are passing, narrowly watching each machine to see if it runs smoothly and properly. If a wheel revolves unevenly here, or a "bearing" pinches or is too loose there, back goes the machine to have the deficiency remedied, after which it must again pass the same ordeal. The Assembling and Adjusting Departments are 50 feet wide, and occupy a length of 1,100 feet on two floors. The views in these rooms cannot be adequately described, and we therefore give our readers accurate full page representations of the same.

Next comes the Machine Inspection Department, 200 feet long and 50 feet wide. Here the machines are again inspected by competent artisans, and if perfect in every respect are passed over to long rows of girls, who put them through the further test of stitching, and see that they are capable of producing an absolutely perfect stitch. Over fifty girls are constantly employed in this particular work.

[Illustration:

"SETTING UP" THE MACHINES.]

The next process is what is technically known as "setting up." The Setting Up Department is 460 feet long and 60 feet wide, and here the stands and tables are put together and placed in long rows; the complete machine head is properly fastened in its place, the belts and treadle are adjusted, and the machine stands on its table ready for duty.

Only one more operation is necessary for transportation, and that is packing or crating the machine. This is all done in the Shipping Department, which is 230 feet long by 60 feet wide. The boxes and crates have already been completely made up in the Box Shop, and nothing remains but to put the machine into the box or crate, as the case may be, drive three or four nails, mark the package with a stencil plate for its proper destination, on New England's shores, on the great prairies of the West, amid the savannas of the South, or, perhaps, across the seas, lower it upon the elevator to the great shed, where it is loaded upon the cars. If its route lies _via_ New York, it is placed upon a platform car, which the Company's own locomotive, the "I. M. Singer," draws to the dock to be shipped on board the Company's boat, the "Edward Clark."

A few parts of the machine require to be smoothly polished in order to secure the very best working capacity, and these are sent to the Polishing Room, which is a study of itself. Black wheels of all sizes are here revolving with great speed; some are rolling around on a horizontal axis, some are whizzing rapidly on a perpendicular axis, and from all of them the streams of fiery sparks are flying in unceasing currents, throwing the grimy room and the darkened forms of the busy workmen into a still darker background. This Department is 125 feet long and 50 feet wide.

[Illustration:

POLISHING ROOM.]

Another room is devoted to the manufacture of the steel springs used in the machine. In another large department, 200 feet long, screws are being made by automatic machinery. In another room, 100 feet long, the tools are made and repaired, and here a large force of skilled workmen is constantly employed. In still another room, filled with electro baths, the silver plated attachments are covered with their silver coats.

The Button Hole Department is 150 feet long and 50 feet wide, and here the new Singer Button Hole Machine is put together. This is an intricate and wonderful piece of mechanism, by which an expert operator can make from 1,500 to 2,200 button holes a day, and sew the same thoroughly. This machine has but recently been introduced into general use, but has come rapidly into favor with manufacturers, especially tailors and makers of shoe uppers. It makes and works a complete button hole in either cloth or leather, and has come so extensively into favor that the Button Hole Department has outgrown its original quarters, and must be considerably enlarged. This, indeed, is true of almost every Department in the entire factory. When this great establishment was built, in 1873, it was thought a good week's work to turn out 4,000 complete machines; but at this time its weekly product is upwards of 8,000 complete machines. Besides these, the Singer Company's other factory at Glasgow, Scotland, is turning out between 4,000 and 5,000 complete machines each week, and yet the offices throughout the United States and Canada are complaining of the injury their business receives because they cannot get enough machines. The factory at the time of writing is largely behind its orders. Enlargements of various departments have been made from time to time, but the demand is yet far ahead of the capacity for production.

The Needle Department is one of the most interesting features of the entire establishment. Here a coil of steel wire of fine quality is put into a machine, which straightens, then grooves it on both sides above and below the spot where the eye of the needle should be, and cuts it to proper length. A girl then takes a handful of needles, and, feeding them into a machine, punches the needle eye at a single blow. Then they are ground down to a point; after which they are tempered, and then the inside of the needle eye is polished out to prevent its cutting the thread. The whole needle is finally polished, and nothing more then remains but counting the shining bits of steel and packing them away in boxes for the trade. The Needle Department gives employment to 100 men and 50 women.

Below the main building is a three-story brick building 200 feet long, in which the cabinet work is partly done. The Company has a large factory at South Bend, Indiana, where most of the black walnut tables, covers, and cabinet cases are made. Portions of these are sent to Elizabethport in a partly finished condition, and all such receive their finishing in this shop.

Still below is another similar building, the "Box Shop," where some sixty men are employed in making the packing boxes and crates in which the machines are shipped from the factory. The Box Shop cuts up for this purpose no less than 300,000 feet of pine and

spruce lumber every month.

To run this immense establishment, six stationary steam engines are required, which have a combined strength of one thousand horse power. It takes twenty-two boilers, averaging seventy-five horse power each, to furnish the steam for running these engines and heating the buildings. The floors of the buildings have a combined area equal to _thirteen acres_ of ground; and every square foot of the entire area is in constant use. The whole premises, including the fine dockage, covers no less than thirty-two acres of ground.

Such, in brief, is the factory where your Singer machine was made, dear reader. It is believed to be the most complete, systematic, and best-equipped in the world. It is believed to be the largest establishment in the world devoted to the manufacture of a single article. It gives employment to over 2,300 men and women, and when it "shuts down" to take the annual account of stock, it takes 200 men to do it; and this they call "shutting up the factory!" The men are paid off every _Monday_, instead of every Saturday, and thus in more than one family the wife and children have had cause to bless the kind forethought which removed temptation from the path of some easily persuaded man, and saved him and his week's earnings to themselves.

[Illustration: [Pouring Molds]]

The Singer operatives are among the most thrifty of mechanics. In every case of injury to any of its employés, the Company has dealt with great generosity, and many are the households from which much of the black shadow caused by sickness has been chased by the substantial aid it has afforded. Nor do the hands leave this work alone to their employers. Hardly a man is stricken by disease among their ranks but his comrades interest themselves in his case; and if pecuniary aid is required, the subscription list goes around till every want is supplied at the sick man's home.

These kindly offices are not confined even to these ample limits. When the ghastly Yellow Fever Spectre was carrying dismay and death throughout the Southern States, the employés of this great factory made up, in less than four days, the splendid sum of $4,100, and sent it out on its errand of mercy to men whom they had never seen nor known.

The factory hands have organized among themselves several very creditable associations. One is a fine Rifle Team, to which the Company contributed a handsome badge for an annual prize; another is a Brass Band of excellent reputation, besides several Ball Clubs having very good records.

CHAPTER VI. THE REASON WHY.

There is a valid reason for everything in this world, whether we are able to find it or not, and for all this wonderful growth and Aladdin-like success there is a reason too. In 1872, when the great Chicago fire had impoverished thousands of the residents of that city, the Relief Committee undertook to furnish sewing machines to all the needy sewing-girls who might apply. Each girl was permitted to choose her machine from among the sixteen different kinds kept by the Committee. The total number of women who took machines was 2,944, and of this number 2,427 chose Singer machines, and the other 517 women distributed their choice among the fifteen other kinds of machines. These poor women expected to earn their living on these machines, and there must have been some reason why such an overwhelming majority of them took "Singers" instead of machines of other make, each of which was loudly proclaimed by its manufacturers to be the "best in the world."

The Singer Machines have been awarded the first premium over all others more than two hundred times, at great World's Fairs, at State Fairs, and at County Fairs in every part of the United States.

As we have before stated, three-quarters of all the sewing machines sold throughout the world in 1879 were "Singers," and there must be a reason for that. When any one style of machine, used in millions of homes, leads all the other kinds to such an extent as that, there must be some way of accounting for it all, and if our readers choose to read on they will shortly discover why.

An interesting fact in this connection was related to the writer recently by Mr. Galland, a large manufacturer of ladies' garments, whose factories are located at Scranton, Pennsylvania. The Gallands use several hundred sewing machines in their factories, operating them by steam. They had machines of many different makers originally, but gradually, as these machines wore out, had been replacing them with "Singers." The reason assigned was that they had noticed, from time to time, that when a Singer machine became vacant, the girls who worked on machines of other kinds were clamorous to obtain the Singer and leave their own; and, when machines of other make were vacant, the girls were full of excuses for not taking them, but seemed desirous of waiting for the next vacancy, in hope of getting a "Singer." These observations led to inquiry from their master mechanic, who explained that the

girls working on “Singers” lost less time in repairing, and in those peculiar sewing machine “fits,” than the girls who operated other machines. At this point the pay rolls were consulted by the inquiring proprietors, and there the whole secret lay exposed to view; for the work was paid for by the piece, and the rolls showed that the girls operating Singer machines were earning from one dollar to two-and-a-half dollars a week more than the other operators!

[Illustration:

TESTING THE MACHINES.]

Here then is the open secret of the Singer Machine’s favor with the people. It is so simple that a child can understand it; it is so strong that a bungler can hardly get it out of order, and every part (as we have seen) is made with such scrupulous exactness out of the best materials, fitted in its place to the _thousandth part of an inch_, and tested and re-tested so many times before it is permitted to leave the factory, that it does not get the “fits” which try a woman’s patience, destroy the fruits of her labor, and consume her time in vexing attempts to coax the machine back to duty. A gentleman wrote to the Company quite recently that he had a Singer Machine bought twenty-three years ago, and in use all that time, which sews perfectly to-day.

Many people sit bewildered by the immensity of the Sewing Machine trade, and wonder what becomes of all the machines. The answer is very simple. If the trade is large, the world is larger still. Carefully prepared statistics show that the entire world contains at the present time not over six million sewing machines, good, bad, and indifferent. The United States alone contain nearly ten million families. But fully one million machines are not in homes but in factories, operated by steam, driven at the highest possible speed, and consequently wearing out in a few years. Therefore, if all the machines in the world were brought here they would supply only half the families of our own land. The civilized countries of the globe, where sewing machines are now being introduced, have over seventy million families, not including China, Japan and India, where a trade is being rapidly developed. In a word, the sewing machine is now being offered to a population of not far from a hundred million families, and the world contains not more than six per cent. of the number of machines necessary to supply them, without considering the enormous consumption of machines in shops and factories.

It is plain, from these figures, that great as the trade has grown from the small beginning, it is yet in its infancy. Nevertheless, it has proved, except in a few instances, one of the most hazardous of enterprises. Probably as much money has been lost in the sewing machine business as has been made. The introduction of steam into manufactures and commerce has wrought changes so marked and rapid that none but keen and careful students of their own times could keep track of them, and thousands of good men have gone down because they had not considered the new elements introduced, particularly into manufacturing industries, by steam and improved machinery. These have brought in a subdivision of labor which our forefathers scarcely dreamed about, and which we have seen in our trip through the factory. It is almost incredible what speed a mechanic acquires whose task consists in performing one single brief operation, and repeating it over and over a hundred times an hour for months and years. We watched, with wondering interest, a man varnishing the under surface of the machine bed-plate. The space to be varnished was about a square foot in area, filled with obstructions and angles, every one of which must be touched with his brush. The operation was reduced to an exact science. His left hand caught the machine arm in just such a place every time; his brush went into the pot in just such a way; just so many sweeps it gave this way, exactly so many that way, and with precisely such a toss every time it was spun across the table to his assistant. Spring and summer, fall and winter, that man did nothing but wipe that brush just so many times across that square foot of iron, and he did it with a precision and rapidity that was marvelous. The quickest painter we ever saw could not do one machine while he would finish five.

[Illustration:

PUNCHING THE NEEDLE EYE.]

And this is but a type of several hundred different operations into which labor is subdivided here, and which, by such subdivision, is so cheapened that employers whose capital and business will warrant it, can pay labor a good price and yet drive out competitors who are without large capital, large business and skill to use the advantages which are thus available. On this rock many sewing machine manufacturers have split without, perhaps, knowing that it was only the lack of a large demand for their machines, and the absence of a large and well-directed capital which wrecked them. In the last few years over fifty sewing machine companies have failed, and swamped large nominal capital in the aggregate.

The lesson is almost too obvious to justify the formulating of a prophecy that the sewing machine business of the future is likely to concentrate in a comparatively few corporations, whose skill, capital and facilities will be sufficient to bring out the best machines, made of the best materials; paying their skilled operatives liberal wages, and yet enabled, by this subdivision of labor, to offer them to the people at a price within the reach of all.

Such is the story of the Sewing Machine from its paltry and inauspicious beginning. Such were the struggles and trials of the man to whose genius the world owes the vast, incalculable, and forever accumulating benefits of this great invention. And when we try to conceive what the world would be to-day if the Sewing Machine and all its concomitant blessings were suddenly removed from among its inhabitants, we look at this record of his achievements and rich triumphs, and rejoice that the common experience of inventors was not realized in the Sewing Machine invention, but that in this instance, at least, a great mechanician lived to see his

[Illustration:

SINGER'S ORIGINAL MACHINE.]

TRANSCRIBER'S NOTES

Page Changed from Changed to

18 "_cat_ the first ship that "_eat_ the first ship that should cross the Atlantic by should cross the Atlantic by steam!" steam!"

● Typos fixed; non-standard spelling and dialect retained. ● Enclosed italics font in _underscores_.

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Untitled

Edward Mahon Wev

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Transcriber's Note

In this transcription, bold text is denoted by =equal signs=. Small capitals in the original text have been transcribed as Title Case.

See end of this document for details of corrections and other changes.

———————————— Start of Book ————————————

TELEPHONE TROUBLES

THEIR LOCATION AND REMEDY.

BY E. M. WEV.

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NOTE.

In putting this little book before the telephone workers I do so with the idea of helping the beginner and furnishing a guide for the experienced man. It is composed of information gained by 15 years' practical experience. E. M. W April, 1907.

CONTENTS.

CHAPTER. PAGE.

I. Direct Line 1

II. Two Party Line 14

III. Four Party Set 17

IV. How to Test For and Clear Troubles in

Private Branch Exchange Switchboards 25

Inspection 40

TELEPHONE TROUBLES. ————————

CHAPTER I.

DIRECT LINE.[1]

Bell Doesn't Ring at all.

May be caused by any of following:

1st. Condenser open. 2d. Ringer open. 3d. Hook contacts crossed. 4th. Desk stand cords or induction coil crossed. 5th. Extention bell open. 6th. Ringer short-circuited. 7th. Trouble at central office.

1st. When condenser is open you will get weak hook clicks and side tones and hearing very weak. Prove by short-circuiting the condenser at the lugs with a test cord, which should make the ring of the bell and hearing O.K.

(While the condenser is short-circuited you will get only one hook click.)

2d. Only one hook click, the side tones normal, and the failure of the ringer armature to move when you raise or lower the hook, indicates that the ringer is open.

Prove by replacing the receiver on the hook and then bridge across the condenser lugs with your head receiver; if you do not get a good click every time you make contact, the ringer is open.

Or you can make the following test; open the strap at the top of the bell, then short-circuit the condenser lugs with a test cord; then connect one side of your head receiver to one of the line binding posts, and feel with the other side on the terminals of the ringer; if you get battery on one terminal and not on the other the ringer is certainly open.

3d. Only one hook click, side tones normal, failure of the ringer armature to move when you raise and lower the hook, and the receiver in circuit while the hook is down, indicates that the hook contacts are crossed together. When this is the case, the bell will ring poorly or not at all, and the ring can be heard in the receiver when the hook is down. Open the receiver circuit at one of the receiver binding posts, this should allow the bell to ring all right.

4th. Red and white strands of desk stand cord or primary and secondary of induction coil crossed together will generally cut down hearing; it may or may not cause only one hook click, and may or may not put battery through the receiver, and may wholly or only partly prevent the bell from ringing. Disconnect the strap on top of the bell and test with your head receiver from the G post to the L2 post; if you get battery there is a cross; disconnect the red and white strands of the desk stand cord, this will show whether the trouble is in the desk stand cord or in the bell. If it is in the bell, disconnect No. 2 and No. 4 terminals of the induction coil, and test again, to prove certainly that the trouble is in the coil itself and not in the wiring.

5th. If there is an auxiliary bell, and it is open, the set will test as though it had an open ringer. Test by short-circuiting the L2 and G posts, which cuts out the auxiliary bell and makes it a straight set for the time being.

6th. If the ringer is short-circuited you will get battery through the receiver, which can be detected by listening while you short-circuit the receiver binding posts with your screw driver blade. To prove, disconnect the bridge from the top of the bell, and connect the two line wires to the L2 and G posts instead of the L2 and L1 posts; short-circuit the condenser lugs with a test cord, and then bridge your head receiver across the ringer terminals; if the ringer is all right you will get a heavy click, if it is completely short-circuited you will get no click at all, if it is partially short-circuited you will get a partial click.

Bell Rings Weakly.

May be caused by:

Poor adjustment of armature or gongs.

Pivot screws too loose or too tight.

Clapper rubbing on guard.

Wiring interfering with the clapper stem.

“Whiskers” on the magnet heads.

Magnet heads sticky or gummy.

Desk stand cord, induction coil, or hook contacts crossed.

One or both coils of the ringer partially short-circuited.

Polarizing magnet weak.

Carbons in protector dirty and generator current jumping across them.

Trouble at the central office.

Bridge on the Line, Steady Light at Central Office.

Prove whether the trouble is in the instrument or not by disconnecting both sides of the line at the top of the bell and going in with your head receiver. If you get central the trouble is in the instrument and the same will be found either in the wiring, desk stand cords, or the hook. If opening the strap (see diagram No. 1) does clear the trouble, the leak is across through the ringer, and must be due to:

1. Receiver contact of hook not breaking. If this is the case, opening the receiver circuit at one of the receiver binding posts will clear the trouble temporarily.

2. White and green strands of the desk stand cord crossed together. If this is the trouble, disconnecting the cords from the bell will clear it.

[Illustration: Fig. 1.]

3. The condenser must be short-circuited if the trouble is not in the hook or cords; if the condenser is completely short-circuited, there will be but one hook click, but often there is enough resistance in a condenser short-circuit to give both hook clicks. To make sure that the trouble is in the condenser itself, and not in the wiring, disconnect one terminal of the condenser and go in series with your head receiver.

Instrument Entirely Dead, Nothing can be Heard in the Receiver.

See first that you have battery at the top of the bell.

The trouble may be due to:

1. Receiver circuit open. 2. Receiver short-circuited.

1. If there is an open in the receiver circuit, it may be in either the receiver itself, the receiver cord, the white strand of the desk stand cord, the receiver contact of the hook, or the secondary; bridge your head receiver successively around these parts, when you bridge around the open you will get the side tones in the head receiver.

2. To prove whether a receiver is short-circuited or not, connect your head receiver in series with it; if the head receiver responds while another receiver in series with it does not, the other one cannot be open, and therefore, must be short-circuited.

Transmitter out of Circuit, but Hearing not Entirely Cut Out.

May be caused by:

1. Open in green strand of desk stand cord, transmitter or transmitter wiring.

2. Transmitter short-circuited.

3. Red and white strands of desk stand cord crossed together.

1. No hook clicks, transmitter entirely dead, but can hear induction on the line, and can hear the effect of short-circuiting the line at the top of the bell indicates an open. Locate by connecting one terminal of your head receiver to the L1 post, and feeling with the other terminal successively on the several points of the transmitter circuit from the L2 post to the hook; as soon as you pass the open you will cease to get battery through the head receiver.

2. Strong hook clicks, transmitter entirely or nearly dead, but can hear induction on the line and the effect of short-circuiting the line at the top of the bell, indicates transmitter short-circuited. Open at the transmitter and put your head receiver in series to see whether the trouble is a short-circuit inside of the transmitter head, or a cross of the transmitter cord or the green strand of the desk stand cord with the frame of the desk stand.

3. Two hook clicks, but the transmitter dead and cannot hear induction on the line, and cannot hear the effect of short-circuiting the line at the top of the bell, and bell rings poorly or not at all, indicates red and white strands of the desk stand cord crossed together which short circuits the receiver while the hook is up. Disconnect the strap at the top of the bell, and test as previously directed from the G post to the L2 post; if you get battery the cord is crossed.

Transmission Poor.

May be due to:

1. Transmitter packed or otherwise bad.

2. Red strand of desk stand cord, primary, or hook contact open (in which case the hearing will also be poor).

3. Primary or secondary reversed.

4. Primary and secondary crossed together (this will also affect the hearing).

5. High resistance in the line or instrument.

1. When a transmitter is believed to be packed, call the wire chief, being very careful not to shake it up or jar it, and get him to note the way it transmits; then shake it up thoroughly, and see what the effect is on transmission. When a transmitter is suspected of packing but you fail to catch it in the act, you can sometimes pack it by blowing gently into the mouth piece for a minute or so; but in making this test be careful not to condemn a good instrument, as almost any transmitter is liable to a certain amount of packing, and will come up stronger immediately after having been shaken up.

When a transmitter is suspected of being otherwise defective a sure test can be made by temporarily swapping faces with some other instrument that is all right.

2. Only one hook click and weak side tones indicate primary or red cord open. Connect one terminal of your head receiver to the L2 post and test with the other successively on the L1 post, No. 1 and No. 2 terminals of the induction coil, red cord post in desk stand, hook spring, and hook; as soon as you pass the open you will not get battery.

3. Examine 1 and 2, and 3 and 4 of the coil to see that they are not reversed, that is, see that the numbers of the coil terminals correspond with the numbers of the lugs that they connect to. If the coil is reversed internally, so that the numbers correspond but nevertheless one of the windings is wrong, it can only be detected by the man at the other end. Call up the wire chief or go to another instrument yourself and listen to the transmission from the suspected instrument; if the coil is reversed the transmission will be muffled. Prove by reversing either the primary or the secondary, which should clear the trouble.

4. Test as previously directed for primary and secondary crossed together.

5. Get the wire chief to test the resistance of the line, or test it yourself as follows: Bridge your lamp on at the top of the instrument, the lamp will burn rather dimly on an ordinary line, very dimly if it is a long line, or an extension line from a private branch exchange with a high resistance drops and retardation coils. (In the latter case the test can be made better after the operator has plugged up the line.) Next connect your line in series with the instrument, take the receiver off the hook, and compare the brightness of the lamp while the instrument is in circuit, and while it is cut out by short-circuiting the L1 and L2 posts. If there is much difference noticed there is a high resistance in the instrument. Forty ohms is a fair average for the resistance of a central battery instrument, but it may be higher or may be lower, it may run below 30 ohms. About 16 ohms of this is in the primary and the rest is in the transmitter.

[Illustration: Fig. 2.]

To prove that there is no resistance in the soldered connections or hook contact, short-circuit both the primary and the transmitter; this should cut out all of the resistance and completely short-circuit the instrument, so that you will get no battery from L1 to L2 posts when the hook is up.

The resistance of a 24 volt test lamp is somewhere about 400 ohms cold and 240 ohms hot.

Hearing Poor.

May be due to:

1. Receiver bad.

2. Receiver cord or white strand of desk stand cord bad.

3. Condenser open.

4. Primary and secondary crossed together.

5. Primary short-circuited.

6. Secondary short-circuited.

7. High resistance in secondary circuit.

There will be two hook clicks with any of the above troubles, but one of the clicks may be cut down more or less.

1. Examine the receiver for dented diaphragms, "whiskers" on the magnets, magnets too close to diaphragm, or magnets weak; test by putting your head receiver in series with it and comparing the hearing.

2. To test the receiver cord and the white strand of the desk stand cord, put battery through them and listen in the receiver for a cut out or scratchy sound while you shake them. Short-circuiting the condenser with a test cord puts battery through the receiver and its cords when the hook is up.

3. If the condenser is open the ringer usually will not ring, but sometimes you can ring through a condenser that you cannot hear through at all. Test by short-circuiting it with a test cord.

4. Primary and secondary crossed together will usually short-circuit the ringer and prevent your getting a ring. Test as previously directed.

5. If the primary is short-circuited bridge your head receiver around it; you will get no click when the hook comes up, and no side tones. If the primary is all right you will get both clicks and side tones in your head receiver.

6. A short-circuited secondary can be tested by exactly the same method as is given above for testing the primary.

The above tests work very well if the primary or secondary is completely or nearly short-circuited, but if the short circuit is only partial it is very hard to detect. If you are in doubt, change the bell temporarily for another bell that is all right or change the induction coil, and compare results.

7. To test for a high resistance in the secondary circuit, put battery through it by short-circuiting the condenser with a test cord while the hook up, then listen in the receiver while you short-circuit successively the receiver hook contact, the two sides of the receiver cord, the white strand of the desk stand cord, the wiring from receiver cord to secondary, from secondary to condenser, and from condenser to L2, and the secondary itself; when you short circuit out any part of the circuit that contains resistance, such as the secondary itself, more battery will flow through the receiver, giving you a click.

An instrument in which the ringer is not connected, will, of course, give but one hook click.

Reversals in the connecting up of desk stand cords may cause only one hook click or poor hook clicks, poor transmission, poor hearing, transmitter nearly dead, etc., according to the combination in which the three strands of the cord are connected.

If the ground side of the line is open outside the set may be put in temporary service by working to a local ground.

If the induction coil is bad, temporary service can be given, if necessary, by putting the transmitter and receiver in series, and properly poling the receiver.

CHAPTER II.

TWO PARTY LINE.

No. 1 Set.

(The battery side of the line goes to the L2 post.)

Gives two hook clicks, and can be tested in very much the same way as a straight set, but the following points should be remembered: on sets that ring to ground an open ground will, like ringer open, cause the bell not to ring and only one hook click.

Resistance in the ground may cause poor ring.

Reversal of the three wires on top of the bell may cause only one hook click, bell not to ring, and transmitter nearly dead.

Transmitter very poor may be caused by the ground side of the line being open outside. (You can still call the operator and talk, with difficulty through the ringer and ground.)

No. 2 Set.

Gives but one hook click, but otherwise can be tested in very much the same way as a straight set. Remember the following points:

On sets that ring to ground:

Ground open will prevent bell from ringing.

Resistance in the ground may cause poor ringing.

A ground on the ground side of the line may cause the bell to ring poorly or not at all by taking the generator current off to ground before it reaches the instrument.

Condenser short-circuited will not only put a ground on the ground side of the line through the ringer, but on exchanges which use pulsating current for ringing will also cause bell to ring poorly or not at all.

Reversals of the three wires on top of the bell may cause two hook clicks, bell not to ring, and transmitter nearly dead.

On two-party sets, to find reversals of the wires at the top of the bell, trace out the wire to the protector, or else find out with your head receiver which one of the three wires is alive to both of the others, or to an independent ground. This one is the battery side of the line.

To test for reversal of the ground wire with the ground side of the line, bridge your head receiver from an independent ground to the two doubtful wires successively. You will get induction on the line wire, and none on the ground wire. Or, bridge your receiver from the battery side of the line to the other two wires successively; the one that gives the most induction in this case is the ground wire. Or again, test by bridging your lamp from the battery side of the line to the other two wires successively. If the ground is good, bridging to it will give a brighter lamp than bridging to the ground side of the line; only a little brighter if the line is short, much brighter if the line is long.

The above is also the way to test for a poor ground. The resistance of the ground return back to the central office should be less than the return through the cable, therefore the lamp should burn brighter on the ground wire than on the ground side of the line; very little brighter if the line is short, much brighter if the line is long.

An extension bell open will prevent the main bell from ringing, just as in a straight set. Test by running a temporary ground, or by short-circuiting out the extension bell.

If you are in doubt when testing a two party set, disconnect the ground wire and strap the bell, making it a straight set temporarily, and then test the ringing, transmission, and hearing. A straight set will respond to all rings, direct, two-party, and four-party.

If on a two-party set the ground side of the line is open outside, temporary service may be given, if necessary, by working to the local ground.

If the ground is open, temporary service can be given, if necessary, by converting to a straight set; but in this case the bells will respond to both calls.

If second instrument is properly poled and bell rings when first station is being called, the trouble is probably due to party at first station taking his receiver off the hook before the operator has stopped ringing, and vice versa.

CHAPTER III.

FOUR-PARTY SET.

(Diagram No. 3.)

Tests of the transmitting and hearing circuits can be made in very much the same manner as in a straight set. On account of the relay coil being bridged between No. 2 and No. 3 terminals of the induction coil, a four-party desk set, if in perfect order, will give two hook clicks, no matter how it is poled.

To make a perfectly sure test for primary and secondary crossed together, it is necessary to disconnect one terminal of the relay winding; then with the receiver on the hook, test from the L2 post to the secondary with your head receiver; if you get current there is a cross.

Reversals of the three wires at the top of the instrument may cause a variety of troubles, just as in the two-party sets.

Ringing Circuit.

=Relay=: Failure of the relay to come up when the operator rings may be caused by:

Condenser open.

Relay short-circuited or open.

Hook contacts, or red and white strands of desk stand cord, or primary and secondary of induction coil crossed together.

Primary open.

Trouble at central office.

Test just as though it was a straight set except when testing for relay short circuited, or for a cross between primary and secondary, (in which case you must open one terminal of the relay winding, as previously directed); and except when testing for relay open, which you can do by bridging your head receiver from L2 post to No. 2 and No. 3 terminals of the induction coil successively; you should get strong battery on No. 2 terminal, if the relay is all right and a strong condenser discharge when you make contact, but a weak battery click when you break contact, on No. 3 terminal.

A ground on the ground side of the line may also prevent the relay from operating, by carrying the generator current off to ground before it reaches the instrument.

If the relay is held up, usually the lamp is kept burning at the central office also, and this means that current is flowing from the central office over the battery side of the line, passing through the relay winding, and returning to the central office over the ground side of the line, or through the ground wire and ground. This condition may be due to:

1st. Winding of relay crossed with frame. Test by disconnecting the “A” or “B” terminals of the ringer from L2 which should release the relay.

2d. As in the case of current through the ringer of a straight set, the trouble may be caused by receiver contact of hook not breaking, white and green strands of desk stand cord crossed together, condenser short-circuited. Test as though it was a straight set.

[Illustration: Fig. 3.]

If the relay vibrates continuously the winding is probably crossed with the frame. To find out whether this is the case, disconnect the ground wire, which should stop the vibrating.

If the relay “jumps” while the operator is ringing, instead of pulling up and staying up as long as the ringing current continues, the relay may be weak, due to a part of the winding being short-circuited out, or to some other cause; or there may be too many bells and relays on the line, so that, owing to the resistance of the line, not enough generator current will flow over it to divide up and give each bell and relay a proper amount of current; or there may be a slight ground on the line, which carries off a part of the ringing current.

To prove that a relay is all right:

1. Short-circuit the condenser; this should hold up the relay, by putting battery current through it.

2. Prove that the spring contact is not crossed with the frame as follows: Disconnect “A” and “B”, then connect the frame of the relay to battery with a test cord, and bridge from the spring contact to ground with your head receiver; if you get no current there is no cross.

3. Prove that the winding is not crossed with the frame as follows: Disconnect “A” and “B” and then test with your head receiver from the frame to the L2 posts; if you get no battery there is no cross.

=Ringer=: If the relay comes up, but the bell does not ring, the trouble may be due to:

Ringer poled wrong.

Bias spring too tight or too loose.

Ringer open.

Ground open.

Ringer short-circuited.

Bridging your head receiver across the ringer while the operator is ringing will show whether or not you are getting generator current on the terminals of the ringer winding; going in series at the “A” and “B” terminal will show whether or not you are getting current through the ringer.

To prove whether a ringer is open or not, connect “A” to battery, hold the relay closed, and then test from “B” to ground with your head receiver; if you get no current the circuit is open; prove that the open is in the ringer itself by testing direct from the two terminals of the winding successively.

The ground can be tested in the same manner as on a two-party set.

To prove that the ringer is short-circuited, connect “A” and “B” across the line, close the relay contact, and bridge across the terminals of the ringer winding with your head receiver; if you get no click the ringer must be short circuited; check this test by putting your head receiver in series with the ringer, while it is connected across the line, and closing the relay contact; this should give you a strong click if the ringer is short-circuited.

=Bell ringing weak may be due to=:

Poor adjustment of armature.

Poor adjustment of bias spring.

Pivot screw too loose or too tight.

Clapper rubbing on guard.

Wiring interfering with clapper stem.

“Whiskers” on magnet head.

Magnet head sticky or gummy.

Polarizing magnet weak.

One or both coils of ringer partially short-circuited.

Too many bells and relays on the line.

Ground on one side of line which takes part of the generator current off to ground before it reaches the instrument.

Trouble at central office.

Earth currents.

To test for earth currents bridge your head receiver from the ground side of the line to the ground; you should get no current; if you do get current you will probably find that it varies continually, being due to trolley cars; report the matter to the chief inspector. In making this test be sure that the line is not in use; if the receiver is off the hook at any station on the line you will get a false test.

Earth currents very often cause bell troubles on suburban stations, particularly those that lie near to trolley lines; but in the city, earth currents are seldom noticeable.

=False rings may be caused by=:

Very strong earth currents.

One coil of ringer short-circuited.

If a biased ringer has one coil short-circuited, then when it is poled for either 1st or 2d stations it will respond to both rings; and likewise when poled for 3d or 4th stations it will ring with either current.

In the bell diagram No. 3 you will see that "B" connects to the spring contact of the relay, the frame of the relay connects to the biased side of the ringer, and the unbiased side of the ringer connects to "A."

In the older bells, "B" connects direct to the biased side of the ringer; the unbiased side of the ringer connects to the spring contact of the relay, and the frame of the relay connects to "A."

Therefore, in connecting an extension bell to a set that has no extension bell binding posts, connect one side of the wire to the frame screw of the relay, under the bottom of the set, and the other side to the post at the top of the bell that "A" connects with. Or solder one of the extension bell wires to the spring contact of the relay, and connect the other to the post at the top of the bell that "B" connects with. In every case the auxiliary bell must be connected across the terminals of the ringer without being bridged around the break of the relay. Pole the extension bell by reversing the wires either at the bell or at the set.

=Ringer Adjustments=: In adjusting a biased ringer find out the two points where the bell ceases to ring on account of the bias spring being too tight and too loose, and adjust the spring half way between these points. To locate them, slack off the bias spring until it has no tension at all, and then get the operator to ring while you tighten up the spring, and note the point at which the bell commences to ring; continue to tighten the spring until the bell ceases to ring; by making the adjustment half-way between these two limits, you will have a margin both ways, so that if the generator rises a little above or falls a little below its proper voltage, the bell will still ring.

The little set screw in the yoke at one end of the armature should be adjusted so as to hold the opposite or bias spring end of the armature a little away from the head of the magnet core; 0.02 of an inch, which is a little less than the diameter of a No. 22 cross-connecting wire, "In every test use a little judgment."

CHAPTER IV.

HOW TO TEST FOR AND CLEAR TROUBLES IN PRIVATE BRANCH EXCHANGE SWITCHBOARDS.

=Station can't call=: When a station can't call, the trouble may be due to the line being open, or too much resistance in the line; or to the signal being open, or short-circuited, or stuck.

Short-circuit the line in the back of the switchboard or at correcting frame; if the signal does not operate plug up the jack with a plug and see if the cord signal will operate; if it will not the open is between the frame and the springs of the jacks if the cord signal will operate, the trouble is back of the jack springs, and may be an open, or it may be that the drop is short-circuited or stuck. Test with a receiver or lamp, if you get good battery on the locknuts but can't throw the drop, it must be short-circuited or stuck; if you get no battery there is an open; short-circuit the inner contacts of the jack, and if this brings up the signal the open is in the jack; take the jack out and repair it. If short-circuiting the inner contacts will not operate the signal, the same may be open; test from the ground strap of the jack direct to the signal terminals; if the signal tests all right the wire leading from one side of the signal to one inner contact of the jack must be open; prove by short circuiting same out with a test cord.

If there is battery on the jack but the signal won't come up, push gently against the back of the armature of the signal with a tooth pick until it starts to raise; you can tell by the feeling if it is at all stuck.

Another good way to tell whether the signal sticks is to go to the station and hold the receiver to your ear and then allow the hook to raise. When the signal flies up it can be heard in the receiver as a sort of "tremble." This "tremble" should take place the instant the hook comes up; if it is delayed, the signal must be sticking.

This test can also be made from the frame with a head receiver.

To test whether the signal is short-circuited, see how brightly your lamp burns when connected at the frame and then compare with other signals which are all right; a signal which is wholly or partly short-circuited will have less resistance than the others, and the lamp will burn brighter.

If the signal comes up from the frame but will not come up from the instrument, the line may have too much resistance and the signal will have to be adjusted so as to be more sensitive.

If a station on a long line has trouble calling at times, there may be a poor connection in the circuit which varies; or it may be that the signal fails to work only when the board is busy, due to the drop in voltage on the battery feed when much current is being drawn from it; the signal will have to be adjusted more delicately or the battery feed increased.

[Illustration: Fig. 4.]

=Station Signal Stays up=: The line must be either crossed, or grounded on the battery side. Plug into the jack with a detached plug and cord, and then test successively on the ring and tip of the detached cord with a receiver or lamp that is connected to battery. This will show if there is a ground on either side of the line. If both sides test clear of grounds, there must be a cross; to prove this, ground the tip side by holding the tip of the detached cord on the tip of any other plug; if there is a cross the ring side will then test grounded. To locate the trouble, open the line successively at the frame cable box instrument, etc., and note the effect on the signal.

In testing with a receiver for grounds or crosses on lines, you should be guided by the click when you break contact; otherwise, you are likely to be deceived by the electrostatic capacity of the line and condenser in the instrument. In such tests you may get a strong click when you make contact, particularly if the line runs through a cable, and you may also get plenty of induction on the line; but if you do not get a click when you break contact, there is no current flowing through your receiver, and therefore the line is clear.

If plugging into the jack does not restore the signal, the trouble must be a cross in the jack, or in the signal itself. Examine the jack lugs, and also the inner end of the signal winding, which may be in contact with the iron mounting strip. If the trouble is not here, disconnect the wire going to the jack from the signal; this will show whether the trouble is in the signal itself.

If the sleeve of a station jack is grounded, the cord circuit relay will operate when you plug into the jack, and cut the battery off of that pair of cords. Touching the tip of a plug to the sleeve of a station jack with the listening key thrown will show if the sleeve is grounded by giving a click in the operator's receiver, the same as touching the sleeve of a trunk jack will do. The ground may be due to the sleeve being crossed with the sleeve of a trunk jack, or crossed with the sleeve of a station jack that is connected to a trunk jack; or it may be between the sleeve and the inner contact of the jack on the ground side.

=Battery Feed and Trunks=: The battery feed and trunks must always be poled properly. To test the poling of the feed, run a temporary ground and touch it to the ring of the back plug. If this does not bring up the cord signal the feed is poled wrong, and the feed and ground will have to be reversed.

To test the poling of a trunk, plug into the trunk-jack with the front plug of any pair, say No. 1 pair; then touch the tip of any other plug to the ring of the back plug of No. 1 pair; if this does not bring up the cord signal on No. 1 pair the trunk is poled wrong.

One of the troubles caused by the wrong poling of a trunk is that if the operator plugs in to answer the trunk while she has another listening key thrown, her transmitter goes dead.

If operator at the central office can't throw a trunk drop at a private branch switchboard the same may be open, or the condenser may be open. Bridge a receiver across the drop; if you can get a good ring in the receiver the condenser is all right and the drop is probably open. If you can't get a ring across the drop, short-circuit the condenser; if this puts battery through the drop and brings it

up, the condenser must be open.

If a cord circuit relay fails to operate on any trunk, the ground strap may be broken off of the jack. Plug up the jack, then touch the butt of the plug with the tip of a plug of any other pair; if this operates the relay, it shows that the sleeve of the jack did not operate it, and therefore the sleeve connection must be open.

The sleeve connections are often taken off purposely on tie trunks.

If the operator complains of central cutting her off, some of the holding coils may be open. Instructions are given further ahead for testing them.

If plugging up a trunk causes the cord circuit relay to vibrate the battery feed or ground must be open.

If the line or cord signals fail to come up properly the battery feed may be weak; this may be due to a poor connection in the feed or ground, or to one of the conductors of the feed being open, or to the feed being grounded through resistance. Bridge a lamp across the feed; it should burn brightly if no current is being used on the switchboard. Throw a listening key, or bridge a receiver across the feed; if this puts the lamp out, or dims it excessively, the feed or ground has a high resistance on it, or some of the conductors are open. Disconnect the conductors one at a time at the table head or protector, and see if each one will light your lamp properly. If the lamp burns dimly when no current is being used on the switchboard, the feed is probably grounded through resistance; disconnect it from the switchboard and test; if it still gives a dim lamp disconnect at the protector and test again to prove whether trouble is inside or outside.

The amount that a lamp bridged across a battery feed will be dimmed by throwing a listening key or bridging on a receiver depends upon the resistance of the feed. If the feed is very long the lamp will be dimmed very much; if the feed is short or consists of several pair, the lamp will be dimmed but slightly. Each inspector should become familiar with the behavior of the battery feeds on all his important boards; he should know how the lamp burns when the board is idle, and how much it is dimmed when a certain number of connections are up, so that in case of trouble he can tell at once by a lamp test whether the feed is O.K. or whether it has too much resistance, or is partially grounded.

Troubles Causing Bells to Ring.

A swinging open or swinging ground on the battery feed causes the bells at the stations to ring by charging and discharging the condensers.

Generator feed crossed with the battery feed causes bells to ring. Examine wiring and generator contacts at ringing keys.

Where the spring of a station jack does not break from, or is crossed with the inner contact, all bells may be rung by ringing on that jack with power generator, which is always grounded on one side.

If the outer contact of a ringing key makes before the inner contact breaks, all bells may be rung when that key is used, by the generator current passing down through one side of the retardation coil to the battery feed.

Cord Circuit.

Tip and sleeve crossed causes vibrating relay on that pair.

Tip and ring crossed short-circuits the cord.

Ring and sleeve crossed causes relay to vibrate when ring and tip of plug are short-circuited, or when the plug is put in a station jack with the station receiver off the hook,—sometimes merely throwing the listening key on that pair will make the relay vibrate.

Touching ring to tip and tip to ring of the two plugs of any pair should give a spark, and the signal should also come up when the ring of the plug is touched with a tip. If there is trouble, take any other plug which is O.K. and test the bad pair; if both rings or both tips fail to give a spark, there is probably an open at the relay, the retardation coil, or the soldered connections on the listening key. If only one cord tests open, and the other one of the same pair tests O.K., ring on the bad cord and feel for generator current in the plug. If you get current, the open must be at the inner contact of the ringing key; or, it may be in the cord signal. If you cannot get generator on the plug, the open is in the cord.

To locate any open that effects both cords, test successively on inner contacts and swinging contacts of relay, inner and outer lugs of retardation coil, and swinging contacts of listening key, you should get battery across all of these points.

If either cord of a pair is short-circuited it short-circuits both cords and you will not get proper sparks when touching ring to tip and tip to ring but you may get small sparks. Also the operator's transmitter will be dead on that pair of cords and if you test with a receiver or lamp you will get little or no battery between the ring and tip of either plug, but will get battery of about half the proper strength from either the ring or the tip of either plug to either the ring or the tip of a plug of any other pair.

You can also tell whether a cord circuit is short-circuited by bridging your receiver around one half of the retardation coil; if there is a short-circuit, part of the current that is flowing around through the coil will go through your receiver, giving you a click.

To locate the short-circuit, ring on the two cords successively, and feel on the plugs for generator. If both cords test clear, the trouble must be back of where the circuit branches at the listening key; disconnect successively at the relay, the retardation coil, and the listening key until you locate the trouble.

In most of the private branch exchange switchboards the battery goes first to the inner contacts of the relay, then through the swinging contacts to the retardation coil, and from the retardation coil to the swinging contacts of the listening key; in other boards the battery goes first to the retardation coil, then through the relay contacts to the listening key. From the listening key it goes to the inner contacts of the ringing key, and from the swinging contacts of the ringing keys to the cord fasteners.

If a cord circuit is open at the relay or retardation coil, it will still work on a trunk connection, the trunk supplying the battery, if the central office is common battery system.

Lamp tests of the retardation coils and cord signals can be made by bridging a lamp across the bus-bars and then short-circuiting the tip and ring of every cord successively. Each one should dim the lamp the same amount; if one cord dims it less than the others, it shows that there is more resistance in that cord circuit—possibly a bad connection, or a cord signal with too much resistance. If one cord dims it more than the others, there must be less resistance in that cord circuit, probably one half of the retardation coil is short-circuited. (This test fails where there is a floater battery, or a battery feed of very low resistance.) To prove that one side of the retardation coil is short-circuited, short-circuit one of the plugs of that pair, and then bridge a receiver successively around the two sides of the coil, no click on one side should mean that that side was short-circuited.

A finer test can be made by bridging the lamp across the tip and ring of the cord, and short-circuiting out the two sides of the coil successively; each side should brighten the lamp exactly the same amount. If one side brightens it more than the other, that side has more resistance than the other.

Unbalanced coils are usually noisy, especially on long lines. An unbalanced coil can usually be detected by simply listening on each pair of cords, successively; if the battery feed induction is stronger on one pair than on the other, that pair is probably unbalanced.

In most boards the holding coil is bridged across the outer contacts of the relay. In other boards one end of the coil connects to one swinging contact of the relay, and the other end to the opposite outer contact. To test the holding coil, plug into a trunk jack with the back plug and throw the listening key, which will bring up the cord signal, then throw the listening key normal. If the signal stays up the holding coil is O.K., if it disappears the holding coil circuit must be open. The trouble may be that the relay contact does not close, or the coil itself may be open.

Test by plugging into a trunk with the back cord and then short-circuiting the holding coil; if the cord signal comes up the holding coil must be open; if it does not come up, leave the short-circuit on the coil and bridge out the holding coil contacts of the relay. When you bridge out the contact where the open is, the signal will come up.

To test the relay on any cord circuit, touch the tip of any other plug to the sleeve of either plug of that pair; if this does not operate the relay the sleeve conductor of the cord may be open; if neither plug of the pair will operate it, the relay itself may be open; test with a receiver or lamp.

Touching the tip of one plug to the sleeve of the other plug of the same pair should make the relay vibrate.

To test a switchboard cord, plug into the cord testing jack (every board should have a testing jack connected to put battery direct on your head receiver) and shake the cord, and turn and shake the plug in the jack, while you listen in the operator's receiver for any

cut-off or bad connection. Do not have any listening key thrown while you are testing switchboard cords; also see that the operator's receiver is poled so that the current from the cord strengthens the magnetism instead of weakening it otherwise you will not get a sensitive test. The tips and rings of the plugs must be clean, or else they will be scratchy.

Be very careful that none of the plugs are bent or "lopsided;" such plugs may work all right in some jacks and cut-off in others. If turning a plug around in a jack causes a cut-off the plug should be condemned; sometimes the jack may be at fault, and the long spring will have to be given more "set." After changing switchboard cords, always test the new ones for opens, short-circuits and reversals.

=Cross-Talk=: Solder dropped on the cord fasteners, or a cross at the keys, may connect two different cord circuits together, and cause cross-talk between them.

Retardation coils may be crossed with their cases, and cause cross-talk by the cases being in contact. Condensers on trunk drops may make two trunks cross talk in the same way. Test by bridging a receiver from the case of the suspected coil or condenser to battery and to ground successively. There will be no click if the case is clear.

Unbalanced retardation coils, or a weak battery, may also cause cross-talk.

A listening key that does not break contact on both sides will cause cross-talk when that pair of cords is used; if with all keys normal you get a click in the operator's receiver when you touch the tip of any plug to the frame of the operator's transmitter, the operator's circuit is in contact with some cord circuit at the listening key. To find out which key, see that all keys are normal and then vibrate the relay on each pair of cords successively by touching the tip of one plug to the sleeve of the other; when you come to the pair where the cross is, the buzz will be heard plainly in the operator's receiver; on the others it will be heard very faintly.

=Operator's Set=: To test the receiver cord, put a plug in the cord testing jack, this puts battery through the receiver, and by shaking the cord any fault will show up provided the receiver is poled properly. Do not have any listening key thrown when making this test.

To test the transmitter cords, throw up any listening key and listen in the operator's receiver while you shake the cords.

To locate an open in the operator's primary circuit, throw any listening key, and then bridge a receiver successively around the several parts of the circuit, that is, the 200 ohm resistance coil, the transmitter, (including its cords), and the primary. When you bridge around the part that is open, you will get a click in the receiver.

To locate an open in the secondary circuit, short-circuit out the condenser so as to get battery through the circuit and then bridge around the receiver and secondary with a receiver until you have found where the open is.

=Buzzer and Buzzer Relay=: If a buzzer which works off the battery feed fails to operate at times, although the buzzer relay comes up, probably it is not sensitive enough, and when the board is busy the battery feed it not strong enough for it. Adjust the buzzer more delicately and test it when the board is idle and when it is busy. To make a board busy artificially, bridge a head receiver across the bus-bars; that is equivalent to several pairs of connections being up.

If some of the station lines are very long, the buzzer relay may fail to come up on them, or come up so weakly as not to make good contact. To cure this, adjust the relay more delicately.

If a trunk drop won't operate the buzzer relay when the key is up, the trouble is probably at the night bell contact of the drop. If none of the trunk drops will operate it, the relay may not be adjusted delicately enough, or the 500 ohm resistance coil may be open. Bridge around the trunk drop contacts with a receiver. If you get no battery the coil must be open; prove by bridging the coil out and repeating the test.

A heavy ground on the ground side of any station line will prevent the buzzer relay from coming up by shunting it out. A light ground will sometimes cause trouble on the long lines only.

A short-circuited condenser or a slight leak across any line or lines, may hold up the buzzer relay. Test the lines for crosses and grounds, as previously instructed. If the buzzer relay comes up at times when no signal is up, the trouble may be due to some station on a long line trying to call, and the signal not sensitive enough to come up.

General.

To prove that a board is perfectly clear, disconnect the battery feed from the negative bus-bar, and put a lamp or receiver in series. If you get no current then all the lines are free from crosses, they are free from grounds on the battery side, and the other circuits in the board are also clear of crosses. (This test can only be made when there are no connections up, no listening keys thrown, and no stations calling.) To prove that the ground sides of all the lines are clear, disconnect both the feed and ground wires from the bus-bars, and then test through a lamp or receiver from the battery feed to the ground bus-bar; if you get no current, the lines are all clear on the ground side.

INSPECTION

How to Inspect Subscribers' Instruments.

1st.—Ask the subscriber if his instrument works properly and repair any defect that he reports. Also be sure the instrument is securely fastened to the wall or desk.

2d.—Clean and polish the varnished and nickeled parts of the instrument; open the bell and see that it is clean and in proper condition inside, and that the hook, ringer, and other moving parts work properly and clean the hook contacts with paper if they are dirty or make a scratching noise in the receiver.

3d.—See that all binding post connections are tight, test all cords; in testing the receiver cord, put battery through it by short-circuiting the condenser; change any cords or other parts that are defective or unsightly.

4th.—Clean the receiver outside, remove the cap and examine the diaphragm and clean the magnets; in cleaning the magnets rub them off with your coat sleeve or a clean rag rather than with your hands, as the moisture from your hand will cause them to rust.

5th.—Examine the adjustment of the bell and test by getting a ring from the operator, at the same time test the transmission and hearing.

Test all extention bells by getting a ring from the operator; inspect all other apparatus, such as hand generators, switches, local batteries, fans booths and signs. It is important that signs should be kept in good condition; dirty or unsightly ones should be cleaned or ordered changed, and you should be particularly careful to see that all signs are securely hung.

6th.—Inspect all wiring, including the leading in wires, the inside line wires, the battery wires and the ground wires; also the protection, the fuses, any extention bells and also see that the ground is properly made that it is connected to the proper pipes. If a gas pipe has been used see that the bridge on the meter has not been disturbed since the last inspection.

7th.—See that the protector contains the proper kind of fuses, and if it can be gotten at readily; examine the connections and remove the cap from over the carbons to see that no one has left the carbons out.

8th.—If a subscriber applies to you to have an additional instrument installed, take his name and address and turn them in to the manager; if he wants his telephone moved or disconnected, or circuit number changed, or extention bell or sign installed, request him to call up the managers office.

If he complains of poor operating service, or of interference by other subscribers on his line, refer him to the manager.

If he complains of some trouble that is in the outside line or at the central office, report the matter to the chief inspector at once.

9th.—In making recommendations, state briefly but plainly just what you want done and give the reason why. If the installer has done any work at the station since your last inspection, and has failed to leave it in proper condition, accompany the recommendation that you make with a written complaint.

Making First Inspections of New Installations.

In inspecting a new installation, or an instrument that has been moved or changed since your last inspection, or in going over your instruments for the first time, the inspection should be made more carefully than at other times.

Ask the subscriber if he has any extention stations, extention bells or other apparatus attached to his instrument, also look out for them while you are making the inspection and tracing out the wiring.

Open the desk stand and see that all the locknuts are tight and soldered connections are perfect.

Examine and shake all soldered connections in the bell.

Trace out all of the wiring and be sure to see that all splices are properly soldered and taped and see that no tacks are driven in the splice.

Make a lamp or receiver test of the protector and the instrument ground, to see that they are good and have no resistance.

See that the protector is securely fastened, that the connections are all tight, that the fuses and carbons are of the proper kind, and that the micas have the open side down.

Test the fuses for loose connections inside, by bridging your head receiver across the binding post at the instrument end of the protector and listening for a cut-off, while you shake and jar the fuses.

Test all switches to see that they make all proper connections, oil the hand generators and see that the bell clapper works freely.

See that the specifications have been complied with in placing the protector and the instrument, in running all the wire, and in every other particular; that the desk stand cords are cleated, and protection cleats used where needed; that desk sets give two hook clicks; that snap switches are of the indicating type; that the connections to all binding posts are neat and of proper length; that the booth is clean and have plugs in all the screw holes; that they have no broken glass and have linoleum on the floor, and that the doors and latches all work freely.

See that the protector is placed so as not to be in the way of curtains; that no damage has been done to the subscribers property; that all apparatus has been installed so that it will not be in his way, and will not be exposed to disfigurement, damage, trouble from dampness or rain, etc., that wire is run where it will be safe from injury, dampness and wear; in short, see that the installation is done according to specifications in every respect.

See that the cut-in (the wires from the pole to the house) are properly made and are of the proper kind of wire.

DON'T FORGET THAT YOUR REPUTATION AS AN INSPECTOR IS AT STAKE.

FOOTNOTE

[1] Where reference is made to "hook clicks" in these instructions, the instrument is understood to be a desk stand, wall sets are so connected as to give only one hook click on raising or lowering the hook.

When reference is made to the red, white or green strand of the desk stand cord, it is understood that the red goes to the hook, the white to the receiver and the green to the transmitter, using the standard Western Electric cord.

When reference is made to L1, L2 or G you will find them on diagram No. 1 or No. 2. When reference is made to "A" or "B" you will find them on diagram No. 3.

———————————— End of Book ————————————

Transcriber's Note (continued)

Page 42 – "deskstand" changed to "desk stand" (Open the desk stand)

Page 43 – "lineoleum" changed to "linoleum" (have linoleum on the floor)

Footnote – "G1" changed to "G" (When reference is made to L1, L2 or G)

The words "extension" and "extention" are used interchangeably throughout the book and have been left unchanged. Some missing punctuation and other minor typographical errors have been corrected without note.

The single footnote has been placed at the end of the book.

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Some Points in Choosing Textiles

By

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[Illustration]

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SOME POINTS IN CHOOSING TEXTILES

In the past century a great change has come about in the position of the woman in the home, which has very vitally affected her relation to the textile industries. In the early days in this country nearly every woman produced the clothing for herself and family, also the household linens from the raising of the sheep or flax to the finished product. Now all is changed; with the introduction of ready-made suits and other garments, even the sewing is rapidly going from the home, while the manufacture of cloth is a forgotten art.

In olden times the quality of home-spun and woven material was the best possible to be obtained from the materials and methods known. Woolen cloth was all wool, and linen cloth was not adulterated with starch, or half cotton. Honest and durable materials were the rule of the day.

With the introduction of machinery and the factory system came keen competition. Modern discoveries, chemical and otherwise, have increased the possibilities of cotton, linen, silk and wool so that now it is difficult to recognize the original fiber in some of the materials sold.

Thus on the one hand the field of textile knowledge has grown very much, while on the other hand the knowledge of women concerning textile fabrics has decreased, since they are no longer the makers of cloth, nor do they always gain a knowledge of its characteristics through the making of garments. The result has been that women depend more and more on the word of clerks, who are often as ignorant as themselves, until by painful experience the buyers learn some of the things to be avoided.

As cost of living increases, and demands upon the family purse increase, it is more and more important that the woman of the household should know how to spend the family income most economically. Since from ten to twenty percent of this income is spent for clothing and house furnishing, it is imperative that more thought and careful study should be put upon this branch of household economy. The object of this bulletin is to give some bits of information about textile fibers, their manufacture and adulteration, which may help in gaining that judgment in buying essential to every woman.

Certain adulterations and devices of the modern manufacturer are so skillfully concealed as to be detected only by the use of chemical tests, or the high power microscope. With these this bulletin will not deal, but only with those qualities and adulterations which may be detected without the aid of laboratory equipment. Much of course may be learned by experience, but it seems better to save time and money by knowing beforehand what is to be demanded, what guarded against.

Each one of the common materials used for textile fabrics, cotton, linen, wool and silk, has its characteristics, each its definite uses. Certain peculiarities in physical or chemical nature make each fiber peculiarly adapted to certain uses, but so long as these general

qualities are maintained the variety of materials produced from these fibers may be enormous. Combinations of fibers in one material, adulteration with cheaper fibers, or with starches or metallic salts, may serve to reduce the cost, and yet the purpose of the material may be fulfilled. For certain purposes the materials may be used interchangeably.

COTTON

Cotton is cheap and very plentiful. It has short, flat fibers, with a spiral twist, thus giving elasticity and the possibility of being spun into fine thread. Being in itself very useful and inexpensive and capable of replacing, to a certain extent, any other fiber, it is used in very large quantities the world over, and is manufactured into a great variety of materials. The quality of these materials depends on the strength of the fibers, the fineness or coarseness of material, the weave, the color and design, and the adulterations.

Cotton, being cheapest, is not adulterated with any of the other fibers mentioned, when the material is to be sold as cotton cloth, but it can be made to appear heavier by the addition of mixtures called sizing. Starches, gums, dextrine, glue, china clay, as well as other ingredients in varying proportions, constitute this sizing which may add a large percent to the weight of the cloth. The spaces between the threads are filled up and a good finish is given to the cloth, although the wearing quality is not increased. If present in large quantities the cloth is greatly reduced in weight and firmness after the first washing.

Adulterations of this kind can be detected by the feeling, a large quantity imparting a harshness to the material. In very thin fabrics the sizing may often be detected by holding the cloth up to the light when the starch shows between the threads. Washing or thorough boiling of a sample will show the amount of sizing present.

Another method of adulterating cotton is shown in certain kinds of dotted swiss. A good swiss has thread dots woven or embroidered in the cloth. Fig. 1A shows a piece of material sold at the price of a good swiss, but in this case the dots are merely a heavy paste, printed on the cloth. Fig. 1B shows the result of continued washing, where the dots have disappeared, and Fig. 1C, the result of ironing with a hot iron, which turned the spots brown before the cloth itself is harmed.

Mercerized cotton is a cloth produced by the action of a strong alkali on cotton fiber rinsed under tension. It is a strong, attractive material, with good wearing qualities. An imitation of this may be made by the action of very heavy and very hot cylinders on ordinary cotton cloth. The mercerized cloth has a high luster which it retains after many washings while the imitation loses its luster with the first washing.

Sometimes cotton cloth which has been on the market for some time is weakened by the action of the chemicals used in bleaching, dyeing or in the sizing. This may be easily detected by tearing the cloth.

Standard cotton materials such as muslins, organdies, percales, calicoes and sheeting, differ only in the weight of the material, fineness of thread, hardness of twist and method of finish. Ginghams have the thread dyed before weaving and fancy weaves are frequently used. Duck, denim and some other heavy materials have very hard twisted threads and are frequently woven with a twill. Silkolene is a trade name for a fine cotton cloth with a silky finish given after the cloth is woven.

Mercerized cottons make lustrous materials as poplin, imitation pongee and numerous attractive house furnishing materials.

India “linon” is entirely cotton, with a fleecy surface on the wrong side, as is “outing flannel” and “canton flannel”.

Many “tussahs,” “voiles” and “economy linens” and other materials with rather deceptive names are cotton materials made to imitate silk, wool or linen.

LINEN

Linen was formerly the most important vegetable fiber, and was commonly used for all household purposes. Of late years it has been largely replaced by cotton with which it may be compared although there are still uses for which we demand linen, and others for which we prefer linen to cotton.

The linen fiber is long, smooth and quite lustrous, when spun into a thread. It is very strong and there are not so many fuzzy ends as are found in cotton. Cloth made from it is not only lustrous and rich looking, but because of its smoothness stays clean longer than cotton. The snowy whiteness of linen obtained with some difficulty in bleaching is quite permanent, and since the fiber takes dyes with difficulty and parts with them quite readily, it also does not retain stains as persistently as cotton does.

Linen is much more expensive than cotton, and when linen prices are paid linen should be demanded. Since the two fibers are rather hard to distinguish, especially when heavily starched and given a good finish, it is quite easy to deceive the buyer. "Linen" collars are frequently largely cotton, "linen" handkerchiefs may not have a thread of linen, as is apt to be the case with rather inexpensive embroidered handkerchiefs, and table "linen" may be mercerized cotton, cotton and linen, or even ordinary cotton.

[Illustration:

A

B

C

FIG. 1]

To distinguish linen from cotton, examine the threads carefully; cotton is made up of short fibers which project from the surface of the thread, and become fuzzy when the thread is rubbed between the fingers; when broken, cotton has a tufted end, while the linen fibers break more unevenly and leave a more pointed end. The linen thread should be stronger than the cotton; it has more luster and is usually more uneven. Some kinds of linen have flat threads, but cotton is frequently finished in imitation of flat thread linen.

The old test of moistening the finger and putting it under the cloth is not always a sure one, as the moisture will not come through a heavy linen, or one with much starch in it, and it will come through a sheer, tightly twisted cotton. A better test is to put a drop of olive oil on the cloth and press between blotting papers. The linen becomes more transparent than the cotton.

There is a peculiar leathery feel about good table linen, which cotton will not give, and the luster is different although the difference is hard to describe.

The typical weaves used for linens are as follows. The damask, satin or sateen weave used for table linens and towels is especially good for the former because of the very smooth lustrous surface it affords, but not so good for towels as it does not absorb moisture very readily, although it is very attractive. Huck, an uneven weave, giving a good surface for the absorption of water, makes splendid towels, and decorated with designs in damask weave may be very handsome. Many linens in plain weaves are available for clothing, embroidery, etc., while the coarse Russian crashes are becoming quite popular for decorative purposes.

The texture of linen is such that the heavier kinds hang well in folds, lie flat on a table, and are very artistic for many purposes.

WOOL

Wool, the second fiber in amount used for clothing, is an animal fiber and differs greatly from the vegetable fibers discussed. Wool from the sheep's back differs from hair of goats or other animals in several ways. Wool is very curly, and possesses a scaly structure in a much more marked degree than hair, in which the external scales lie flat. The surface of wool has sometimes been compared to a pine cone, or the scales of a fish, although these two are quite different. The scales on the wool fiber when moist and warm stand up, more as the pine cone, and when cold and dry or cold and moist, lie flat. This peculiar structure of the surface of the wool fibers gives them the property of felting, or matting very closely together. Wool is also quite elastic, although it has not great strength.

Since the demand for woolen cloth far exceeds the supply of new wool there are many devices for making the supply go a long way, and consequently many methods for deceiving the buyer. In adulterating a material the manufacturer seeks a material cheaper than the fiber he wishes to adulterate, one which can be concealed readily. Wool when combined with the cheaper cotton fiber makes a material which wears well, but does not keep its shape as well as all-wool cloth, is less warm, and should of course receive a lower price than all-wool.

Because of the felting property of wool it is quite possible to conceal a good deal of cotton under the surface of the woolen cloth, and when the fibers are mixed before the threads are spun the task of detecting them becomes doubly difficult.

WOOLENS AND WORSTEDS

Two classes of cloth are manufactured from wool. Woolens are made usually of short wool carded and spun into yarn in which the threads lie in all directions. This is woven into cloth which usually has the surface heavily felted, so that all of the intersections of

threads in weaving are covered. Here then is splendid opportunity for adulteration, since cotton or poor wool may be covered up by the surface felting.

WORSTED

The other class is made from longer staple wool, combed, and drawn until the fibers are parallel, then hard twisted. When woven the ends of the threads do not project on the surface, and the finish is not intended to cover the weave, hence it is more difficult to adulterate unless entire cotton threads were woven with the worsted, and these are more easily detected than a mixture of cotton and wool, or shoddy in woolen cloth. Common examples of woolens are flannels, broadcloth and venetian cloth; of worsteds, serge, challie, men's suitings and voile. Mohair is a worsted cloth woven of the wool of the Angora goat, with a warp usually of cotton or silk.

[Illustration:

A

B

C

D

FIG. 2]

The most reliable tests for a mixture of cotton and wool are chemical or microscopic ones, but as these are not practical for the average buyer, others must be sought. Wool has luster and "kinks;" the ends of the threads are stiff and look rather wiry. When a sample is carried home, burning will serve to distinguish between the two. Wool burns slowly, chars, has an odor of burnt feather, goes out easily and leaves a crisp ash; cotton burns quickly with a flame, with little odor and leaves no ash.

A little practice in breaking the threads will help one to distinguish between the two; the difference is not one that can be easily explained, but the experienced housewife knows it well.

Fig. 2A shows a sample of all-wool cloth, of the class of worsteds which cost seventy-five cents a yard. Fig. 2B shows a sample of cloth of the same price, called by the clerk, all-wool, but which on examination was found to have only four threads of wool to every twelve threads of cotton. Fig. 2C shows this same cloth with the wool removed by strong alkali, caustic potash, leaving the cotton. Fig. 2D shows the wool left when the cotton has been ravelled out, or has been removed by a strong acid solution.

Fig. 3 shows a sample of mohair in which the wool has been partly removed, and the cotton warp is left. In this case the price is not high, and because of the character of the cloth the mixture is a good one, light, smooth, and clean. This cloth is not sold for all-wool, so is not considered adulterated.

[Illustration: FIG. 3

SHODDY]

As has been said before, the demand for woolen goods is so much greater than the supply that it is necessary to resort to various measures to increase the supply of cloth. One method is to use the wool over and over again. Rags are bought up by the rag man, sold to the larger dealer, again to the "shoddy" manufacturer who cleans them, sorts them, tears them to pieces, using the best all-wool rags to produce fibers, which are respun and again woven either separately, if of very good quality, or mixed with new wool or cotton. Such a material is warm, looks well for a time and has its place, but must not be bought for new wool, or demand the price of good woolen cloth. This industry is enormous and shoddy is often found in expensive novelty materials as well as in cheap "all-wool" cloth. Because of the shortness of the fibers it may be detected readily, when used alone, but in combination with good wool it is more difficult.

One class of shoddy consists of very short fibers, clippings from the mills, which are worked into the surface of a felted cloth after it is woven. These short fibers after a time work out, and are found in the bottoms of coats, inside the linings, etc., leaving the surface of the cloth threadbare.

Fig. 4 shows a piece of shoddy cloth, sold for all wool at fifty cents a yard. This cloth would be warm, but does not look as well as more expensive cloth, and will not wear as long as new wool. There is some cotton mixed with the wool before spinning, therefore it is difficult to detect.

[Illustration: FIG. 4]

SILK

Silk is frequently known as the fiber of luxury. It is the most expensive to cultivate, the most beautiful and the strongest fiber. Since it is the most expensive fiber to buy, and the demand for it is so great, the temptations to adulterate are also naturally very great. The long, strong, lustrous silk fiber which bleaches and dyes beautifully and is fine as a spider's web, is not to be duplicated. The best grade or "reeled silk" is taken from the cocoon in one continuous thread which may be several hundred yards long. In manufacturing reeled silk many defective cocoons are found in which the fibers are not perfect, or are broken. The silk from these cocoons may be treated like a short fiber and spun into threads varying in strength according to the length of the fibers. This so-called "spun" silk has not the high luster nor strength of "reeled" silk, but is often used as warp with reeled silk filling, or in imitation pongee, and back of satins, velvets and in many other ways.

In olden times the price of silk was much greater than now, but the material was much more durable. Silks which have been laid away for a hundred years are still in fairly good condition. Now our silks are much cheaper, but the result is that when they are put away, even for a few months they may fall into bits, and their wearing quality can not be compared with the good old silks of long ago. The reason for this change is not hard to find. The cost of raw silk is about thirty times that of raw cotton and the waste at least five times that of cotton. The manufacturer must make up in some way if he is to sell silk at the prices demanded by the public.

Silk has a very great ability to absorb dyes and metallic salts without apparently changing the quality of the material, and since dyes and metallic salts are much cheaper than pure silk, the manufacturer makes great use of these materials. Loading is the common name for this process of treating silk and it is common practice to add thirty percent of foreign material, just the percent lost by the silk when the gum is removed, while it is possible to add two hundred fifty or even three hundred percent.

When we buy novelties and do not care how short their life is to be, these heavily weighted silks answer the purpose very well, but when we wish for durability and the silk begins to crack and split or to become shiny after a few wearings we realize the disadvantage of our modern methods. Practically no silk can be found on the market entirely free from loading, but there is a great difference in the amount present.

Burning is the simplest test for good silk; a thread of pure silk will burn slowly leaving as it burns a very small amount of crisp ash in a ball at the end of the thread. Heavily weighted silk burns and leaves the ash in the form of the original thread; this ash of course drops to pieces readily. Fig. 5A shows a piece of taffeta sold for one dollar a yard. Fig. 5B shows the result of burning the silk. This ash, left in the shape of the original sample, is made up of metallic salts, dyestuffs, etc. A very small percent of ash would be left from the silk itself.

Another method of adulterating silk is with cotton. The fibers are not spun together here as the cotton and wool, but the threads of the two materials are woven together. In satins, velvets and brocades the cotton is entirely covered by the silk threads on the surface, and appears as the back of the cloth. In cheap silks a fine cotton thread sometimes forms either warp or filling.

Pongee is a material made from the cocoon of the uncultivated silk worm; rajah, tussah and other uneven, coarse materials are from the same source. These silks are very strong, but do not have a high luster. Mercerized cotton looks quite silky and is sometimes mixed with these silks, or a material of mercerized cotton and spun silk may be sold for pongee, or even a material entirely of mercerized cotton.

CONCLUSION

To sum up, the adulterations most likely to be found and the tests for them are as follows:

METHOD OF ADULTERATION

1. By combination. Use of other fibers than the one indicated by the name of the material. Example, cotton in woolens, cotton in linens, etc.

2. By substitution. Selling one fiber under the name of an entirely different one. Example, mercerized cotton sold for silk or linen.

[Illustration: A

B

FIG. 5]

3. By increasing the weight of a material. a, Cottons and linens with starch; b, silks with metallic salts and dyes.

4. By giving a finish which is deceptive. a, Heavy pressing or calendering an ordinary cotton to imitate mercerizing; b, finishing cotton to look like linen; c, printing paste dots on cotton to produce the effect of embroidered dotted swiss.

5. By use of made-over yarns. Example, shoddy in woolens, also addition of short wool, felted in surface.

TESTS FOR ADULTERATION

1. Examination of cloth to see if all threads are alike, and to distinguish kind of thread.

2. Examination of individual threads.

Cotton: short fibers, ends appear fuzzy in thread.

Wool: short fibers, decidedly kinky and stiff.

Silk: long straight fibers with luster; if spun silk, fibers short; thread looks more like cotton; breaks more easily than reeled silk.

Linen: strong threads; high luster; when broken ends very uneven and straight.

3. Burning tests: a, cotton burns quickly with flame; b, wool burns slowly, chars, gives off odor of burnt feathers; c, silk burns slowly, leaves small crisp ash, and when weighted leaves more ash; d, linen, similar to cotton.

4. Linen if without much starch, becomes translucent when treated with olive oil; cotton remains opaque.

5. A mixture of cotton and wool when wet, wrinkles more than pure wool.

6. A careful examination of the finish of the material. Observe if alike on both sides, if the apparent beauty of the material is due to finish or to good quality of material.

Finally, the best grades of material are generally what they seem to be; although this does not always hold true in silks, nor in materials where the effect is more important than the wearing quality. Expensive broadcloths, worsted suitings, expensive table linens, good cottons, do not pose for more than their true worth. It is when one turns to novelties, to silks and to inexpensive materials that one needs to be most vigilant. Be sure the inexpensive is not cheap, unless you want a material, cheap in wearing quality and appearance, as well as in cost.

OTHER POINTS IN BUYING

Aside from the question of whether the buyer is getting the kind of material she pays for as to character of the fiber, there are other things to be considered in choosing textile fabrics.

The weave affects the appearance and often the wearing quality of cloth. A close twill weave makes a firm, durable material, while the loose basket weave gives quite a different effect and is frequently lacking in firmness. The satin or sateen weave makes a beautiful surface especially in linens or silks, but may cover up defects in the hidden threads. Fancy weaves in cotton novelties, in shirt waist materials and in fancy mulls, etc., often leave loose threads which become soiled easily and may not be as attractive after washing. A cloth with a very heavy cross thread or filling, and a very fine warp, or vice versa, may split because of the great difference in the strength of the threads.

Sometimes figures are woven in such a way that when the cloth is finished each figure has short ends of thread. For example, in weaving madras curtain material, the filling thread which makes the figure, jumps from one figure to another, and after the material leaves the loom the loose threads are cut off of the back of the material. Often these short pieces wash out or the ends become rough and fuzzy looking.

In choosing a material from the large variety on the market the first thing to be determined is the use to which it is to be put, then determine what is appropriate to that use. The cloth which is suitable for a street suit is obviously not suited to the party gown, neither are laces of dressy waists appropriate for working clothes. Clothes that are to be worn constantly need to be of material that will stand frequent cleaning. In materials used in house furnishing certain ones must be cleaned often, and unless one can afford to pay frequent cleaner's bills, washable materials are better for curtains, bed-spreads, table-covers, etc. The cost is the next point to be considered, and that must necessarily be determined by one's purse. It is not always economy, however, to buy the inexpensive things, for, as we have seen, the inexpensive articles are more likely to be the cheap ones. With our desire for continual change, our love of novelty and fad we have become very extravagant. So long as the fashion demands new garments every few months and women attempt to follow the styles, they must choose inexpensive materials unless they have a large amount of money, and care nothing for wearing quality. In the end, however, the woman who buys carefully, makes use of conservative styles which do not change every few months, and chooses handsome material, is not only more economically, but also usually better dressed.

The hygienic properties of materials should be carefully considered. Those next the body should be able to care for the perspiration and the excretions of the skin. Woolen and silk are best suited by their physical structure to do this, but wool is too warm and too irritating to many people, and does not wash well, while silk is too expensive. Many kinds of cotton underwear have been manufactured which by their structure aid in absorbing moisture. Underwear knitted or woven with meshes containing large enclosed air spaces is more hygienic than closely woven cotton garments. The air spaces in the mesh material are non-conductors of heat, and also ventilators. The closely woven garment does not allow a change of air next the skin and becomes clammy when moist. Garments which come in contact with the outside air must be more closely woven to keep out the wind. Two layers of lighter weight material are warmer than one layer of thick because of the non-conducting air between. Heavy clothes are bad for the body because of the extra load which must be carried about.

Finally, in choosing materials, if one is to have the greatest pleasure from them and give one's friends the greatest pleasure, color and design are very important. Colors should be suitable to the use, and to the person who is to wear the material. Bright colors make one conspicuous, and are exciting; dull ugly colors are depressing, while soft rich colors are elegant, becoming, and in good taste.

Designs should fit the place in which they are to be used. Rugs should be so designed that they serve as a background to the furniture of the room as well as add richness in color and some variety. Materials which are to hang in folds should have designs which do not depend on smoothness of surface in order that they may be effective. For clothing, designs should be inconspicuous, modest stripes, dots and plaids being most successful, except on very soft thin materials when larger and less conventional designs may be used.

To be an intelligent buyer it is necessary then that the woman knows before she purchases a piece of cloth just where it is to be used, just what she can afford to pay for it, what she should be able to get for that amount of money and then be able to tell whether the piece of cloth she buys is really what it is represented to be. At the present time the rush to the bargain counter, the enormous amount of cheap, poor material manufactured, and the great waste in dress, all go to prove that there are many women who are not intelligent buyers.

When women demand a better quality of materials and refuse to buy the cheap things, the manufacturers will cease to produce worthless things. Perhaps however, before that day arrives, the thoughtful workers of the land will have succeeded in passing a pure textile law, which shall do for our cloth what the pure food act is doing for our food supplies; then the honest though ignorant buyer will be protected, but it will still be her part to demand good, artistic and useful materials.

* * * * *

Transcriber's note

Minor punctuation errors have been changed without notice.

Spelling was retained as in the original except for the following changes:

"certain nses, but" "certain uses, but"

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Unknown

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TRANSCRIBER'S NOTE

Italic text is denoted by _underscores_.

Footnote anchors are denoted by [number], and the footnotes have been placed at the end of the paragraph. Some minor changes to the text are noted at the end of the book.

[Illustration: ST. TROPHYME AT ARLES.]

A SHORT HISTORY

OF

ARCHITECTURE

BY ARTHUR LYMAN TUCKERMAN

WITH ILLUSTRATIONS BY THE AUTHOR

[Illustration]

NEW YORK CHARLES SCRIBNER'S SONS 1897

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"To build, to build! That is the noblest art of all the arts. Painting and Sculpture are but images, Are merely shadows cast by outward things On stone or canvas, having in themselves No separate existence. Architecture, Existing in itself, and not in seeming A something it is not, surpasses them As substance shadow." —LONGFELLOW, in _Michael Angelo_.

PREFACE.

I have written this short history of architecture to meet the requirements of those who wish to become acquainted with the main facts without having to read voluminous works, many of which are addressed, not to the student, but to the connoisseur, who is presumed at the start to have a knowledge of the subject sufficient to enable him to comprehend critical and theoretical essays.

The plan I have adopted has been to trace the origin of each style, its characteristic points and its connection with those which preceded and succeeded it, without introducing technical terms or any but the most important dates.

There is a temptation to enter into the social and political histories of each building race, but brevity forbids this, as well as any of the gushing descriptions usually found in modern handbooks on art.

I imagine that very few people have the time to read lengthy treatises on architecture, but that there are many who would be glad to know the chief historical facts, were these to be presented within a small compass. I hope, therefore, that this volume may be of interest to the general reader and may find its way to schools other than those which make art matters their specialty, for it seems to me that if the average schoolboy were taught as much about the history of the most useful and beautiful of the creations of the people of each age, as about the manner and quantity of warfare and slaughter in which they indulged, he would obtain as valuable a quality of information.

ART SCHOOLS OF THE METROPOLITAN MUSEUM. March, 1887

LIST OF PLATES.

ST. TROPHYME AT ARLES, _Frontispiece_.

FACING PAGE

THE GREEK ORDERS, 56

PLAN OF THE TEMPLE OF THESEUS AT ATHENS, 62

THE ROMAN ORDERS, 70

PALACE OF DIOCLETIAN AT SPALATRO, 73

PLAN OF THE PANTHEON AT ROME, 74

PLAN OF THE BATHS OF AGRIPPA, 75

PLAN OF THE TEMPLE OF THE SUN AT BAALBEK, 76

PLAN OF THE OLD BASILICA OF ST. PAUL'S BEYOND THE WALLS, 89

ST. VITALE, OF RAVENNA, 92

THE TEMPLE OF MINERVA MEDICA, 93

THE TEMPLE OF VESTA, SOMETIMES CALLED THE TEMPLE OF HERCULES, 94

THE BAPTISTERY OF CONSTANTINE, 94

THE PENDENTIVE SYSTEM IN BYZANTINE DOMES, 97

CHURCH OF SERGIUS AND BACCHUS AT CONSTANTINOPLE, 98

PLAN OF ST. SOPHIA, CONSTANTINOPLE, 99

ROMANESQUE CONSTRUCTION, 121

COMPARATIVE SERIES, SHOWING GREEK, ROMAN, ROMANESQUE, AND GOTHIC METHODS OF SUPPORT, 124

PLAN OF STRASBOURG CATHEDRAL, 128

CHEVET OF NOTRE DAME DU PORT AT CLERMONT, 130

PLAN OF RHEIMS CATHEDRAL, 134

PLAN OF AN ENGLISH CATHEDRAL, 136

PLAN OF ST. PETER'S AS ORIGINALLY DESIGNED BY MICHAEL ANGELO, 155

PLAN OF CHURCH OF THE HOTEL DES INVALIDES AT PARIS, 160

CONTENTS.

PAGE

INTRODUCTION, 1

I.—CELTIC OR DRUIDICAL REMAINS, 5

II.—THE MONUMENTS OF EGYPT, 10

III.—ASIATIC ARCHITECTURE, 30

IV.—GREECE, 52

V.—ETRURIA AND ROME, 68

VI.—THE EARLY CHRISTIAN STYLE, 88

VII.—THE BYZANTINE STYLE, 95

VIII.—MAHOMETAN ARCHITECTURE, 105

IX.—THE ROMANESQUE STYLE, 115

X.—GOTHIC ARCHITECTURE, 132

XI.—THE RENAISSANCE, 151

XII.—CONCLUSION, 162

A SHORT

HISTORY OF ARCHITECTURE.

INTRODUCTION.

Architecture is an art combining the qualities of utility and beauty. Its object is, and has been from its origin, to satisfy both the necessities and tastes of the various building races.

For this purpose the two distinct, and yet closely related, sciences of construction and decoration have been employed, and the history of the progress which has been made in each, goes hand in hand with the history of each age and each race.

The requirements of the inhabitants of every country have always been defined by its character and climate, and, in order to satisfy these requirements, the art has adapted itself to them and grown up and expanded in the different fields in which it has been directed.

It is customary to explain the origin of the art of building somewhat as follows: The first impulse of the barbarian, in whatever part of the globe he may be born, is to seek a shelter from the varying temperature of night and day. If he lives in the mountains, he chooses the caves and clefts in the rocks for his habitation; if on the plain, he follows the example of the animals and hollows out a retreat in the ground where he may seek warmth and protection. Where the soil is rocky, he gathers branches and moss, and piles them in such a manner as to form a rude dwelling. Soon after, he perceives the inconvenience of these untrimmed boughs, and remedies the discomfort by driving four straight posts into the ground, and roofing them over with cross-pieces, inclined so as to shed the rain.

This is the first semblance of a thoughtful construction, and the improvements upon it gradually develop into the more studied forms of architecture.

When the first requisite of shelter has been obtained, the early builder cuts off the rough edges and carves upon the posts rude emblems of the natural objects he sees about him, and in doing this takes the first step in design and decoration.

When wood is not abundant, he seeks a similar result in stone, and the treatment of each material gives rise to distinct principles of construction.

The Greeks, who had marble-quarries of easy access, bridged over their posts or columns with straight lintels, capable of supporting the weight of the roof without danger of fracture. The Romans, who found their travertine difficult to handle, built their baths and palaces of brick, and, in seeking to connect their pillars and piers, adopted the round arch as a means of effecting this end, and this round arch was the main principle of Roman architecture. When, in due time, the pointed arch was found to combine great strength and beauty, this new method of building became the leading principle of Gothic art. So, according to each necessity, the different styles of architecture arose.

When civilization increases the requirements of man, it is no longer possible to begin a rude construction, and alter it afterward to suit these needs; therefore it becomes necessary to consider beforehand all the elements required, and, in order to facilitate this consideration, drawing comes in as a simple means of placing before one all that enters into the proposed building.

Therefore, in the study of architecture four divisions of the art must be considered, namely: The construction of buildings with various materials, the appropriate proportions of the same, their representation by draughtsmanship and their history in various times and among various peoples.

It will be readily understood that each of these divisions embraces a wide scope individually, and yet no one can be separated from the others without affecting the result as a whole.

It is proposed, therefore, to review briefly the history of this art, and the causes which have affected it, in order that, knowing the reasons which led to the formation of each style, the student may follow its study with the practical understanding and logical inference which lead to the best results.

* * * * *

The question of which country furnished the first or earliest period of approach to civilization in the building of monuments or habitations has been, and is likely to be, an open one for some time to come.

Speculative discussion on this point can serve no end of importance to architects; it interests more especially the historian and antiquarian. Consequently we will, for the sake of convenience, glance over the periods of architecture in the following order:

1. Celtic or Druidical remains. 2. The Monuments of Egypt. 3. Asiatic architecture. 4. Greece. 5. Etruria and Rome. 6. The Early Christian style. 7. The Byzantine style. 8. Mahometan architecture. 9. The Romanesque style. 10. Gothic architecture. 11. The Renaissance.

I.

CELTIC OR DRUIDICAL REMAINS.

The Celtic race has left enduring marks of its power in the numerous monuments which are found in various parts of Great Britain, France, Germany, and Spain, and scattered through adjacent countries.

These consist of collections of huge uncarved boulders, arranged in geometrical lines, and often found in the centre of vast plains, far removed from quarry or mountain-side.

The more common forms are called “menhirs or peulvans,” signifying in Celtic “long stones.” These are either found separately or ranged in long parallel lines.

The most remarkable examples are at Carnac, in Brittany, where there are twelve hundred of these huge stones, varying from three to eighteen feet in height, ranged in eleven rows, leading to a semicircular enclosure.

What purpose they served, and whether of a religious or civil character, has not been conclusively determined. Some consider that they served to mark the burial-spot of the Druids; others that they were landmarks or emblems of victory.

To another class belong the so-called Rocking Stones, which consist of two immense blocks of rock, placed one upon the other, and either balanced so exactly that the slightest touch will suffice to shake them, or pivoted so as to revolve. There are examples at Tenanville, near Cherbourg, in the north of France, and in Sussex, England. One of these, called the “Great upon Little,” is estimated to weigh a million pounds.

Batissier considers them to have been erected by the priests, either to strike terror and wonder into the hearts of the people, whom they sought to hold in subjection, or as emblems of the world suspended in the air. We know that they have existed from remote ages, as mention is made of their antiquity by Pliny and Ptolemy.

Trilitha, or lichavens, are formed with three stones, two vertical and one horizontal resting upon the others, in the shape of a rude gateway. This is what they were probably intended for, though it has been suggested that they were used for altars. Similar to these are the dolmens, or table-stones, consisting of one large flat boulder supported by several smaller ones. Their upper surfaces, as a rule, have channels cut in them, which are generally believed to have been receptacles for the blood of victims sacrificed upon them, and some are even hollowed out in the shape of the human body.

The Merchants’ Tables, at Lochmariaker, are the most noted among the many that still exist.

From fragments of skeletons usually found in the vicinity of dolmens, it has been imagined that either the priests or their human offerings were buried there as upon consecrated ground.

There are several instances where these dolmens form covered ways or avenues, being placed one beside another in continuous line, and generally surrounded by a plantation of trees. They are frequently divided by blocks of stone into several compartments, and, like the tumuli or barrows, were probably used as places of interment for the dead.

The most interesting, perhaps, of any of these groups of stones are the "cromlechs": enclosures formed of numerous boulders, arranged either in elliptic rows or in concentric circles, with a large monolith in the central point. Each circle is composed of a definite number of "menhirs," and the whole is usually surrounded by a ditch.

It is supposed that each stone represented a minor deity, and the central one the chief of the gods. Their purpose apparently was to mark the place of large assemblies, called together for the administration of civil, military, and religious rites.

The cromlech of Stonehenge in Wiltshire is the most celebrated and one of the largest known. The country folk call it the Cor-Gaur, or dance of giants, and attribute its formation to the magic of the famous enchanter, Merlin. It is composed of two circular and two elliptic enclosures, the one within the other, and is several hundred feet in circumference.

In none of these Celtic monuments is there anything which may be called strictly architectural, but some of them illustrate a principle of building which is of importance to note. To place a row of stones in upright positions denotes no special phase of intelligent thought, beyond a desire to permanently mark some interesting locality, but when the ancient race which raised these massive rocks conceived the idea of supporting one block upon a number of smaller ones, it had reached a first principle of construction, destined to be employed for many centuries afterward in some of the finest buildings. After the trilithon came the table-stones, and from these it was but a step to the covered alleys, which were in themselves a first conception of a rude habitation, walled in and roofed over. There can be nothing more elementary than this, and no simpler constructional expedient, in whatever country it may first have been evolved. We do not know the precise date of Celtic monuments, nor is it probable that they are as ancient as the Egyptian pyramids, but as in any case they illustrate the transition from brutal ignorance to an era of thought, we may place them at the commencement of our chronological list. In the various themes and discussions advanced by archæologists, and the strange legends and tales of the peasantry with regard to them, we have no concern. It is sufficient for us to know that they exist and afford us an insight into the dawning efforts of a barbaric people to progress in the art which we propose to study.

II.

THE MONUMENTS OF EGYPT.

The history of Egypt is divided into five periods, from the earliest ages down to its conquest by the Romans at the beginning of the Christian era. The first period comprises the first fourteen dynasties of ancient kings, among whom the most important are: Menes, founder of Memphis, Shoofoo or Cheops, Shafra or Chephren, and Mycerinus, builders of the pyramids of Gizeh, and the two Theban monarchs, Osirtasen I. and Amenemha III., by whom the tombs at Beni Hassan, the Labyrinth and Lake Moeris were constructed. According to Bunsen these fourteen dynasties date from 3623 to 2547 B.C.

The second period is marked by the invasion of the Hyksos, or Shepherd Kings, of whom there were three dynasties. They remained in power until 1625 B.C. and were a warlike and destructive race, leaving no permanent traces of their occupation.

The third period is the most brilliant in Egyptian history, extending from 1625 to 525 B.C., and comprising nine dynasties of great conquerors and builders. The best known of these are: Amosis, Thothmes III., Sethi I., Rameses II. (the Great), called also Sesostris, and Rameses III. Under these kings the great temples of Luxor, Abydus, and Karnak were erected and the arts were assiduously cultivated.

The Persians under Cambyses occupied the country in the year 525 B.C. They were expelled a century later, but were again victorious in 340 B.C., and remained in possession until the conquest of Alexander the Great in 332. This fourth period was as unproductive in works of art as had been that of the Hyksos dominion.

After Alexander, the Ptolemys ruled until the close of the first century before Christ. Their government promoted the cultivation of the arts and industries and formed the fifth and last period in the history of ancient Egypt as an independent state.

Of these five epochs there are, therefore, only three—namely, the first, third, and fifth—during which architecture flourished, and these three in reality form but one long period in the history of an art which remained almost unaltered, scarcely either improving or receding, from the remotest times to its last day.

Our knowledge of ancient Egypt has been chiefly derived from bass-reliefs, mural paintings and hieroglyphics. The latter were unintelligible until the discovery of the Rosetta stone by the French consul Champollion, in 1798. This was part of a stone tablet bearing three inscriptions, one in hieroglyphics, one in the Cursive letters used by the lower classes, and the third in Greek. By means of this the old alphabet was reconstructed and all the ancient inscriptions deciphered.

TOMBS.

The most important monuments of the first period are the pyramids, the oldest of which were built between three and four thousand years before Christ.

There remain about a hundred of these in the vicinity of the ancient city of Memphis, extending over a considerable extent of country, and others are found in Thebes and at Meroë in Ethiopia. There have been many theories advanced upon the subject of their origin and purpose, and many arguments set forth seeking to prove that they were observatories, temples, granaries, meteorological monuments, or tombs. Nearly all modern authorities agree upon the last as the most probable solution of the problem, not only from the sarcophagi and mummies found within many of them, and from inscriptions relating events in the lives of important personages which adorn the walls of some of their inner chambers, but from the fact that these buildings are never found beyond the confines of cemeteries.

In erecting these monuments, the Egyptians usually selected a site upon a rocky plateau, on which a space equal to the superficial area required for the base was made level, a mound being left in the centre which was bonded in with the masonry. Below this platform a sepulchral chamber and connecting passage were hollowed in the rock. The pyramid was built over this chamber and contained one or more additional apartments, reached from the outside by narrow and inclined corridors. It was generally constructed with blocks of limestone, in successive steps receding at an angle varying from forty-five to seventy degrees. The outside was afterward cased with slabs of polished syenite, upon which inscriptions were engraved or painted. The interior chambers and corridors were likewise lined with polished granite, sometimes so mathematically jointed that a needle could not be pushed between the stones. Ceilings were formed by inclined slabs resting against each other or the walls were corbelled inward until they met.

The entrances to the passages were invariably closed and concealed, and portcullises of heavy granite blocks, sliding in grooves, were placed at intervals along the corridors, the more effectually to preserve the sepulchre from violation. Nearly all have, nevertheless, been entered and rifled, so that but little is left to aid the archæologist in his researches. Fragmentary inscriptions and local observations compared with the accounts given by Greek and Latin authors have, however, resulted in the piecing together of what may be presumed to be an accurate history of the pyramid-builders. The three largest pyramids are situated at Gizeh, a small village near Cairo, and are respectively those of Cheops, known also as Suphis or Shoofoo, Chephren or Shafra, and Mycerinus.

The following table shows the dimensions given by two of the best authorities:

SIDE OF BASE. PERPENDICULAR HEIGHT.

Sir G. Col. H. Sir G. Col. H. Wilkinson. Vyse. Wilkinson. Vyse. Cheops 756′ 764′ 480′ 9″ 480′ 9″ Chephren 707′ 9″ 453′ 454′ 3″ Mycerinus 364′ 6″ 208′

All of these are oriented and the entrances are all on the North sides. This is a rule applicable to all the pyramids except that of Sakkarah, which is placed without reference to the points of the compass and was probably erected at a much later date.

The first or Great Pyramid contains one subterranean chamber, reached by a passage some three hundred feet long, and two other apartments above the level of the ground, the one above the other, called the King's and Queen's sepulchres. The entrance to the connecting corridors is placed 45 feet above the ground and 23 feet away from the true centre in order to deceive explorers. The Queen's Chamber is about 18 feet square by 20 feet in height, and is placed directly under the apex of the pyramid. It is 67 feet above the ground, and 71 feet below the King's Chamber. The passage leading to the latter is 28 feet high, formed by corbelled walls. This chamber is roofed by a flat ceiling and measures 34 feet in length by 17 in breadth, and is 19 feet high. The walls and ceiling are built of finely polished granite, and the apartment contains a sarcophagus of the same material. The weight of the

superincumbent masonry is relieved by five other compartments placed over the chamber, four of which are covered by flat slabs, and the fifth by inclined stones resting against each other. It was in this highest compartment that some hieroglyphics scrawled in red ochre on the walls were discovered, by means of which the name Shoofoo became known. Herodotus says that one hundred thousand men were employed during twenty years in building the Great Pyramid, after they had devoted ten years, previous to its erection, to the construction of a causeway to the Nile, over which the stone was carried, which had been brought down the river from the Arabian hills.

Diodorus asserts that the number of workmen employed was upward of three hundred and sixty thousand.

The second pyramid contains two chambers, the most important of which is on the ground level, partly sunk in the rock. Its dimensions are 46 feet long by 16 in width, and 22 feet high. Within it a granite sarcophagus was found, containing the bones of an ox. This discovery gave rise to much speculation, as to whether the pyramids were not originally intended for the sepulchres of the animal deities worshipped by the Egyptians, the bull Apis in particular. The third pyramid was covered by a casing of polished red granite, formed of blocks with bevelled edges. There are several chambers inside, one of which contained a mummy and case, now transferred to the British Museum.

Near the pyramid of Cheops, on the same plateau, is the Sphinx. This great statue, with a human head and the body of a lion, is carved in the natural rock, deficiencies being made up by added masonry. Its dimensions are colossal, the body being 140 feet long, and the face 30 feet high by 14 feet in breadth. This mysterious creation was intended as the representation of a god, and as such had sacrifices offered before it, as the altars and temples erected beneath it attest. From inscriptions upon a stone found near by, it is known that the Sphinx was called Hor-em-khoo, "The Sun in his Resting-place." The head was originally surmounted by a royal helmet, the face had a beard, fragments of which have been unearthed, and it is otherwise badly mutilated. This fanciful creature has doubtless much affinity with the winged bulls and lions of the Assyrian epoch.

The Egyptians also buried their dead in smaller tombs, in subterranean vaults, and in catacombs excavated in the rock of mountainous regions. A great number of these smaller tombs were built in the vicinity of ancient Memphis and are now commonly called "mastabahs." In arrangement they were nearly all similar, the sepulchre consisting of three parts: a temple overground, a pit or well, and a subterranean chamber. The temple was in the shape of a frustum of a pyramid, the walls inclining inward at an angle of seventy degrees. It contained one or several apartments, used as places of assembly for the relatives and friends of the deceased, who came at stated intervals to hold services and to bring offerings of a suitable character. A list of these occasions was placed over the entrance, and on a second tablet or stella, inside, the name, titles, and virtues of the dead were recorded. The walls were brilliantly painted, domestic and religious scenes being the usual subjects depicted. The well-opening was usually concealed and filled with masonry. Its sides were formed of slabs of granite down to rock level and then excavated in the rock, sometimes thirty or forty yards below the surface. From the bottom of the pit a doorway, usually walled up, opened into a chamber containing a stone sarcophagus, in which the mummy was placed.

The finest excavated grottos are found at Beni Hassan and in the neighborhood of Thebes. Those at Beni Hassan follow the type of the "mastabah," having the assembly hall, the well, and the chamber beneath, all being hollowed out of the rock. The sides are decorated with columns, architraves, and cornices, in imitation of constructive architecture, and the ceilings are cut out to represent vaults, the uncarved surfaces being adorned with paintings and hieroglyphics. The columns are especially interesting, as having evidently furnished the Greeks with the model for their Doric temples, and the order has in consequence been called the proto-doric. They have a diameter of five feet and are sixteen feet high; the shaft has sixteen sides with flutings and is surmounted by a tile or abacus. Besides these, there are other columns with capitals in the form of a lotus or papyrus bud, which are more commonly found in Egyptian temples.

The tombs of the kings at Thebes are arranged on a different principle; they consist of long sloping corridors opening into chambers and halls, and penetrating in a continuous line into the mountain rock. There are several groups, the most important of which is situated in the valley of Biban-el-Molook, or the "Gates of the Kings." The tomb of Sethi I., the father of Rameses II., discovered by the explorer Belzoni in the earlier part of the century, is the finest example, the sculpture and paintings which it contains being very remarkable for their execution and of great historical interest, as they illustrate very completely the manners and customs of the ancient Egyptians. Every effort had evidently been made to conceal the tomb, for not only was the entrance closed and covered with loose rock, but the first chamber, reached by a succession of passages and steep staircases, had been walled up and the four sides painted, so as to have the appearance of being the limit of the extent of the tomb. The hollow sound, caused by hammering on the walls at one point, led the explorer to continue his efforts, which were rewarded by the discovery of several more halls and

chambers, terminating in a great vaulted chamber, thirty feet long, containing an alabaster sarcophagus. It has been conjectured that many of these excavated grottos were occupied as residences by the kings and great personages of the empire during their lifetime, and converted into sepulchres after death. The custom of relatives meeting at intervals in an assembly hall connected with the tomb does not seem to have prevailed here as at Memphis, but it is not improbable that the great Theban temples were used, if indeed they were not erected for this purpose.

The great mass of the people were not honoured by such magnificent tombs, but were buried in subterranean vaults in the necropolis (Greek, "city of the dead") attached to each great town. The largest are those of Saïs, Sakkarah near Memphis, Thebes, and Abydus. These underground galleries were reached by deep wells, and often contained several stories of small chambers in which the embalmed bodies were placed, together with vases, statuettes, and other votive offerings. There were also cemeteries in which the animals worshipped by the Egyptians were buried, containing thousands of embalmed birds and reptiles, particularly the ibis and crocodile. The Apis mausoleum at Sakkarah, where the sacred bulls were interred, is one of the most important, the chambers and galleries being excavated in the rock and covering an immense area. The mausoleum was connected with the Serapeum, a temple above ground, where the living bull was worshipped as a deity.

TEMPLES.

There are two classes of Egyptian temples—those hollowed out of the mountain rock, commonly called speos, and those built upon the open plain and distinguished by the term "hypæthral" (Greek, "under air"). The most important of the latter are the temples of Sethi I., at Abydus; Amun re, at Kooneh; the great and small temples of Medeenet Haboo, erected by Rameses III. and Thothmes II.; the Rameseum or Memnonium, of Rameses II.; Luxor and Karnak, at Thebes; and the temples of Denderah, Edfou, and Philæ, built by the Ptolemys. All of these are similar in general plan, consisting of a greater or less number of courts, halls, and sanctuaries, which in each case are placed "en suite," that is, one opening into the other in a continuous line, the larger apartments being in about the centre of this line and gradually diminishing in size, the last chamber being the smallest. As the main characteristics of the largest temples apply in a modified form to the smallest, a description of a complete temple would seem to be the best way of explaining the usual arrangements. A wall of crude brick usually enclosed the whole structure, which was surrounded by a sacred grove, or temenos. This wall was entered by an outer gate, or pylon, built in the shape of a frustum of a pyramid, and surmounted by a coved cornice, the doorway having perpendicular or slanting jambs. From this an avenue, or dromos, bordered with sphinxes with human or rams' heads, led up to the propylæa, or towers. The latter resembled the outer pylons, but were on a larger scale, containing staircases leading to upper terraces. They were spaced a short distance apart to admit of a passage between them, which was entered through a second gateway similar to the first. The sides of these buildings were usually elaborately painted, and rings were inserted in the masonry to hold the poles upon which the royal banners were hoisted. This second entrance was often flanked by two obelisks—long tapering monoliths with pyramidal summits, covered with hieroglyphic inscriptions recounting the dedication of the temple by the king to his favorite divinity. These obelisks were sometimes ninety feet high, and mounted upon square blocks. They were not always of equal size, probably owing to the difficulty of obtaining single stones of such enormous length. It is of interest to note that their sides were made slightly convex in order to prevent their appearing concave, which would be the effect had they been left quite flat. A second set of towers, or propylæa, with staircases, came next, with a court or area intervening. On each side of this court a colonnade was generally placed; and sometimes before the entrance to the towers two colossal statues of the king, represented seated, with his hands resting upon his knees in the conventional attitude of repose. The most famous are those known as the Colossi of Memnon, which stand on the plain of Thebes. They were probably in the court of the temple of Amunoph III., of which scarcely any vestige now remains. They are fifty feet high, mounted upon pedestals. One of them is called the Vocal Memnon, as, in ancient times, it gave forth sounds at the break of day—a phenomenon more easily explained as a trick of the priests, than by natural causes.

Beyond this court there was usually an inner vestibule, with columns forming porticos on the four sides; those opposite the entrance being connected by stone screens, reaching half-way up, forming a shaded anteroom, or pronaos, to the great hall of assembly, which was the next apartment.

The shafts and capitals of the columns varied in different buildings. The plain cylinder, carrying an inverted bell decorated with palm or other smaller leaves, or a capital in the shape of the lotus flower were the commonest forms. A column, representing the stems of water-plants bound together with rings, and swelling out at the top in the place of the capital, was also often employed. Besides these, statues of kings, or shafts surmounted by the heads of Isis or Osiris, were used as supports. The architrave, or beam, did not rest directly upon the capital, but upon an intermediate block. This block, when on the heads of deities, was in the shape of a

miniature pylon. The cornices were formed of a deep cove and fillet decorated with winged asps.

Some idea of the size of these inner vestibules, or peristyles, may be formed from the dimensions of that in the great temple of Medeenet Haboo, which measures 123 by 133 feet, and has a height of 39 feet 4 inches. Each of the porticos of the East and West sides is supported by five columns; those on the North and South by eight Osiride pillars, having a circumference of 23 feet and a height of 24 feet.

The great hall of assembly, which adjoined the vestibule, was generally the finest portion of the temple. The architraves supporting the roof rested upon a great number of lofty columns, which in the centre rose to a greater height, in order to obtain a clerestory, by which the hall was lighted. The largest of these is in the temple of Karnak, measuring 170 by 329 feet. The central avenue consists of twelve columns, 62 feet high by 11 feet 6 inches in diameter. Besides these there are one hundred and twenty-two others, 42 feet 6 inches in height and 28 feet in circumference. The lintel over the doorway by which it is entered measured 40 feet in length. The sanctuary was contiguous to the great hall, and terminated the suite. This consisted of a chamber, either occupying the whole of the rear space, or isolated by corridors on each side, with smaller sanctuaries opposite. In many of these, altars and statues have been found, some of the former formed of a single block, hollowed at the top and pierced through from top to bottom, so that sacrifices placed upon them could be consumed apparently without ignition, by means of fires kindled in subterranean vaults.

In connection with the halls in the temple of Abydus and elsewhere there were a number of vaulted chambers; the vault not being formed of a series of true arches, that is, with joints radiating to a common centre, but consisting of stone beams placed one beside the other, and hollowed out on the under side. The arch, however, was not unknown to the Egyptians—there are stone vaulted tombs at Sakkarah of the time of Psammetichus (650 B.C.), and crude brick arches have been found at Thebes dating as far back as the period of the eighth dynasty (2925 B.C.?). The antiquity of the arch has been the subject of much debate, owing chiefly to the fact that the Greeks made no use of it; recent explorations have, however, shown that this constructive expedient was known both in Egypt and Assyria many years before it was adopted by the Etruscans, to whom its invention was long attributed.

The exterior walls of all temples were built on a batter, sloping inward at an angle of about seventy degrees and with scarcely any openings. The inside walls were perpendicular, and decorated with bass-reliefs and paintings. These were often of a most elaborate character, and it is from them that so much has been learned concerning the ancient history of the country.

The rock-cut temples of Nubia are laid out on much the same plan. They usually consist of a pronaos, naos, and sanctuary, forming a suite, with an entrance marked by colossal statuary hewn out of the side of the cliff. Some have a dromos of sphinxes, propylæa, and a peristyle court of masonry preceding the excavated portions. The temple of Wady Sabooah is the best example of the latter. Of the former none can compare with the Great and Small temples of Aboo Simbel, or Ipsambool, which are of the time of Rameses the Great.

The smaller of the two is dedicated to the goddess Athor, the Venus of the Egyptians. The exterior is ornamented with six statues of deities recessed in the rock, each measuring thirty-five feet in height. In the interior there is a first hall, supported by square pillars, opening into a corridor, flanked by smaller halls, leading to the sanctuary.

The front of the Great temple is adorned with four statues of the king seated upon his throne, each sixty feet high. In the great hall there are eight Osiride pillars, upward of thirty feet in height. The sides of the speos are carved with bass-reliefs, representing the conquests of Rameses the Great. There are some sixteen smaller chambers, the suite terminating in the sanctuary, which contains an altar and four statues—the three deities, Amun re, Phre, and Phtah, with the king seated in their company.

Under the headings tombs and temples are comprised the chief architectural works of the Egyptians. Besides these there were one or two gigantic constructions, famous in antiquity, but which have now almost disappeared. Of these, the Labyrinth and the Lake Moeris were the most important. The former appears to have been an immense structure, half palace, half tomb, built by Amenemha III., of the twelfth dynasty. It was built on three sides of an open square, measuring about five hundred feet on the side, consisting of numerous chambers and courts, in two stories, one above and the other below the level of the ground. At the open end was placed a large pyramid, of which the ruins still remain. Herodotus admired the Labyrinth more than any other of the Egyptian buildings, declaring it to surpass the pyramids in labour and expense. Near by was the artificial Lake Moeris, formed to retain the Nile waters during the inundation, for the purpose of irrigating the country surrounding Memphis, during the dry season. It covered an immense area; tradition says 450 miles in circumference. The banks were fortified with massive masonry, and the waters distributed by means of locks and sluices.

The Egyptians appear as a civilized nation, having a scientific, artistic, and political knowledge of no mean order, at a time when the greater part of the world's inhabitants were but a step removed from the level of ignorant savages, and when, according to a generally accepted chronology, the world itself had existed but a few hundred years. The construction of the Pyramids reveals a building capacity which has rarely been rivalled, requiring not only immense mechanical power, but an accuracy of judgment and calculation in the adjustment of blocks of granite weighing many tons, not simply piled one above the other, but perfectly jointed and polished, and so disposed that passages and chambers were roofed over and their ceilings relieved from superincumbent weight by ingeniously contrived compartments, one above the other, and closed by sliding doors of monolithic stones, the handling of which could only have been successful by people well versed in the theories of equilibrium and support; and yet all this was done at a date which the best authorities agree in saying could not have been later than three thousand years before Christ. Their temples show an equally advanced erudition, and the paintings and hieroglyphics with which the walls of these buildings are adorned give a faithful representation of the customs of a people acquainted with the minor arts and sciences and the appliances requisite for agriculture.

The admiration with which we may regard the excellence of so ancient an art is tempered when we find that it contained no element of progress. The monuments of the eighteenth dynasty, though numerous and imposing, scarcely differ from those of the preceding period, and even in the days of the Ptolemys, who encouraged the native art, there was nothing attempted but a repetition of the old methods. From beginning to end the arts were so fettered by conventionality and dogmatic laws, opposed to originality or change, that the only improvements made were in mere mechanical execution.

A great prevailing thought seems to have actuated this people,—that of death and eternity. Their aim in erecting their buildings was to render them quasi-eternal, and by embalming the bodies of the dead they even sought to perpetuate the semblance of life. Their kings at the beginning of their reigns commenced the construction of their own sepulchres, employing hundreds of workmen and immense expenditure of the national funds for the purpose, and countless thousands passed their lives in hollowing temples in the mountain rock and in carrying huge blocks from great distances for the building of the pylons and hypostylic halls of the Nile, in which durability and massiveness were considered all-important.

Egyptian architecture, simply from the enormous scale of everything it produced, was always dignified and it had also the merit of severe simplicity; but mere size can scarcely be rated as an artistic quality of a high order, and on that account it cannot compare favourably with the art of the Greeks, who were probably inspired by what they saw in Egypt, but who, in their own work, succeeded in combining the qualities of majesty and beauty without resorting to the use of extraordinary materials.

III.

ASIATIC ARCHITECTURE.

It would, perhaps, be reasonable to suppose that in India, where the Aryan race had its origin, the earliest traces of dawning art would be found. It has, however, been fairly well established that all remnants of very ancient art, which may have existed there in former times, have now virtually disappeared, and that at present there are no remains in Hindostan of a remoter antiquity than the second or third century before the Christian era.

The architecture of India loses much of its interest for us from the fact of its having had no influence upon the origin or development of the European styles of building, which, starting in Egypt and Assyria, formed a continuous chain, each linked with its predecessor and successor down to modern times.

The Indians were, in fact, never a migratory or colonizing race of people, and their architecture was a distinctly native production, executed in accordance with the rules laid down by the priests in their sacred books, having no affinity with the constructive principles of the Western world and showing no trace of the arts practised by Western nations, except in the slight resemblance of a few mouldings and fragments of sculpture.

The chief structures of the country are temples, pagodas, and dagobas, which are found in many different parts of the peninsular and adjacent islands, resembling each other in general style, but with some local peculiarities which have caused them to be usually classified in certain comprehensive divisions, of which the following are the most important:

The Buddhist style, including the stambhas or lats, a species of commemorative pillar, the stupas or topes, of which the best examples are found at Sarnath and Manikyala, and the viharas of Bengal.

The Dravidian style, exemplified in the temples of Chidambaram, Tanjore, Combaconum, and Madura, and the rock-cut temples of Mahavellipore, and those known as the Kylas at Ellora.

The Indo-Aryan, or Northern, comprising the temples of Kanaruc, Bhuwaneswur, Jajepur, and Cuttack, in the province of Orissa.

The stupas, or dagobas, were a form of structure specially erected for the purposes of Buddhist worship. They were sometimes built in the shape of a square tower upon rising ground, of which that at Sarnath, north of Benares, is the best known. The more important, however, are cylindrical and surmounted by a semicircular dome. These are usually erected on artificial mounds or tumuli, and are constructed either with jointed stones or with rough blocks bedded in cement. The interiors are of solid masonry, with the exception of a small square chamber, used as a repository for sacred emblems, the walls of which are continued up to the top of the dome. The stupa at Manikyala, is of great size, being upward of eighty feet in height, and measuring some three hundred feet in circumference. The base of the building is in the form of a cylinder, six or seven feet high, supporting an attic decorated with pilasters; above this the walls recede, and are capped by a hemispherical dome. There are a great number of dagobas in Ceylon, in the mountainous districts. They are usually placed in a walled enclosure, and surrounded by commemorative pillars. Smaller constructions of the same description are found in the interior of some of the temples, being placed where the baldachins, or altars, would be placed in Christian edifices.

The rock temples of India are of two classes, the one consisting of grottos hollowed in the mountain side, and the other of a series of monolithic buildings cut bodily out of the solid rock, and detached from the surrounding hill plateaus by wide excavated areas.

The former, resembling the speos of Egypt, consists of long galleries, divided into aisles by piers of the natural rock left at regular intervals to sustain the superincumbent mass. A recess or sanctuary is placed at one extremity, containing the statue of the divinity to whom the temple is dedicated. In some cases the interior is terminated by a semicircular apse with a hemispherical vault, and the entrance preceded by a vestibule containing votive figures, the whole forming a plan very similar to that of the Latin basilicas, which will be described in a subsequent chapter. The grottos are frequently excavated in several stories and connected by corridors and ramps.

The walls or sides are ornamented with rude sculptures, representing various forms of animal life and monstrous creations of native fancy. The piers or pillars are generally either square or octagonal, decorated with mouldings and flutings, and having well defined capitals and bases. The capitals usually support a stone beam or bracket, evidently in imitation of those used in wooden construction, in which a similar expedient would be employed to distribute the sustaining power over a wider surface than that directly above the column or post. This imitation of wooden forms, which we have already noticed in Egypt, is found universally in all ancient constructions showing that in nearly every country wooden architecture was employed before stone.

The group known as the Kylas of Ellora, is the finest example of the temples fashioned both inside and outside from the solid rock.

The whole edifice is monolithic and situated in an oblong court formed by a trench excavated “vivo saxo” on the four sides. The exterior surfaces are richly carved, and the piers shaped to represent elephants, lions, and fantastic creatures supporting the superstructure on their backs. The court is entered from a monumental porch, the upper story of which is connected with a small chapel by a bridge. This chapel is flanked by two colossal elephants, and by two columns or towers standing isolated on either side. A second bridge leads from this to the hall of Shiva, the chief room in the suite, which is divided by sixteen columns, with corresponding pilasters on the walls. At the farther extremity is the sanctuary containing the statue of the presiding divinity. Beyond this are open terraces, surrounded by chapels. The great hall is connected laterally with subterranean chambers in the surrounding cliffs, reached also from excavated corridors which follow the perimeter of the court, the mass above being sustained by square piers spaced at short distances apart.

The inside walls are decorated with bass-reliefs and the ceilings ornamented with stucco relievos, which were originally brilliantly painted. The height of the hall of Shiva is about fifty feet, the hillside opposite to it being about ninety feet high.

These temples may be said to be the most remarkable and unique architectural productions to be found anywhere. They are examples of long-continued perseverance and patience, and can only be the result of a preconceived design which must have been thoroughly studied in all its elaborate detail before the first stroke was given toward its realization. The unity of conception and execution exhibited in such works is truly wonderful, and it is not astonishing that the superstitious natives should attribute their creation to Visvakarma, the heavenly architect. On the other hand, there are but few practical lessons to be learned from their examination. Such methods are not possible in our day, nor if so, would they be desirable. Architecture of this kind is scarcely more

than wholesale sculpture, and as such can in no sense compare favourably with the grace of form and scientific construction which we see in the works of Greek and Gothic artists.

The Pagodas are the most important of the buildings constructed with jointed materials. They consist of vast enclosures containing numerous religious and domestic edifices. There are often double or triple series of enclosing walls of great height and thickness. The sides are usually placed so as to face the points of the compass and each contains a monumental entrance, richly sculptured, and adorned with bands of embossed copper.

The chief buildings within are the temple proper, or vimana, and a number of hypostylic halls with small sanctuaries dedicated to different divinities.

The form of the vimana differs in the North and South of India. In both cases it is pyramidal, but while in the Southern temples the plan is rectangular and the elevations marked by a series of horizontal stories and mouldings, in the North the exterior surfaces are convex and the outlines curved, showing vertical instead of horizontal divisions. The lower story, containing the idol, is usually a hollow cube of granite, and serves as a base to the pyramid above, which is most frequently built of brick with stucco facing.

The halls are composed of a great number of columns of varied design, placed in parallel rows. The ceilings are formed by stone beams or slabs resting upon the columns. The central aisle is frequently wider than the others and is roofed over by a corbelled vault.

A tank of sacred water surrounded by an open colonnade is not uncommonly placed within the enclosure, the waters being used by the infirm for the healing properties which they are supposed to contain.

The pagodas of Tanjore, Combaconum, and Madura are among the finest and most celebrated. They were built between the fifth and eleventh centuries of the Christian era, and should hardly, therefore, be described among the ancient buildings of the world, were it not that they are linked in with the chain of the older Indian art too closely to be separated from it.

In the period corresponding to the Middle Ages of Europe, Mahometan architecture was introduced in India and many beautiful buildings were erected in a new style blending the foreign art with the native ideas and taste, but offering a marked contrast to that which preceded it. Although China was one of the oldest of civilized countries it contains but few monuments of great antiquity. The temples and palaces, being built of wood, were exposed to fire and decay, and were often pulled down and rebuilt. With the exception of the great wall and of the numerous bridges crossing rivers or arms of the sea, there are no important stone constructions to be found there.

The latter are formed of huge granite piers, spanned by massive stone lintels, requiring the united labour of thousands of men to convey them from the quarries to their destination and to set them in place. In the mountains the ravines are bridged by iron chains suspended from cliff to cliff.

The great wall was built as a frontier protection, and extended the entire length of the boundaries of the country. It has always been kept in repair, although obviously absurd as a fortification in modern times. It is of great thickness, and upward of twenty feet in height. The foundations are of stone, and the upper part of brick with stone facing, the joints of which are extremely accurate. At short intervals there are towers, placed so that the middle distance between any two is within arrow-shot.

Chinese wooden buildings are all much alike, whether temples or palaces. As a rule, they have but one or two stories; they are surrounded by porticos, consisting of wooden columns mounted on stone bases, without capitals, which are replaced by a species of bracket. The roofs project considerably, and their angles are turned up, this form being undoubtedly borrowed from the old tent habitations, which were composed of hides stretched tightly on bamboos. The tiles with which they are covered are semicylindrical in shape and are enamelled with bright colour.

The celebrated taas, or Buddhist towers, are of similar construction. They are generally octagonal, and from six to ten stories high. Each story is set back from the one below, and has a balcony and projecting roof, with bells hung in the angles. The walls are covered with tiles or paintings. A high staff is placed on the top and connected with angles of the roof by chains.

The tower of Nankin, known as the Porcelain Tower, was the most famous. It was erected in 1431, and but recently destroyed.

The Chinese have always excelled in artificial or landscape gardening. In this work they build airy bridges, with open-work balustrades, pavilions highly ornamented and enriched with painting and gilding, and boundary walls with circular openings,

disclosing vistas of great beauty.

Their commemorative gateways are of interest, as they have a central opening and a smaller one on each side, like the Roman triumphal arches; the heads are square, however, with brackets in the corners. The upper parts are ornamented with figures in relief and inscriptions recording the virtues of persons to whose memory they are dedicated. Although communication existed between China and the countries bordering upon the Mediterranean from remote ages, Chinese architecture, like the Indian, was without influence upon that of Europe. It is only in Western Asia that the first forms of building are discernible, which were subsequently imitated or followed in European constructions. The most important of these are situated in Mesopotamia, the fertile region comprised between the Tigris and the Euphrates.

The political histories of Assyria, Babylon, and Persia are generally treated separately, but the architecture of each belongs to one style, which may be called the Assyrian, for its distinguishing characteristics remain the same in all the great cities which were in turn the capitals of reconstructed kingdoms and empires.

It may be considered in four chronological divisions: In ancient Babylon, from 2234 B.C. to 1520 B.C., at Wurka and Mugheyr; in Nineveh, from the fourteenth to the seventh century B.C., at Nimrod, Khorsabad, and Koyoundjik; in the second Babylon, during the seventh century and after the capture of the latter by Cyrus in the year 538 B.C., in Persia, at Persepolis, Passargadæ, and Susa. A renaissance of the art may be traced in Sassanian buildings erected eight centuries later.

The citadels, palaces, and other important structures of these cities were usually built upon artificial mounds or terraces, strengthened by massive walls. The materials used were bituminous bricks, cemented with bitumen, slabs of gypsum anchored with copper nails and bands, and timber for roofs and columns. Stone and gypsum or alabaster were employed in Nineveh and in the cities of Persia. In Babylon the only available material was bituminous clay, and consequently all the buildings there were built of brick. At the present day nothing remains of these but irregular mounds, from which but little can be gathered toward an understanding of what their appearance was when entire.

Wood was probably used to a great extent, and was naturally most easily destroyed by the fire of invading armies. The roofs, formed of thick layers of earth carried on beams, in falling in, buried the lower portions of buildings, and it is probably due to this fact that the bass-reliefs have been preserved.

The surfaces of the bricks were frequently enamelled in colours, and the wood-work was probably brilliantly painted, as traces of pigments have been found upon the more durable materials.

But little was known of Assyrian art prior to 1843, when the excavations of Botta, the French consul at Mosul, followed soon after by those conducted by Layard, brought to light many ruined buildings, in which bass-reliefs, inscribed stones and metals, and other important relics were found, enabling historians to form a consecutive account of the government, warfare, and arts practised by a people whose cities have lain buried and whose very name has almost been forgotten for over two thousand years.

The explorations were made in Nimrod, Koyoundjik, and Khorsabad. The palace of Asshur-bani-pal, erected at Nimrod, in the ninth century B.C., is situated upon a terrace, or platform, approached by a wide staircase, and preceded by two gates decorated with winged bulls.

These winged bulls, or lions, were placed as the guardian deities, at the portals of all the great Assyrian palaces, after the manner of the Egyptian sphinxes, not standing isolated like these, however, but built into the masonry, one side or the front and one side only, being carved. The head was human, with long beard and hair, and surmounted by a helmet, the wings large and proportioned to the body. As Sir Henry Layard remarks, it would have been difficult to find more fitting symbols to express at once the wisdom, power, and ubiquity of a supreme being.

The chief apartments of the palace are a large assembly hall, 152 feet in length by 30 feet in width, and a number of smaller chambers and banqueting-halls, ranged around an open court. The walls of the great hall were decorated with bass-reliefs, representing triumphal processions, carved upon slabs of gypsum eight feet in height.

The palace of Esarhaddon, erected in the seventh century, on the same terrace, contains a large hall, 165 by 62 feet, divided in its length by a wall, surmounted by a gallery of columns. One of the only well-preserved ramps which has been discovered was that leading to this palace.

At Koyoundjik, opposite Mosul, the palace of Sennacherib was found at the Southwest corner of a mound a mile and a half in circumference. It contained a vast number of courts and halls, decorated with bass-reliefs and winged bulls, and two colossal statues.

The palace of Sargon at Khorsabad, erected in the year 704 B.C., is among the best preserved. Like the others it is placed upon an artificial terrace, enclosed by a wall a mile long on each side. It was defended by a citadel of eight towers with doors flanked by winged bulls. The palace was reached by a long, narrow passage leading to a court and entered through three great gates. The bulls of the central portal were 19 feet high. On each side were two bulls, 13 feet high, with the figure of a giant strangling a lion between them.

The halls and chambers were grouped around two great courts measuring about 350 by 200 feet. The hareem formed a separate set of buildings, as did also the stables and outhouses. The walls were of great thickness, evidently for coolness. They were decorated with slabs of alabaster, enamelled tiles, and designs painted on stucco.

There has been much speculation on the method of roofing these rooms, some believing that circular vaults were employed and others that wooden beams, supported on wooden columns, similar to the stone ones found in Persian palaces, were used for this purpose. The latter theory seems the more probable, as the local manner of building is the same as this at the present day. No traces of columns remain, however, and the spans are in many cases too great to be roofed by single pieces of timber. One of the most interesting discoveries made at Khorsabad was the gate of the city, the jambs supporting a semicircular arch over a span of eighteen feet. The gate was a double one having two separate passages, one for vehicles and the other for pedestrians: the marks of chariot-wheels still remaining in the pavement of the former. The sides were ornamented with winged bulls, and the archivolts of the arches were decorated with blue and yellow designs in enamelled tiles.

It had been long supposed that the Etruscans were the first to make use of the true semicircular arch (_i.e._, formed of wedge-shaped stones or bricks, with joints radiating to a common centre), but this discovery, and the finding of pointed arches in the sewers of Babylon, by Layard, places the date when both these expedients were known, at a much remoter period, though even these are probably much later than the examples found in Egypt.

No complete example of a Chaldean temple has been found, but there are several the lower stories of which are sufficiently well preserved to give an accurate idea of their size and details, and in the tomb of Cyrus at Passagardæ, in Persia, we have probably a model on a small scale of one of these buildings when entire. This tomb consists of a platform of six steps, eighteen feet high, surmounted by a rectangular chamber. The latter has a doorway and a ridged roof abutting against pediments.

It has been surmised that all the temples were like this, consisting of a chamber or cella built on the summit of a several-storied structure, each story being either concentric and reached by a ramp winding around the four sides or placed farther to one side than that immediately below it and approached by straight flights of stairs.

The oldest is probably that at Wurka, dating as far back as 2000 B.C., known as the Bowariyeh. There are the remains of two stories, the lower occupying about 200 square feet. It is probable that a third story or a cella was placed above these, but nothing positive can be said on the subject, owing to the extremely ruinous condition of the building. The temple of Birs Nimroud, probably identical with the tower of Babel, is in a more satisfactory condition, the upper story having been preserved by a process of vitrification. The lowest story occupies a square measuring 272 feet on the side, each of the upper ones, of which it is supposed there were originally six, being 42 feet less.

For the materials used in its construction we have the scriptural authority: “Go to, let us make brick and burn them thoroughly. And they had brick for stone, and slime had they for mortar” (Gen. xi.); slime being probably bitumen.

M. Place discovered the remains of a tower at Khorsabad, with a winding ramp, which he thinks was originally seven stories in height. The walls were strengthened with buttresses and decorated with sunken panels, and from traces of colour found upon them it has been supposed that each floor was painted in a different hue. The area covered by the base is about one hundred and fifty square feet, and the total height was probably one hundred and thirty-five feet.

The ruins of Persepolis are the best preserved of the ancient Persian buildings, those at Susa and Passagardæ being in too bad a condition to offer much that is interesting.

They are situated in the plain of Mardacht, upon a terrace partly formed of masonry, and partly cut in the rock of the adjoining range of hills. The wall is composed of huge blocks of stone fitted together without mortar, but with the finest of joints. The terrace is reached by a splendid double flight of steps, upward of twenty feet in width, and on a grade easy enough to permit of the passage of long processions without interruption. At the head of the stairs is a propylæum, or outer gate, flanked by colossal human-headed bulls. Beyond this, a second staircase, ornamented with a triple row of bass-reliefs, gives access to the Chehil Minar, or great hall of Xerxes.

This building occupies a rectangle about three hundred and fifty feet long by three hundred in width. It consists chiefly of a central hall and three lateral porticos, the roofs of which were sustained by 72 columns, 36 in the hall and 12 in each of the porches.

Thirteen of these are still standing, and the position of all the others is well defined by broken bases or shafts. They are of two different kinds, the one having a capital composed of double-headed bulls, and the other a capital with volutes, not placed horizontally as we see them in classical columns, but vertically and resting on a complicated series of mouldings. These last may have been also surmounted by the double-headed bulls, as without such an addition the columns are shorter than the others, which measure 67 feet 4 inches. The beams which they sustained, rested upon the body of the bull between the two heads.

The shafts of the columns at Persepolis are fluted and taper upward from the bases, which are elaborately ornamented with mouldings.

It is probable that the Greek Ionic capital was derived directly from the Persian voluted model, as the order originated in the Greek colony in Asia Minor.

The Chehil Minar is the finest building on the platform, the other halls of Darius and Xerxes being smaller, and though a hall containing 100 columns has been found, it is inferior in height, the total altitude not exceeding twenty-five feet.

The hall of Darius contained sixteen columns, forming a square, preceded by a portico with eight more. The walls have long since disappeared, but the façade of the building is reproduced upon the face of the rock-cut tomb of Darius in the neighbouring hill called Naksh-i-Rustam, so that a restoration of the structure as it originally appeared is easily made.

This tomb shows the four front columns of the porch with double-headed capitals, sustaining an entablature, above this is placed an attic decorated with bass-reliefs and a figure is represented standing on the top in the act of sacrificing on an altar.

The stone buildings of Persia are generally supposed to be reproductions of the wooden constructions of Assyria, as the character of the art is similar in both, the bass-reliefs and winged bulls of Persepolis being practically identical with those of Nineveh.

We find no traces of Assyrian art for several centuries after the erection of the buildings just described, though it is probable that it had influence in all Eastern edifices erected during the interval, not only in Asia, but in Greece and later in Byzance. There was evidently a revival of Assyrian taste during the dynasty of Sassanian kings who reigned between the third and seventh centuries of our era. The remnants of their palaces are found at Firouzabad, Al Hadhr, Serbistan, Ctesiphon, and Mashita, where we find large halls vaulted and domed and ornamented in a manner directly traceable to the ancient buildings in Assyria. The chief peculiarity of these structures lies in the use of the horseshoe or elliptical arch, which is found nowhere else. The porch of the Tak-Kesra at Ctesiphon consists of a great elliptical tunnel-vault, 115 feet deep, 85 feet high, over a span of 72 feet.

There is more or less Roman influence in the details of the Sassanian palaces, but it is not altogether certain whether the knowledge of domical construction which they exhibit was derived from, or was not itself parent to, Byzantine art.

Comparatively little is known concerning this Assyrian style, but it contains interesting elements, and it may be that its constructive forms are susceptible of a greater development in our own time.

Asia Minor, Palestine, and Cyprus are fields covered with the evidences of the glory of past ages, but the ruin and desolation everywhere is complete. The case of the temple of Jerusalem, where not one stone remains upon another, applies in most instances in places which have formerly been great cities, filled with magnificent buildings which were their pride in the day of their prosperity.

The temple of Solomon was situated upon Mount Moriah, and was built to accommodate the Levites, to offer a place of assembly for the people, and as a temple for the worship of the priests. The two sanctuaries were richly decorated with polished cedar and gold, with columns and cornices of bronze, and divided by linen curtains embroidered with purple and scarlet.

The peculiar formation of the hill upon which it was built, required immense walls of the most substantial character to be raised from the valley below to enlarge its summit, so as to afford sufficient space for the erection of the various courts. "It was built of stone, made ready before it was brought thither; so that there was neither hammer, nor axe, nor any tool of iron heard in the house while it was in building" (2 Kings vi., 7).

The temple itself is supposed to have been 60 cubits long, the porch 20 cubits, the Holy place 20 cubits; the width was 20 cubits and the height 30 cubits. The porch, however, was 120 cubits high. (The cubit is estimated to equal from 10 to 20 inches.)

The temple underwent several profanations, and at last was utterly destroyed in the reign of Jedekiah by Nebuchadnezzar, 580 B.C. After laying in ruins 42 years, the foundation of the second temple was laid by Zerubbabel and in breadth and height was double that of Solomon's. This second temple was plundered and profaned by Antiochus Epiphanes, and afterward rebuilt by Herod. It was considerably larger than its predecessor and was made of marble and of the most costly workmanship. It became the admiration and envy of the world, but, as our Lord predicted (Mark xiii., 2), it was completely demolished by Titus, A.D. 70.

Many restorations of the temples of the Greek colonists in Ionia have been attempted, but they are based on historical descriptions, inscriptions on coins, and other uncertain records, and are too conjectural to be accepted as accurate. There are, in fact, but few architectural remains sufficiently well preserved to be of interest to the architect, excepting the temples at Baalbek and Palmyra which are of the Roman period.

There are several groups of tombs, the most important being in Lycia.

These are of interest, as they illustrate more completely the transition between wooden and stone building than any other examples. There are two kinds, the one consisting of sarcophagi standing isolated, and the other of excavations in the mountain-sides. The former are composed of a stylobate or pedestal, serving as a base to a coffer ornamented with uprights and cross-pieces and panelled doors imitating exactly a wooden original. The roofs are curved, having in section the form of a pointed arch, being probably the earliest instances of its employment as a decorative feature.

The tombs cut in the face of the rock are of a similar description, having the same carpentry framework. The upper parts are terminated by a low pediment or by a row of stone logs supporting a horizontal moulding.

Later on during the Greek occupation, these wooden forms were abandoned and replaced by porticos of the Ionic order.

In various parts of Asia Minor, there are remains of tombs similar to these erected by the Pelasgi and Etruscans, which will be described in another chapter.

IV.

GREECE.

The oldest architectural works in Greece are those erected by the Cyclopes or Pelasgi, a race who came originally from Lycia, and moved gradually Westward, peopling successively the islands of the Grecian Archipelago, the Peloponnesus, Sicily, and Italy. At Tiryns and Mycenæ, in the province of Argolis, are to be seen the most remarkable remains of the buildings of this people, which were always grouped together in walled cities, serving as strongholds to protect the inhabitants of the province from the wild tribes with whom they came in contact. These cities were generally placed upon a rocky eminence, difficult of access and commanding a view of the surrounding country.

There are remains of high walls at Tiryns built of huge stones extracted from a neighbouring quarry and put together without cement or mortar, the interstices being filled with smaller stones. From the fallen blocks lying scattered at their base it is estimated that they originally measured sixty feet in height. At intervals these walls are pierced by triangular doors and windows, the sides of which are curved, forming arches obtained by corbelled or overlapping instead of wedged stones. These Cyclopean constructions date from the seventeenth century before Christ.

The Acropolis of Mycenæ is entered by a doorway formed of two vertical monoliths of great size supporting a lintel, and called the Gate of the Lions, from the carving above, representing two rampant lions separated by an engaged column.

This city was surrounded by high fortified walls, and contained a place of assembly for the people and rude habitations, the remains of which are still visible. There is also still to be seen a conical or bee-hive-like structure, commonly called the Treasury of Atreus.

This cone is formed by overlapping stones, curving gradually until they meet at the top of the vault, which is capped by a large block. The doorway by which it is entered is composed of slanting jambs of stone, sustaining a massive lintel. This lintel is relieved from direct weight above by a triangular opening, obtained by a similar process of corbelling. The Cyclopean remains are of interest to architects chiefly on account of this system of corbelled vaulting employed in their construction, which would never have been adopted had their builders been acquainted with the voussoir principle.

Dr. Schliemann has recently excavated the Acropolis of Mycenæ, and found there many interesting objects of gold and pottery. Bronze nails with flat heads have also been found within the Treasury of Atreus, which were evidently used to attach copper plates with which the interior was lined. Pausanias speaks of a similar treasury belonging to King Minyas, at Orchomenos, and other remains of the same description have been discovered in different parts of the Morea, bearing a resemblance to the ruined cities of Etruria.

In fact, the various tumuli found in Western Europe, Sardinia, Sicily, Greece, and Asia are all of the same type, and were a form commonly adopted by the ancient nations.

When we come to the epoch preceding Roman architecture, we will examine the character of Etruscan buildings, which were similar in many respects to the works of the Pelasgi; at present the subject of most interest is that of the great century of Greek art, for it marks the transition from Crude Art, to which belongs all that has preceded, to Fine Art, in which the Greeks excelled.

Greek buildings were erected according to the rules of three systems or orders, of the origin and character of which Vitruvius gives the following account, which, if not strictly accurate, is at least as reasonable as some of the versions which have been advanced. "Dorus, King of the Peloponnesus, having had a temple erected to Juno, in Argos, it was built by chance in the manner which we call Doric; afterward, in several other towns, other temples were built in this same order, having no established rule for the proportions of their architecture. About the same period the Athenians established several colonies in Asia Minor under the guidance of Ion, and they called the country which he occupied Ionia. These colonists built Doric temples there at first, of which the chief was that of Apollo, but as they did not know what proportion to give to the columns, they sought the means of making them at once strong enough to sustain the building, and of rendering them at the same time agreeable to the eye. For this they took the measure of a man's foot as the sixth part of his height, and on this measure formed their column, giving it six diameters.[1]

[1] We have already seen that there are columns at Beni Hassan, in Egypt, resembling so closely the Greek Doric, that it is reasonable to suppose that the Greeks borrowed their conception of the order from the Egyptians and refined it.

"Some time afterward, wishing to build a temple to Diana, they endeavoured to find a new method, equally beautiful and more appropriate to their purpose. They imitated the delicacy of a woman's form; they heightened the columns, gave them a base like the twisted cords which bind a sandal; they carved volutes in the capital to represent that portion of the hair which falls to the right and left of the head; they put circles and rings on the columns to imitate the rest of the hair which is braided and caught up on the back of women's heads; and by flutings they imitated the folds of the dress. And this order, invented by the Ionians, took the name of Ionic.

"The Corinthian column represents the delicacy of a young girl, at the age when the figure is slender and best suited to the display of ornaments which may add to her natural beauty. The invention of its capital is due to the following incident: A young girl of Corinth, who was about to marry, having died, her nurse placed some little vases which she had been fond of during her life, in a basket on her tomb, and, in order that the weather should not spoil them, she placed a tile on the basket. This, having been laid accidentally over an acanthus-root, it came to pass, when the leaves began to grow, that the stems of the plant crept up the sides of the basket and, meeting the corners of the tile, were forced to curve downward, and to take the form of volutes. Callimachus, a sculptor and architect, struck by the harmonious result, imitated it in the capitals of columns which he subsequently made in Corinth, establishing on this model the proportions of the Corinthian order."

[Illustration:

DORIC. IONIC. CORINTHIAN.

THE GREEK ORDERS.]

At this stage it is necessary to explain briefly that an order consists of a column, the pedestal upon which it stands, and the entablature, or top member, which it supports. The column is subdivided into the capital, or head; the shaft, or body; and the base,

or foot. The entablature has likewise three divisions: the architrave, or beam sustained by the columns; the frieze, or space occupied by the cross-beams; and the cornice, or line of stone marking the extremity of the rafters. These were originally made of wood and subsequently imitated in stone.[2]

[2] Viollet le Duc maintained that the Greek buildings were in no sense an imitation of wooden constructions, but gave no very satisfactory explanation of the origin of their component parts. It is perhaps best to conclude that they were adaptations of pre-existing edifices to new materials.

The Greek Doric column had no base and rested upon a series of steps in place of the pedestal. The ends of the cross-beams were marked upon the frieze by a projection, upon which were cut three grooves into which the rain-water ran and fell in drops to the ground. These drops were represented in stone underneath, completing an ornament which was called a triglyph (meaning in Greek, three grooves). The spaces intervening between the triglyphs were called metopes. The inclination of the sides of the roof formed the lines of the triangular termination which we call the pediment.

The Greeks employed three methods in their Doric, namely, the hexametric, heptametric, and octometric, that is, a proportion of six, seven, and eight diameters to the height.

We have seen what were the component parts of the Ionic and Corinthian orders in the quotation from Vitruvius.

In Greek temples the shafts of the columns not only tapered considerably, but the vertical lines of an entire building inclined to imaginary points determined by the intersection of lines following the inclination of the end columns. The mass was thus in the form of the frustum of a pyramid, being intentionally so designed to bind the parts of the building together in a manner to withstand effectually the oscillation caused by earthquakes, which occur frequently in this region.

The city of Athens contained numerous examples of each of these orders, and a brief account of the buildings of that city will be the best means of showing their principal characteristics.

The city proper, in which were the chief temples, was built upon a rocky hill rising from the valley of the Illysus, lying between the mountain-chains of Pentelicus and Hymettus, and situated about five miles from the port of Phalerum, on the Gulf of Ægina. This Acropolis (rock city) is approached by a broad flight of stairs leading to the Propylæum, or outer gate, with high pedestals on each side which were formerly surmounted by equestrian statues.

The Propylæum is composed of a porch of six Doric columns, giving access to a large vestibule flanked by two outer halls. This vestibule is divided by a flight of steps, placed between six Ionic columns on pedestals, supporting nine marble beams or architraves which carry the weight of the roof.

Beyond is a second porch, opening on the plateau of the Acropolis by means of five doors of different proportions. The lintel of the central or largest door measures 23 feet, while the architraves are 17 feet in length and of single stones.

The Athenians prided themselves greatly upon the vestibule of the Propylæum, and believed Pericles, by whose direction the building was erected, to have been divinely inspired. The details and proportions of the two orders here combined are of great beauty, and show the most refined study. From the farther porch, the Parthenon (meaning in Greek, virgin), or temple of Minerva, is seen to the right, exhibiting a fine perspective view of its North and West elevations.

The temple is raised upon a platform surrounded by steps, and is rectangular in form, composed of a cella, or oblong room, surrounded by an open portico. It measures 228 by 101 feet, having eight Doric columns on the front and seventeen on the flank, inclusive of the corner ones.

Ictinus and Callicrates were the architects, under the general supervision of Phidias, who designed the gold and ivory figure of Minerva within.

The Doric is of the hexametric order, having an approximate proportion of six diameters of the column to its height.

The pediments of the Parthenon were decorated with rich carvings in high relief, representing, in the one, the presentation of Minerva to the assembled gods by her father Jupiter, and in the other, the contest of Minerva and Neptune for the naming of the city. In the metopes were depicted the battles of the Athenians with the Centaurs, and scenes in the lives of Perseus, Theseus, and Hercules, in the admirable sculpture of Phidias.

The building stood almost intact from the fifth century before Christ to the seventeenth century of our era, when it suffered greatly from Venetian artillery, and in modern times its richest sculpture was torn from it under the Turkish régime, by order of Lord Elgin, who obtained permission from the authorities to remove it to the British Museum. One of the ships containing the marbles was sunk off Cape Matapan. Even in its ruined condition the Parthenon stands to-day a great example of the finest architecture the world has known.

On the plateau of the Acropolis are the three contiguous temples of Pandrosus, Erictheus, and Minerva Polias, and the temple of the Wingless Victory (Niké Apteros), of the Ionic order.

The temple of Pandrosus is virtually a porch attached to the larger temple of Erictheus. It is composed of six female figures or caryatides upon a high base, supporting an entablature without frieze. These figures are of exceeding grace and beauty, and are models of the sculptor's art. The single cella was probably divided into three, to which access was had separately by the several porches. The ceilings of these temples are flat and decorated with sunken panels, ornamented with egg and dart moulds. According to Diodorus Sicculus, the temple of Erictheus was erected in his honour by the Athenians, in gratitude for his having instructed them in the worship of Ceres, Goddess of Agriculture. While Pausanias states that it contained the miraculous spring created by Neptune, who shared in its dedication.

There are three windows in the wall of the cella—unusual features in Greek architecture—and the levels of the temples are different, evidently so arranged, with a view to distinguish them the more completely.

The temple of the Wingless Victory is supposed to have been erected where Ægeus fell from the wall upon seeing the black sails of his son's ship returning after his victory over the Minotaur. Others again assert that it was built without reference to site and so-called because the Athenians considered victory would never leave them, and consequently needed no wings. The temple is composed of a cella and two porches of four columns each, supporting a beautifully decorated entablature.

At the base of the Acropolis stood the resident portion of the city, containing also other temples and public buildings, which are still standing. The most important are the temple of Theseus, the Tower of the Winds, the theatre of Bacchus, and the monument of Lysicrates. Besides these there are many Roman buildings, but they belong to a subsequent period. Plutarch says that the Athenians under Cimon erected the temple of Theseus on his return from Crete, and that it is of older construction than the temple of Minerva. It has six columns in the front and thirteen in flank, supporting marble beams the extremities of which rest on the inner wall and correspond on the other with the triglyphs on the outer face. The metopes had carvings representing the exploits of Theseus. The temple stands at the base of the Acropolis to the North; it is similar to the Parthenon in many respects, being of the same Doric order, though less rich in sculpture. It is the best preserved of all the monuments, having suffered but little during the twenty-two centuries it has existed.

The Tower of the Winds, erected by Adronichus Cyrrhastes, is an octagonal structure surmounted by a frieze, upon which the eight winds of heaven are carved in allegorical figures. The roof is a pyramid of marble slabs and was at one time surmounted by a bronze triton holding a switch, which answered the purpose of a vane, but has since disappeared. The building was used as a water-clock.

[Illustration: PLAN OF THE TEMPLE OF THESEUS AT ATHENS.]

The choragic monument of Lysicrates, commonly called the Lantern of Demosthenes, is a circular structure of the Corinthian order. The spaces intervening between its six columns are closed by panels of a single stone upon which trivets are carved. The stone roof is decorated with scales and surmounted by a finial of delicate workmanship. On this was placed the tripod of the choir which had been successful in the Olympian contest of the year 375 B.C., according to inscription.

There are other Corinthian buildings scattered throughout Greece, but this is generally taken to be the best example and its proportions followed. The carvings of the frieze depict the exploits of Hercules, who is represented clothed in the traditional lion's skin.

On the opposite slope of the hill are the ruined chairs and benches of the theatre of Bacchus, fronting an open stage. In building a theatre, the Northern slope of a hillside was generally selected for the site, in order to avoid the direct solar rays. Seats were provided for the audience by cutting circular tiers in the rock and a marble stage, profusely ornamented, was erected facing them. The stage was raised in order that the orchestra might not interfere with the view of the actors, and a portico adjoining it, served as a promenade during the intervals in the performance.

The stadium, or circus, of Athens was formed in this way, taking in plan the shape of a horseshoe. It was here that the public games and races took place, the upper or circular end being occupied by the seats of the judges. It belongs, however, to a later period, having been constructed in the time of the Roman Emperor Hadrian. A few years ago the King of Greece caused the stadium to be excavated, and several marble chairs and seats were discovered.

Each city of importance possessed a Palæstra, or gymnasium, in which were rooms for bathing in hot or cold water, for the wrestlers to anoint themselves with oil and fine dust, and a school for young lads. The building was enclosed by a portico and surrounded by pleasure-grounds in which the public exercises took place.

The private dwellings were of one story in height, surmounted by terraces and divided by courts. The women's apartments were separated from the men's, and the larger houses contained banqueting-halls with accommodation for musicians and singers. The furniture consisted of tables in wood and choice stone, vases, candelabra, tripods in bronze, and rich Oriental carpets.

Externally the houses were painted brilliantly and decorated with wreaths, garlands, and arms. Outside the entrance door stood the statue of the god of the household—Jupiter, Minerva, or Mercury.

The richer citizens preferred country villas to city residences, which they surrounded with ornamental gardens and woods. The groves of the Academy where Plato held his school in the shade of the olives, outside the city gates, are probably the most celebrated of the latter.

The dead were buried in necropoli without the city, and their place of interment marked by tombs in the form of pyramids or funeral pyres, or more simply by a stella, or upright tablet, inscribed with the name and virtues of the deceased, and upon which were carved scenes in his life. In the colonies in Asia Minor the system of excavating chambers in the rock was adopted, the entrance to them being marked by Ionic columns supporting entablatures and pediments.

The public buildings of Athens were built of white marble from the island of Paros and the mountain quarries of Pentelicus, resembling in its fracture the purest loaf-sugar. The sun and rain have stained them to a tawny red during the many ages which have passed over them, and nearly all trace of the various dyes, with which they are supposed to have been coloured, has disappeared to-day.

The Greeks built their walls of bonded masonry, the vertical joints coming in the centres of the stones above and below, and they were frequently additionally strengthened by metal anchors. In walls of unusual thickness it was customary to construct the inside and outside faces first and fill the intervening spaces with loose stones and mortar, with an occasional through stone to connect the parts and bind them together.

The joints were sometimes emphasized by grooves, but this ornament was used more frequently in Roman work.

Until its introduction by the Romans the arch was rarely, if ever, employed, and the limit of inter-columniation was restricted by the necessity of finding stones of sufficient length to form the architraves.

The roofs were generally of wood, covered with terra-cotta tiles or sheet metal, and left open at intervals for the admission of light. This is, however, a disputed point, as the wood, being perishable, has left no positive proofs of the method employed. It appears that an awning or sail was stretched over these openings when services were being held. It is probable that in many instances there was no light admitted, except that from the entrance door. The effect of a religious ceremony performed in the temples by the artificial light of torches, with the flickering fires from the tripods and votive stands reflected upon the ivory and gold of the statues, and the smoke wreathing weirdly above the heads of the assembled multitude, must have been infinitely more impressive than if lit by the colder light of day.

The Greek colonists carried the principles of their architecture with them, leaving monuments of their genius wherever they established themselves. Of the temple of Diana, at Ephesus, nothing but a few fluted drums and scattered fragments remain to-day. It was the most magnificent temple of the Ionic order, erected with lavish expenditure, and decorated within with panels of cedar wood. It was burned and pillaged by the Persians.

At Agrigentum, in Sicily, and Pæstum, in Southern Italy, there are several Doric temples of massive proportions. Of these the temples of Concord, Jupiter, and Neptune are the most notable. The columns are shorter and their capitals broader than the Athenian type, and in one instance there are two orders superposed, within the cella, to support the roof.

The Greeks erected buildings in many parts of Southern Europe, in Asia Minor, and in Egypt, and in later times, even under the Roman conquest, they remained the masters of the arts, teaching their principles and supervising the erection of the monuments of Rome. The race was, indeed, peculiarly endowed with a genius for creating the beautiful, for though we have but scant information on the subject of Greek painting, we have preserved to us examples of sculpture which have never been surpassed or even equalled, and in architecture, though many more elaborate buildings have since been erected, nothing has ever been produced worthy of comparison with the harmonious proportions and majestic simplicity of the temples of Attica.

V.

ETRURIA AND ROME.

Etruria was peopled, from remote ages, by the indigenous inhabitants, and by colonizing races from Asia and Greece.

To the latter may be attributed the chief architectural works of the country; the ancient Etruscan walled cities resembling, in their general construction, those of Tiryns and Mycenæ.

Judging from the remains found upon the soil at the present day, the Etruscans used their knowledge of the laws of building principally in the erection of tombs. Of temples there now remain no traces; but, according to Vitruvius, they were composed, as a rule, of the rectangular chamber, or cella, of the Greeks, which was divided into three parts, and preceded by a porch of Tuscan columns. The origin of the latter he describes as follows:

"The Greek colonists, having brought to Etruria, the Tuscany of to-day, their acquaintance with the proportions of the Doric order, which was the only one as yet used in Greece, they employed this order there during a long period, in the same manner as in the country where it originated; but finally they changed it in several respects; they lengthened the column, and added a base to it; they altered the capital, simplified the entablature, and, thus changed, it was adopted by the Romans, under the name of the Tuscan order."

Etruscan tombs varied with the nature of the districts in which they were erected. In the flat portions of the country they consisted usually of an earthen cone raised upon a circular foundation of masonry, with one or more chambers within for the reception of the dead. The largest of these tumuli was that called the Cucumella, at Vulci.

In the mountains, where material was abundant, it was customary to bury the dead in a square stone chamber, surmounted by a pyramidal roof, and entered by a doorway ornamented with the Greek architrave. There are several examples of these at Castel d'Asso.

A third form of sepulchre was the hypogee, or underground tomb, the entrance to which was marked by a colonnade of the Tuscan order, carved in the face of the rock; the interior apartment being usually rectangular, and reached by a staircase. The walls were decorated with paintings, and the tomb filled with vases, tripods, arms, and other votive offerings. The body was generally either placed in a stone sarcophagus or laid upon a bronze bed. The ceilings in the older tombs were either flat, being cut in the natural rock, with piers left as supports, and ornamented with sunken panels, or constructed of inclined slabs, resting against and sustaining each other.

The corbelled vaults, similar to those of Mycenæ, were employed for a considerable number of these buildings, but were subsequently relinquished for vaults of voussoirs, or wedge-shaped stones. The invention of the semicircular vault, the joints of which converge to a common centre, was long attributed to the Etruscans, but we have seen that recent discoveries have shown that it was already in use in Egypt and Assyria many centuries before.

This principle, however, was the chief feature of Etruscan architecture, and its great legacy to succeeding styles.

Etruria as well as Greece sent artists to Rome, and the conjunction of the methods used in the two countries produced Roman art.

"The Romans took from the Etruscans the semicircular arch, formed of jointed stones; from the populations of the Campagna they obtained the general arrangement of sacred edifices, the Greek orders, the distribution and decoration of private dwellings. They drew thus from two different sources, and endeavoured to unite two principles diametrically opposed to one another—the principle of the Greek lintel and the Etruscan arch. In doing this they show clearly that their ideas upon the arts were but little better than those of pirates, whose acts are actuated by pride rather than by taste, and who adorn themselves in spoils of distinctly different origin, the mingling of which produces unseemly contrasts."[3]

[3] Entretiens sur l'Architecture.

[Illustration:

COLUMN. ENTABLATURE.

PEDESTAL. BASE. SHAFT. CAPITAL ARCHITRAVE FRIEZE. CORNICE.

WASH. OVOLO. ASTRAGAL. CORONA. ASTRAGAL. CYMA REVERSA. TENIA. FACIA. ABACUS. OVOLO. NECK. ASTRAGAL. FILLET. TORUS. PLINTH. TUSCAN. DORIC.

THE ROMAN ORDERS.]

Illustration:

IONIC. CORINTHIAN.

THE ROMAN ORDERS.]

[Illustration: COMPOSITE.]

In fact, the Greek orders, modified to suit the taste of the Romans, and combined with the Etruscan arch and vault, formed the basis of all Roman architecture. The scale of their buildings, however, was vastly greater than that of those upon which they were modelled. The colonnades of their palaces and the arcades of their aqueducts were to be measured by the mile, the vaults of their baths were of prodigious span, and, in general size and number, the edifices erected by the Romans exceeded anything which had come before them.

The Roman orders were five in number, namely, the Tuscan, Doric, Ionic, Corinthian, and Composite.

The Tuscan we have already examined. The Doric was somewhat more elaborate, having additional mouldings in the capital and base, and the triglyph ornament in the frieze. The Ionic and Corinthian were but modifications of the corresponding Greek orders. The Composite was of the same proportion as the Corinthian, the capital being a combination of the Ionic and Corinthian.

The Corinthian order was the most generally used, its rich character suiting the ostentatious ideas of the Romans. The superposition of columns was a common method of indicating different stories, and different orders were often employed where different-sized columns occurred in the same building.

In plan the Roman buildings were rectangular, polygonal, and circular, or combinations of these geometrical forms. The materials used were local stone, imported marbles and alabaster, and bricks, which were flatter and longer than the form employed at the present day. The Romans excelled in their mortars and cements, which were of a strength sufficient to make their walls virtually of one mass.

In bonding their stone they employed various methods, including those of the Greeks. Of these, a favourite one was the building of exterior faces only, and filling up the intervening space with broken stone and mortar. In order to produce the greatest effect at the least cost, in the use of marble, they resorted to panelling the external surfaces only with thin slabs. Interiors were lined with stucco and frequently ornamented with paintings, and the floors inlaid with mosaic. Roman mouldings were sections of the sphere, differing from the Greek, which were hyperbolas or parabolas.

The chief constructions of the Romans were houses, temples, palaces, amphitheatres, theatres, aqueducts, sewers, baths, triumphal arches, tombs and commemorative structures, camps, bridges, and basilicas.

[Illustration: PALACE OF DIOCLETIAN AT SPALATRO.

(_From Durand._)]

In, and in close proximity to, the Forum Romanum, or Campo Vaccino, are admirable examples of nearly all these different buildings. The level of the ancient market-place is several feet below that of the streets of modern Rome, but in the excavated portions are to be seen the old pavements of irregular stone slabs, laid upon concrete foundations and worn with the wheels of chariots.

Many ruined temples, the arches of Septimius Severus, of Titus and Constantine, the palace of the Cæsars, the Colosseum, and the Baths of Constantine are collected here within a stone's throw. By taking up each class of buildings separately, however, we will get a better idea of the nature of Roman architecture than by a description of isolated buildings.

Roman houses resembled in a measure the Greek, the different apartments being grouped around inner courts. The rooms consisted of halls, vestibules, banqueting-rooms, and sleeping-chambers, the women not being separated from the men, as was the case in Greece. The courts were surrounded by colonnades and in the centre a well was usually placed, to receive the water from the roofs. Many of the houses were several stories in height, but a limit to their altitude was fixed by decree.

The excavations in Pompeii have uncovered many interesting specimens of private dwellings, richly decorated with several paintings and having elaborate mosaic patterns on their floors.

In the city of Rome the palace of the Cæsars was the most notable example of domestic architecture, but at the present day it is difficult to discern among the débris and fallen walls what its original plan may have been. Some paintings in the so-called house of Livia, upon the plateau of the palace, however, show that the artists of the period had attained a high degree of merit.

[Illustration: PLAN OF THE PANTHEON AT ROME]

Roman temples consisted generally of a cella or rectangular apartment, preceded by a porch, the whole being raised on a platform, reached by stairs and enclosed by a colonnade below. Occasionally there was a double cella, with separate entrances and porches, as in that of Venus and Rome; and there are two remaining examples of circular temples—that of Vesta, on the Tiber, in Rome, and of the Sybil, at Tivoli—while still another type, that of the Pantheon of Agrippa, had a circular cella and a rectangular porch.

The Corinthian order was the most frequently employed, that of the temple of Jupiter Stator being the richest, while those of the Pantheon, the Maison Carrée, at Nîmes, and of the temple of Antonine and Faustina are admirable specimens.

This last is one of the best preserved temples, being very nearly entire at the present time; its frieze is of the most refined workmanship, representing allegorical animals, plants, etc.

The temple of Fortuna Virilis is a good example of the Ionic order, but this order was never a favourite with the Romans.

[Illustration: PLAN OF THE BATHS OF AGRIPPA CONNECTING WITH THE PANTHEON, ACCORDING TO PALLADIO.

(_From Durand_)]

A debased form of Ionic is that of the temple of Concord, or Vespasian, where the capital is altered to a considerable extent and a rope moulding added. A remarkable constructional feature of this temple is the relieving arch of brick, concealed behind the frieze, to diminish the weight on the lintel below.

The great drum of the Pantheon, enclosed by a circular vault, is one of the earliest examples of domical architecture. A notable feature in it is the absence of the keystone, which is replaced here by an open ring, leaving an aperture for the entrance of light. The walls are pierced with niches and relieved by immense arches. The pediment of the porch is one of the most perfect remaining; in height its proportion exceeds that of Greek temples.

The temple of Diana, at Nîmes, is a remarkable structure, having three aisles, the central one being decorated with niches and columns, which support an entablature and a ribbed vault.

The ruined temples of Baalbek and of Jupiter Olympius, at Athens, are among the most colossal of this class of building. The Corinthian columns of the latter measure upward of sixty feet, and their capitals are of singularly fine workmanship.

The Emperor Hadrian embellished Athens with numerous and splendid buildings, which to-day have assumed the colour and ruined appearance of the older constructions of the time of Pericles.

Of the temple of Jupiter Olympius there are scarcely more than a dozen columns standing of the original one hundred and twenty. The Turks ground up many of them to make lime for their mortar.

The Romans took their conception of the theatre from the Greeks. The building was composed of two parts, the one devoted to the stage and its accessories, and the other to the accommodation of the audience. The stage was usually in the form of a rectangle,

the longer side of which formed the diameter of the semicircle, which was the plan of the second part. The latter was composed of concentric seats in successive steps, to which access was had by stairs radiating from the centre and leading to an upper surrounding gallery. At the foot of these steps a space was reserved called the orchestra (Greek, "dancing place"), usually occupied by the senators. The stage, which was decorated with columns and niches, was raised above the orchestra, and was connected with the actors' rooms. The wall at the back of the stage was carried up to the level of the circular enclosing wall, and treated with superposed orders. The theatre of Marcellus, in Rome, and those of Herculaneum, Arles, and Orange are among the best examples.

The most celebrated amphitheatre (amphi theatron, Greek, "double theatre") is that commonly known as the Colosseum, or Flavian Amphitheatre. It is composed of the arena or oval space, occupied by the combatants, and of the "visorium," formed by concentric seats placed in tiers, one above the other.

[Illustration: PLAN OF THE TEMPLE OF THE SUN AT BAALBEK.]

It was capable of seating eighty thousand spectators, and upon its arena four thousand gladiators have fought at a time. It was here that before commencing their combats they came to the foot of the emperor's throne, saluting him with the celebrated cry, "Morituri te salutamus."

The substructure of the building consists of vaulted passages, communicating with the visorium by numerous staircases, and with the exterior by the doors called "vomitoria." The arena was surrounded by a ditch of running water, and under it were chambers in which prisoners and animals were confined.

The visorium was divided according to the rank of its occupants. The upper classes occupied the "podium" or lower gallery, which extended on either side of the emperor's throne, at the extremity of the longer axis of the building. For protection from the elements during performances an immense sail was stretched over the building from posts inserted in stone brackets at the top of the exterior wall.

The heights of the three lower stories of the Colosseum are marked externally by arcades and superposed orders with engaged columns, Doric, Ionic, and Corinthian, and the fourth and upper one by Corinthian pilasters. The entablatures of each order are carried around the entire circumference of the building.

Architects generally criticise this construction adversely, for "if, on the one hand, the engaged columns might be supposed to serve as buttresses and thus become a useful decoration, it must be admitted, on the other, that the projecting entablatures carried from column to column do more harm than good as regards the solidity of the building. [The architrave having no longer the force of the Greek lintel, being composed of several blocks supported by the arch below.] The Romans, however, did not always falsely apply the true principles of architecture. In the arena of Nîmes, for instance, the two superposed orders which serve as buttresses between the arcades of the two stories on the exterior of that building, are real buttresses. The lower order is composed of projecting piers, the upper order of engaged columns; the cornices follow the contour of each pilaster or column and do not form those projecting belts which are placed so clumsily and uselessly around such buildings as the theatre of Marcellus and the Colosseum of Rome."[4]

[4] Viollet le Duc.

This amphitheatre was commenced by Vespasian and continued under Titus, who dedicated it in the year 80 A.D. In the ninth century it was half destroyed, and subsequently became a quarry, from which materials were extracted for the construction of the Farnese palace and other buildings.

A large part, however, is standing to-day, having been rescued from total destruction by order of Pope Benoit XIV.

There are celebrated remains of amphitheatres at Verona, Pola, Capua, Arles, and Nîmes. Circuses and Naumachias belong to the same class of buildings, the one serving for chariot and other races, and the other for naval combats. The arena in each was oval in plan and from it rose the successive tiers of broad steps upon which the seats were ranged. At the top a portico decorated with statues enclosed the whole building.

The Circus Maximus was the most important of these, containing numerous splendid statues and obelisks, and covering a vast area.

The aqueducts of ancient Rome stretched for miles across the Campagna. The channel in which the water flowed was supported by one or more arcades, superposed according to the height required. These arcades consisted of round brick arches carried on substantial piers, and were placed where possible upon the highest elevations of the country they traversed. At intervals wide basins were provided for the collection of sediment, and reservoirs received the water at their termination. From the latter pipes supplied the baths and private dwellings.

In France the famous Pont du Gard is a portion of an immense Roman aqueduct formed of three rows of arcades, which supplied the city of Nîmes.

Bridges were constructed on the same principle; the arches increasing their span according to the depth of the piers upon which they rested, being generally of two stories, the upper one having double the number of piers.

The Roman bridges and aqueducts in Spain are among the most justly celebrated, notably those of Segovia, Tarragona, and Alcantara. Bridging rivers by boats was a common method in use by the Roman armies under Julius Cæsar. We have also an account of a wooden bridge over the Danube, constructed by Trajan.

Under every street in Rome there ran vaulted sewers conducting all impurities into the main artery, called the Cloaca Maxima, which in turn discharged its contents into the Tiber. This sewer is one of the oldest examples of the use of voussoirs, dating from the reign of Tarquinius Priscus. It is covered by a triple vault, sustaining the street above.

Agrippa conducted the waters of several streams into the sewers and appointed inspectors to keep them in repair and good order.

In the building of the baths of Rome, Agrippa, Nero, Vespasian, Caracalla, Titus, Diocletian, and Constantine vied with each other in the production of the most magnificent structures. They are to-day in a hopelessly ruined condition, but from the numerous fragments of carved marble and panelled stucco lying on their sites, and from the rich paintings and mosaics of the baths of Titus and Caracalla, it is not difficult to form an idea of their original splendour.

It is not a little significant of what their rich decoration must have been to note that such marvels of statuary as the Laocoon, the Farnese Bull, and the Gladiators have been discovered within them. Besides the necessary administrative rooms, these buildings generally contained a frigidarium or cold bath, a tepidarium or warm bath, and a sudatorium, circular in form and covered in by a dome. The walls, built of brick, were pierced with niches and supported high cross and barrel vaults of immense span. It has been conjectured that the Pantheon was the entrance hall of the baths of Agrippa, the porch having been added at a later period when the building was converted into a temple.

The chief commemorative structures were triumphal arches and votive columns. The former were of two kinds, having either one main arched opening, or a large central arch for vehicles and two lower ones on either side for foot passengers. The arch of Titus in Rome is an example of the first, its main arch being flanked by composite columns, supporting a richly carved entablature, which is in turn surmounted by an attic, inscribed with the dedication to the conqueror by the Senate and Roman people. The bassi relievi employed in its decoration represent the sacking of Jerusalem by Titus; a specially notable feature among the spoils depicted being the golden candelabra with the seven sockets, mentioned in Scripture history.

The arches of Constantine and Septimius Severus are of the second category. They are covered with rich sculpture and are of very beautiful proportion. Famous arches are those of Orange in the south of France, Beneventum, Ancona, Rimini, Pola, and Athens. Everywhere, in fact, where a victory was to be commemorated, or the termination of a great military road to be marked, it was customary to erect an arch.

Another method of paying homage to great men was to erect columns surmounted by their statues. The columns of Trajan and Antoninus in Rome are especially remarkable. The former is the higher and of the best workmanship. The pedestal upon which it rests is ornamented with elaborate carvings representing the arms of conquered nations, and is enriched at the four upper corners of its cornice by imperial eagles with garlands suspended between them. A wreath replaces the torus or round mould at the base of the column, and around the shaft is wound a ribbon of sculpture, representing a triumphal procession, which terminates at the capital. Isolated columns were also often employed for the inscription of legal notices, as boundary-marks, or for marking military limits.

The gates at the entrances of the principal cities were similar to the triumphal arches. There are two especially fine examples in France, those of Autun and Treves. In these the attic story is replaced by a gallery connecting the two flanking wings, which are

several stories in height, and contain chambers which it is commonly supposed were used as courts of justice.

Roman camps were regulated and arranged with military precision, and were of two descriptions. The one, erected for temporary use, was defended by a rude palisade of branches and a ditch, the other, the "castra hiberna," or winter quarters, was generally a permanent structure, built of brick, containing within a square enclosure the barracks, workshops, hospitals, and other necessary buildings. This enclosure was divided by cross-roads, passing through gates in the outer wall. The gate facing the enemy was called the porta prætoria, hence prætorian camp.

Necrological monuments were built in various forms, from the simple tablet to the immense mausoleums of the emperors. Just without the walls of Rome are still to be seen the remains of the sepulchre of Caius Sestius, a large pyramid containing a chamber several feet above the ground level. Farther out, on the Appian Way, is the tomb of Cæcilia Metella, a cylindrical structure upon a square base, of considerable magnitude. The exterior is simple, the only decoration being a series of ox-skulls in the frieze. This building was probably originally surmounted by an earthen cone, after the manner of the Etruscan tombs.

The tomb of Augustus was constructed in a similar manner but on a larger scale. The entrance was preceded by a porch and the exterior walls contained niches. The conical mound above was planted with trees and shrubbery.

The Scipios were buried in stone sarcophagi in a subterranean chamber, which has been but recently discovered.

A curious monument was that of the Horatii, consisting of a rectangular block of masonry, containing the sepulchre, surmounted by four stone cones, grouped around a fifth and higher one. These probably had a symbolical meaning, as a similar structure, called the tomb of Porsenna, is said to have existed in Etruria.

By far the most magnificent building of the kind was the Mausoleum, or Mole of Hadrian, the ruins of which now go by the name of the Castel St. Angelo. The tomb rose conspicuously on the banks above the Tiber, on a square foundation; its two upper stories were circular in plan, and decorated with colonnades and statuary, and the whole was capped by an immense roof, terminated by a pineapple of bronze.

The tombs of St. Helena and St. Costanza were circular structures similar to that of Cæcilia Metella, the cone of earth, however, being replaced by a dome. The interior of the tomb of St. Costanza was divided by columns which sustained a vault connecting with the outer wall.

The practice of burning bodies and preserving their ashes gave rise also to the building of columbariums, rectangular structures containing in their walls receptacles for funereal urns.

In the valley of Jerusalem the hypogee was the form of sepulchre commonly adopted, its entrance being decorated with a colonnade of one of the Roman orders.

Basilicas were the law courts of the Roman people and places of assembly for the transaction of their daily affairs. On the exterior, these buildings were surrounded by numerous courts and porticos, where the merchants assembled daily to discuss their affairs or to await the result of the trials conducted within. In the interior they contained a large hall or nave flanked by side aisles, preceding a transept or further room which was terminated by a semicircular apse. This apse was occupied by the magistrate while presiding in the cases submitted to his decision.

The ruins of the basilicas of Titus and Maxentius remain, at the present day, in sufficient preservation to show that in the one a flat ceiling of timber was employed, and in the other a system of intersecting vaults similar in construction to those of the baths of Caracalla. There are traces of several ancient buildings of this kind, but it is supposed that many were pulled down by the Christians, who erected churches on their sites, using the old basilica as their model.

The plan was, in reality, but an improvement on that of the Roman temple, the side aisles and transepts being naturally developed additions to the older cella to which the apse had been added previously in many examples.

The great administrative power governing the erection of the buildings of Rome was one of the most remarkable features connected with them. Architecture with the Romans was a means to an end, this end being the construction of edifices suiting their requirements and their desire for display. No scope was allowed for individual talent or ingenuity, unless employed in the carrying out of a distinct programme, laid down by those in power; each building forming part of a great scheme, prevailing throughout the conquered world.

In Greece architectural works were produced in the different cities and states under the guidance of independent artists, with the co-operation of their fellow-citizens who were eager to attain the true principles of art; in Rome and the Roman world, art was entirely subservient to a system of politics which ran through all departments.

The vast wealth which flowed into the capital from tributary provinces was the great mainstay which permitted the execution of so many vast and expensive structures, forming a collection never surpassed. Roman art corresponded with the national character, for it was coarse and ostentatious, but at the same time vast and strong. The population of Athens delighted in intellectual pursuits, in philosophy, in art; it crowded the seats on the slope of the Acropolis to enjoy the wit and satire of Æschylus and Sophocles, and the palæstra to witness the development of bodily grace and dexterity, while the Romans flocked to the Colosseum for the enjoyment of scenes of blood and carnage, to gaze upon the slaughter of captives and the anguish of animals. The force of their government, nevertheless, was unquestionable; their patriotism, unlike that of the Greeks, was unaffected by civic jealousies or party feeling; they trod rough-shod upon the nations, but they planted everywhere the imprint of their heroic civilization and made their capital the centre of the world, and left to it, for all ages, the proud appellation of the Eternal City.

VI.

THE EARLY CHRISTIAN STYLE.

After the conversion of the Emperor Constantine to Christianity, in the fourth century, the Christians who, as a persecuted sect had hitherto held their religious observances in hiding, in the catacombs of Rome, adopted the basilica as the most convenient form of building for the purposes of their worship. The bishop occupied a throne in the apse, surrounded by the presbyters or fathers of the church, and the congregation of the faithful filled the central nave.

For several centuries this plan was but little changed, the only notable additions to it being the continuation of the transept beyond the line of the walls of the nave, thus making it cruciform; the occasional substitution of double aisles, making five divisions in the body of the church, instead of the original three, and the addition of a tower or belfry.

All subsequent churches, whether Romanesque, Gothic, or Renaissance were constructed on but slight modifications of this original plan, which, in fact, was itself evolved from that of the Roman temple.

Illustration: PLAN OF THE OLD BASILICA OF ST. PAUL'S BEYOND THE WALLS.

A - Apse T - Transept N - Nave X - Narthex]

The first basilicas erected for Christian worship had double aisles; this form was, however, soon discontinued, probably owing to the difficulty of observing the offices of the clergy from the outer aisle. Of these St. Peter's, St. Paul's beyond the walls, and St. John Lateran were the finest examples. The first-named was built upon the site of the present cathedral, and was removed in the sixteenth century to make room for it. Its dimensions were of notable size, being about 380 feet long by 212 feet in width. It was preceded by an atrium, or open court, surrounded by a colonnade, in which the Christians met to transact their affairs. The basilica of St. Paul's was destroyed by fire in the early part of this century, and a new structure resembling the old was erected in its place on a scale of great magnificence. The columns of its Corinthian colonnade and the floor are of polished marble and the wooden roof lavishly ornamented with carving and gilding. The transept is enriched with mosaics, and contains a baldachin over the altar, in which malachite and other choice stones have been used unsparingly.

A typical basilica was generally arranged as follows: The atrium or quadrangular open court, surrounded by porticos, preceded the main building, or was replaced by a porch composed of columns sustaining a low roof which was called the narthex. Within, the structure was divided into a nave, side aisles, transept, and apse. The nave (derived from "navis," a vessel, symbolical of that of St. Peter) was loftier than the adjoining aisles, the upper wall being usually panelled with pictures and pierced at the top by a range of windows, from which the Gothic clerestory was derived later on. In one or two instances where the side aisles had a second story or upper gallery for the women, the panels and windows were placed in the outer wall.

The interior lines of columns were usually of the Ionic or Corinthian orders, having been taken from older buildings, but if new they were of stouter proportions than the Classical models. These columns supported either a continuous architrave or circular arches.

Wooden doors, often covered by chased bronze, were hung in the main entrance and the wall above was usually pierced by a round window or bull's-eye, afterward developed into the rose window. At the other end of the nave a wide arched opening, called

the triumphal arch, connected it with the transept.

An enclosure, separated from the body of the church by a balustrade, at the upper end of the nave, contained the seats of the choristers and the reading-desks.

The altar was placed in the transept and was frequently surmounted by a baldachin composed of four or six columns supporting a light dome. Behind the altar in the centre of the apse was the throne (cathedra) occupied by the bishop (episcopus), being raised by steps from the semicircular stone seats (exedra) used by the presbyters, which were covered with carpets. The walls of the transept and apse were inlaid with mosaic inscriptions and pictures, in which the head of our Saviour, the figures of saints and holy emblems were the chief subjects. Deep blue, purple, and green were the prevailing colours and the letters were of gold. The floors were decorated with mosaic patterns. The roofs were either flat with sunken panels framed with mouldings and gilded ornaments, or else showed the open trussed wood-work, though the latter was the exception. Externally there was no attempt at enrichment, the exterior generally offering a great contrast to the lavish internal decorations.

At the present day nearly all the basilicas have undergone transformation, the old roofs have been replaced, the walls covered with a modern adornment of pilasters and gaudy paintings, the colonnades have been broken through to allow of entrances to side-chapels, or disfigured by the heterogeneous decoration of the eighteenth century, and the exteriors treated with renaissance façades.

Nevertheless the general plan and arrangements have remained substantially the same, and we have very interesting specimens of this class of building in St. Maria Maggiore, St. Agnese, San Clemente, and others, in Rome, San Appolinare, in Ravenna, the basilicas at Torcello, in the Venetian lagoons, and later examples in St. Ambrogio, of Milan, and St. Maria Sopra Minerva, in Rome. The basilica at Torcello was built mainly from fragments of an older church upon the mainland at Altino. The bishop's throne is one of the most interesting and best preserved examples we have.

The Greek name for this, cathedra, was the origin of our term cathedral, applied to churches containing the bishop's seat, there being no architectural distinction between the buildings.

From the tombs of the Romans the Christians derived their conception of the edifices which they used as baptisteries. Their exterior walls were either polygonal or circular, and of severe simplicity. The interiors were generally divided by a row of columns sustaining a round vault, and forming a circular enclosure in which the font was placed. A wall, carried on these columns, contained windows, and served as a lantern to light the building. This wall occasionally supported a dome. San Stephano Rotondo, in Rome; St. Angeli, in Perugia, and St. Vitale, in Ravenna, are the best examples among the many found in Italy.

San Stephano has a double range of interior columns, taken from Roman temples, the one supporting an entablature, and the other a series of arches. The church has been much modified by successive alterations, and the interior is ornamented with curious paintings, representing the sufferings of the martyrs.

The baptistery of St. Angeli is smaller, but has preserved its original form in a greater degree.

[Illustration: ST. VITALE, OF RAVENNA.]

[Illustration: THE TEMPLE OF MINERVA MEDICA.]

St. Vitale is a type of structure much copied in subsequent buildings. It is itself modelled on the so-called temple of Minerva Medica, differing only in having an octagon instead of a decagon plan. Of this Fergusson gives the following account:

"It certainly belongs to the best days of the Roman empire, if, indeed, it be not a Christian building, which I am very much inclined to believe it is, for on comparing it with the baptistery of Constantine and the tomb of St. Contanza, it shows a considerable advance in construction on both of these buildings, and a greater similarity to San Vitale, at Ravenna, and other buildings of that time, than to anything else now found in Rome.

It has a dome eighty feet in diameter, resting on a decagon of singularly light and elegant construction. Nine of the compartments contain niches, which give great room on the floor, as well as variety and lightness to the general design. Above this is a clerestory of ten well-proportioned windows, which give light to the building; perhaps not in so effective a manner as the one eye of the Pantheon, though by a far more convenient arrangement, to protect from the elements a people who did not possess glass.

"So far as I know, all domed buildings erected by the Romans up to the time of Constantine, and, indeed, long afterward, were circular in the interior, though they were sometimes octagonal externally. This, however, is a polygon both internally and on the outside, and the mode in which the dome is placed on the polygon shows the first rudiments of the pendentive system, which was afterward carried to such perfection by the Byzantine architects, but is nowhere else to be found in Rome. It probably was for the purpose of somewhat diminishing the difficulties of this construction that the architect adopted a figure with ten instead of eight sides."

The plans of the temple of Vesta and of the baptistery of Constantine have been placed here next to one another in order to show the transposition of the columns from the exterior to the interior, which is the chief distinction between the Roman circular buildings and Christian baptisteries.

[Illustration: THE TEMPLE OF VESTA, SOMETIMES CALLED THE TEMPLE OF HERCULES.]

[Illustration: THE BAPTISTERY OF CONSTANTINE.]

VII.

THE BYZANTINE STYLE.

Constantine and his mother St. Helena built churches in Bethlehem, Jerusalem, and Antioch, and embellished Constantinople with numerous splendid edifices. The Eastern basilicas preserved the same character in their construction as those of Italy, but their component parts were more homogeneous, the materials being specially prepared, instead of being borrowed from ancient buildings. The first vigour of emancipated Christianity found vent not only in the erection of edifices devoted to its religious observances, but in the infliction of irreparable injury upon the pagan monuments of Greece and Rome. Constantine brought many fragments of these Classical buildings to the new capital, but they have been destroyed, together with the palaces, churches, and baths which he built there, in successive invasions, by fire, or by earthquakes.

In Thessalonica there are two good examples of early basilicas—the old mosque and the five-aisled church of St. Demetrius; and in Northern Syria there are many admirable specimens. Of these the churches at Rouheilia, Kalb-Louzeh, and Tourmanim deserve special mention.

The latter is a particularly successful building, designed in the new style growing out of the older Roman one, and is a model structure, being constructed exactly in accordance with the requirements of the early Church.

In plan, the Syrian conventual buildings depart but slightly from that of the basilicas of Rome, but in their interior treatment they show a gradual secession from the rules which govern Classical buildings, retaining only their useful and discarding their merely ornamental features.

When the seat of the empire had been transferred to Byzance, the Christians carried with them the principles of the arch and the vault and combined them in a new form of structure. This construction, differing from that employed in Rome, combined with Eastern or late Greek forms of ornament, produced a new style called the Byzantine.

The distinctive feature of this method of construction was the placing of the circular dome, not upon a cylindrical drum, as had been done by the Romans in the Pantheon and other buildings, but upon four walls, square in plan, surmounted by semicircular arches, with the intervening spaces occupied by pendentives. To each side of this central square was joined a nave of the same length, forming thus in plan a Greek cross, that is, one having each arm equally long. These naves were usually short, more frequently semicircular than rectangular, and often terminated by an apse.

[Illustration: THE PENDENTIVE SYSTEM IN BYZANTINE DOMES.]

We have seen, in the baptistery of St. Vitale, at Ravenna (in which Greek artists were undoubtedly employed), a tendency to reduce the number of sides of polygonal buildings supporting circular domes; the architects of Byzance were therefore merely taking another step in the same direction when they placed the dome upon a quadrilateral substructure.

To comprehend the pendentive, let us take a circle and inscribe within it a square; at the four angles of the square we will place solid piers of masonry and connect them with semicircular arches. Let us now suppose that a hemispherical dome had been built upon this circle as plan, and we will see that the planes of the arches and the plane passing at the level of the top of the keystones

of the arches, in intersecting this dome, would leave but four triangular portions of it. These triangular portions are called pendentives, and are the only portions of the original hemisphere which are actually built. As this hemisphere would have been necessarily constructed of materials the joints of which would have radiated from the centre of the sphere, so also do the joints of the pendentives radiate from this same centre, which is identical with the centre of the original circle. The plane passing at the level of the top of the keystones in intersecting the hemisphere describes another circle, upon which the actual dome is placed. The question has not been established satisfactorily whether the Byzantine architects really understood the pendentive, as in many instances they resorted to less scientific methods of filling in the vacant spaces between the arches and the upper dome, but the only logical method of constructing it is that which has just been described.

In building domes, it was not uncommon in the East to replace stonework by light terra-cotta pipes, fitting into each other, giving great lightness and comparative strength.

Justinian gave a marked impetus to architectural work and to the building of religious edifices in particular. He commissioned Anthemius of Thralles, and Isidor of Miletus, to execute the plans for the new church of St. Sophia, upon the site of an older building of Constantine, also dedicated to the "Holy Wisdom," which had been burnt during an emeute soon after it had been repaired by Theodosius.

Justinian had already built the church of Sergius and Bacchus in Constantinople, on a plan nearly identical with that of St. Vitale, at Ravenna, with the exception that the whole structure was externally in the form of a square, enclosing the octagon supporting the dome. This served as a stepping-stone to the conception of the larger church, which became the type of all subsequent Byzantine constructions.

[Illustration: CHURCH OF SERGIUS AND BACCHUS AT CONSTANTINOPLE.]

[Illustration: PLAN OF ST. SOPHIA, CONSTANTINOPLE.]

By comparing the plans of the Pantheon, the temple of Minerva Medica, the baptistery of Constantine, St. Vitale, at Ravenna, and the church of Sergius and Bacchus, in the order in which they are enumerated, with that of St. Sophia, the sequence and continuous progress of domical construction is at once apparent, and such comparison explains the successive steps in a more satisfactory manner than a folio of description.

"The church of St. Sophia," says M. Texier, "is built on a square plan, 251 feet long by 186 feet wide. In the centre of this square rises the dome, the diameter of which, measuring 108 feet, determines the width of the nave. The dome is supported by four great arches and four pendentives. Two hemispheric vaults abut against the two arches, which are perpendicular to the axis of the nave, giving it an oval appearance. Each of these hemispheres is itself pierced by two smaller hemispheres carried on columns. This superposition of domes, whose points of abutment are not visible, gives to the whole structure a lightness difficult to realize."

The church is built upon a foundation of béton twenty feet deep. It is preceded by an atrium surrounded by a portico of the Ionic order. The nave is entered by a double narthex, or porch, extending along the whole width of the West front. The interior, both floor and walls, was formerly adorned with rich marbles, and paintings upon a ground of gold. The dome was built of light bricks faced with hard cement and mosaic, and was lighted by forty windows. Originally a painting of the Holy Father was placed in the centre of the dome, and four cherubim in the pendentives. The latter are still to be discerned under the coat of whitewash with which the Turks have hidden the original magnificence of the interior.

The apse, lighted by three windows, contained the throne and seat of the Church fathers. The columns supporting the great arches and the galleries, originally occupied by the women, are of rare marble, eight of them having, it is said, formed part of the temple of Diana at Ephesus, being brought, together with the spoils of many Eastern and Western buildings, to adorn the great edifice. The foliage of their capitals is fine and sharp and intricately interlaced, having no resemblance to the Classic models beyond a debased form of the volute which terminates their upper corners. This style of ornament is a distinguishing feature of the Byzantine style, and reappears in many examples both in the East and West.

The church, commenced in the year 532, took sixteen years to build, during which time incredible sums were expended upon it. When completed, the appearance it presented was most magnificent, resulting not only from the rich marbles, wood-work, paintings, and mosaics with which it was decorated, but also from the countless candelabras, curtains, precious vases, and golden vessels with which it was furnished. After the capture of Constantinople by Mahomet II., in the year 1453, St. Sophia was converted into a mosque, and suffered greatly at the hands of the Turks. It is only within recent years that any attempt at preserving its original

splendour has been made.

The architectural principles upon which St. Sophia was constructed were reproduced in all Byzantine buildings in Italy and France as well as in the Orient. In Turkey, indeed, the edifices subsequently erected are almost counterparts of the original structure, the mosque of Suleiman and that of Achmet, built as late as 1610, embodying almost identical features of construction.

In Athens there are two or three small Byzantine churches, which, though differing greatly in point of size, are founded upon the plan of the mother church; and in Asia Minor generally and Armenia especially, there are a great number; notably the churches of Daghour and Pitzounda and the cathedral of Anim.

The decoration of some of the latter differs from the usual Byzantine methods in the frequent revival of Classic forms, and in the use of thin pilasters, carrying blind arches on the exterior.

This feature reappears in the buildings of Italy, influenced by the style, particularly at Pisa.

In some later buildings a new manner of obtaining light was introduced, by raising the dome upon a cylindrical drum, supported by the four arches and pendentives of the older system. St. Nicodemus, of Athens, is one of the best examples of this.

When the body of St. Mark was brought to Venice, having been stolen from Constantinople by means of a clever trick about the year 831, the Doge Partecipazio ordered a church to be built to his memory. The greater part of this building as it stands to-day dates, however, from the tenth century. It resembles St. Sophia in a great degree, the frequent intercourse of the Venetian maritime population with the Orient having enabled them to study the principles of Byzantine art, and to bring spoils from the buildings of the East to their native city.

St. Mark's has also much affinity with the church of Mone-tes-Koras, in Armenia, the principal façade, with its five large bays decorated with columns and arches framing the five doors which give access to the church, being identical in general conception.

The interior of the building has the form of the Greek cross, the four arms of which and also the central compartment formed by their intersection, are roofed by domes supported on arches and pendentives. The style of ornament is very similar to that of its prototype, with its rich gold mosaics, frescos, and inlaid marble, some of the details being essentially Oriental in character.

The constructors of the pendentives in St. Mark's do not seem to have properly understood that they formed part of a sphere to the centre of which their joints should have converged, but filled up the spaces between the supporting arches by a series of small superposed arches.

The influence of this Byzantine construction extended into Aquitania, in the South of France. At the close of the tenth century a number of churches were erected there, with the dome as a prominent feature. St. Front, of Perigueux, was built upon a plan closely resembling that of St. Mark's in Venice, and very nearly upon a similar scale of dimensions. The architects of the church, however, seem to have distrusted the strength of the semicircular arch, and resorted to the ogival[5] or pointed form as a means of securing greater supporting power, although this arch had not as yet been adopted in France.

[5] From augere, to strengthen.

They, too, failed completely to grasp the principle of the pendentive, as those of St. Front are formed of corbelled stones with horizontal beds, instead of voussoirs converging to the centre of the hemisphere of which they should form part.

Besides St. Front, the churches of Fontevrault, Souliac, Angoulême, and others in Aquitania were built with similar characteristics, though in plan they adopted the Latin instead of the Greek cross. The abbey church of Fontevrault is perhaps the most successful of these, the four domes of its nave producing a very pleasing effect. The greater number of these buildings were erected during the eleventh and twelfth centuries, in an imported fashion, rather than in a style destined to be engrafted upon French national architecture.

All of them show the want of a clear comprehension of the principles involved, and are evidently foreign to the taste of the people.

The introduction of this style in France, offers a parallel case to the introduction of Gothic architecture in Italy, a century or two later, for in neither case were the styles in accordance with native inspiration.

MAHOMETAN ARCHITECTURE.

The year 622 of our era is a remarkable one in historical annals, being the date of the flight of Mahomet, the Hegira from which all events are computed by followers of his religion. Within a marvellously short period the new faith spread from the confines of Arabia, throughout Asia Minor and Persia and all along the North coast of Africa to Spain, propagated everywhere by the force of the victorious sword, until, scarcely a century later, we find its promoters bearing the crescent against Charlemagne, under the shadow of the Pyrenees.

As a political and theological narrative the history of the rise of the faith of Islam, is a wonderfully interesting one, and to us it is important as it explains the reason for the geographical position of so many buildings, erected in accordance with the requirements of the new religion, and therefore having a great similarity in all countries where it prevailed.

The Kaabah, or "square house," built by Mahomet at Mecca upon the site of a temple which tradition says was founded by Abraham, appears to have been the earliest Mahometan mosque. Mahomet had already erected a building at Medina, but this seems to have been not so much a house of prayer as a dwelling-place for his family. The Kaabah has less importance as an architectural production than as the centre of the wheel of Mahometanism, the faithful being directed to turn their faces toward it when praying, and to regard it as the ultimate goal of their wanderings.

The original structure was built by foreign workmen, and had no great pretensions, but subsequently it was surrounded by a colonnaded court, and by later additions was very considerably enlarged. Although the Koran decrees that all good Mussulmen should make a pilgrimage to Mecca, it does not uphold the Kaabah as a model to be followed in the erection of other mosques nor give any specific directions of the manner in which they should be built. It was therefore natural when the peace, following their rapid conquests, permitted the Mahometans to turn their thoughts to the erection of religious edifices, suitable for the observances of their worship, that they should borrow inspiration from the surrounding nations.

The style they eventually evolved was drawn from Byzantine, Sassanian, Greek, and Roman sources, and became native by adaptation.

In Turkey, Asia Minor, and Persia we find Mahometan mosques closely resembling Christian and Byzantine churches, many domed edifices being copied from St. Sophia and differing only in point of decoration, while the atrium or courtyard preceding the entrance to Christian buildings furnished the type for the wide colonnaded courts, with porticos roofed with a succession of hemispherical or bulbous domes, which became so common in Arabian buildings.

The mosques of Omar, at Jerusalem, on the site of the temple of Solomon, of Wallid, at Damascus, Al-Azhar, Athar-en-Neby, Ibn Touloun, and Hassan, in Cairo, are notable edifices, in which the columns are either taken or copied from Greek and Roman temples, and in which the pointed arches seem to have been suggested by the hyperbolic arches of certain ancient Sassanian structures, such as the palace of Coroes, the Takt Kesra in the ruins of Ctesiphon, on the Tigris, and the buildings of Firouzabad and Sarbistan, which were mentioned in connection with Persian art.

One of the earliest examples of the use of the pointed arch is in the Nilometer, erected on the Rodah, or Isle of Gardens, at Cairo, by Wallid, in the eighth century.

This is a matter worthy of note, as showing conclusively that the Gothic arch was no invention of the thirteenth century, in Europe, but merely the adoption of a form used five centuries before in Egypt, and probably universally known, if indeed it had ever been lost sight of, since the days of the prosperity of Babylon.

Of the early mosques the most important are those of Omar and Abd-el-Malek at Jerusalem and of Wallid at Damascus. The mosque of Omar was but a simple vaulted chamber, oriented in order to enable the faithful to turn in the direction of Mecca while praying. That of Abd-el-Malek, called the Aksah, adjoins it and is an extensive structure. It is chiefly remarkable for its general resemblance to the basilica in its division into aisles. The columns forming these carry pointed arches, built over connecting beams. It is not improbable that this design was inspired by the order of the church of the Dome of the Rock, adjoining it, built by Constantine, where the columns support circular arches, over a continuous entablature.

Wallid, Caliph of Damascus, erected a mosque on the site of the old church of St. John the Baptist, and employed labour and material in its construction furnished by Justinian, Emperor of Byzance.

The mosques of Cairo resemble each other in a great degree. They have usually a first court, giving access to apartments for the accommodation of strangers, with baths, and stables for their camels, connected with a second and larger quadrangular court, having a fountain in the centre and porticos on three sides. The fourth side, facing the entrance, has a series of aisles roofed in and forming the sanctuary, with recesses in the rear wall, where the prayers are offered. Reading-desks, provided with copies of the Koran, and hanging lamps form the chief furniture.

The minarets, one or more of which are usually erected at the angles of the building, are special features. These tall, graceful towers, from whose summits a crier calls the people to prayers five times daily, serve a purpose similar to that of the belfries and campaniles of Europe. The diameter of most of them is small in proportion to the height, giving them a slender and beautiful aspect, very distinct from another class of towers, of which the Giralda at Seville is the best known, which were conceived in the same spirit of massiveness in which the campanile in the square before St. Mark's in Venice was built. They are ascended by spiral staircases placed either within or without, and have projecting balconies at various stages.

The building materials employed by the Arabs were chiefly stone of different colours, combined in bands and patterns, and brick covered with stucco. Enamelled tiles and multicoloured marbles were used both externally and internally, while within, carved wood, gilding, painting, and plaster were lavishly employed.

Of the forms of decoration, the chief were elaborate gold inscriptions in Arabic characters, floral and geometric designs in interlaced patterns of the most intricate combinations, coloured with all the profusion suggested by the Oriental love of brilliancy and with the exquisite harmony which we see in Persian and Indian fabrics.

A favourite form of decoration was that formed by a multiplication of minute pendentives, called the honeycomb ornament, the whole surface, as well as the dome above, being covered with an agglomeration of minute niches, the effect of which is frequently compared to that of stalactites. This form of ornament was much used, particularly in the mosques and palaces of Spain.

In Cairo domestic architecture has a distinctive character of its own. The houses have reception-rooms on the ground floor, furnished with the divans, carpets, and lamps usual in Oriental manner of life, while the upper floors, occupied by the women, have projecting balconies of lattice wood-work, which permit them to see without being seen, and form an agreeable and picturesque feature on the exterior.

The richness and the progress of Arabic art at a period when architecture had sunk to the lowest ebb throughout Europe, is due in great measure to the establishment of the learned academies of Damascus, Bagdad, and other principal cities, and to the revival of Classic learning by the translation of the works of Greek authors.

In Spain, where the Moorish and Christian populations were thrown in constant contact with one another, the difference of religious opinion maintained a wide gulf between them, and while the Christians struggled with the difficulties of the Romanesque revival, their opponents attained a brilliant era in art, as a result of their superior industry and civilization.

One of the oldest Arabian buildings in Spain is the great mosque at Cordova. Here, as in the East, we find Corinthian and Composite columns, taken from Roman buildings on the soil, forming integral parts of the new structure, but the Classical principles of building are in no sense adhered to. The entablature is replaced by cinque-foiled arches with voussoirs of alternate stone and brick; a second order of columns is superposed directly upon the capitals of the first, carrying horseshoe arches, and between the two arcades an intermediary series of trefoiled arches is placed, springing from the keystone of the lower arches and divided at the centre by the upper ones.

The general plan of the building consists of the usual series of aisles, of which there are nineteen, with divisional walls. The sanctuary has a vault with intersecting ribs, surmounted by a small dome and enriched by profuse ornament, and is the object of much just admiration for its beauty.

The chapel of Villa Viciosa, a later structure, has a series of arcades similar to those before the sanctuary, differing only in the arrangement of the intermediary arches, which are carried up to the level of the upper arches from a horizontal course, and are cinque-foiled instead of trefoiled, both on the extrados and intrados.

The mosque was begun by Abd-el-Rhaman, in the eighth century, and successively added to during the four centuries following. It covers a very large superficial area, upwards of one hundred and sixty thousand square feet, and surpasses, in this respect, most European buildings. Its chief defects are the want of height, which does not exceed thirty feet, and the monotony of the aisles,

which are nearly all precisely alike.

At Toledo there are several Moorish buildings of merit, the principal one of which is the mosque called, at present, the church of "Cristo de la Luz." It is similar to the sanctuary of Cordova in general aspect, but is a marvel of intricate and minute workmanship. The whole area which it occupies does not exceed four hundred superficial feet, but the proportions are so nicely balanced that it appears much larger. There are four columns carrying horseshoe arches, above which comes a second arcade, and each division is roofed in by a vault of intersecting ribs. These vaults are formed of wood, overlaid with plaster, and have no pretension to scientific construction. Indeed, in none of the Arabian buildings in Spain do we find anything of the kind attempted, the decorative features being always the most prominent.

In the tower of Seville a species of vault was formed by thickening the walls gradually as they rose from the ground until they met; this, however, was nothing more than extensive corbelling, and, consequently, very inferior to Roman and Byzantine methods.

The Alcázar, at Seville, and the Palace of the Alhambra, at Granada, are the richest examples of Moorish architecture, and show in their design and ornament the most fertile expression of the brilliant imagination with which this warm-blooded people imbued all its creations.

The Court of the Lions in the latter, a rectangular enclosure, surrounded by arcades, with projecting domed pavilions at the upper and lower ends, is generally held to be the finest production of the later period of the style.

The same materials are used here as in the other buildings—plaster shaped in the most exquisite forms and coloured brilliantly, tiles ornamented with patterns and devices of the most elaborate character, and wooden ceilings carved and richly painted. All these are handled with such correct taste that their brilliancy never degenerates into gaudiness.

A splendid fountain in the centre of the court, the lower bowl of which is supported upon the backs of lions, explains the name given to this celebrated structure.

The mosque of Cordova is superior, in respect to materials, to the other remaining Moorish buildings in Spain, in which plaster is used to excess. It is vain, however, to look in any of them for any distinct or novel constructional departure. The lintel and arch in Greece and Rome, the dome carried on pendentives in Byzance, were features giving character to each style, but the art of the Mahometan architects differed only in form and colour from its predecessors. The horseshoe arch with one and two centres, that is both round and pointed, was used by them almost exclusively, but it cannot rank as a constructional invention, for the real arch starts only at the level of the centres, and the remaining lower portion is a mere corbelling to obtain a form pleasing to the eye.

Any new method of construction always affected the surrounding parts, and often altered the whole design of a building. It is obvious, therefore, that a mere change in the appearance of an arch such as this, which affects nothing connected with it, cannot be said to have created any new era in the progress of building.

We hear the question frequently asked why a modern and new style is not developed in our times, and the answer architects make is illustrated by just this case, that is, that no new style can be evolved without a new constructive principle. As yet none such has been forthcoming, the only novel method of construction lately introduced being the employment of iron girders and posts, which, from an artistic point of view, can scarcely be considered an improvement upon the use of what are called the natural building materials.

IX.

THE ROMANESQUE STYLE.

Some late historians have departed from the previously generally accepted nomenclature of architectural styles, in designating under the general term of Christian architecture all buildings erected between the tenth and sixteenth centuries in Western Europe.

As, however, Christian building in Europe began with the conversion of Constantine, this chronology is hardly satisfactory, and as the customary division of Gothic from the styles preceding it, is on many grounds a convenient one, it is preferable to adopt the conventional names, and to distinguish under the title of "Romanesque" the outgrowth of the debased form of Roman architecture which, influenced by Byzantine and Arabic art, formed a distinct method of building throughout the West for nearly two centuries after the year 1000 A.D., giving it the alternative name of "Norman" in Normandy and England.

Previous to this date the long continuance of war and barbaric incursions seem to have prevented the erection of any stable edifices; fire and the poverty of the material with which they were constructed having caused the destruction of the few of which an account has been preserved.

Many churches subsequently built, however, were erected upon the sites of these older ones and have fragments of the older buildings incorporated in them. Of such are the churches of St. Germain des Prés, in Paris, and Notre Dame du Port, at Clermont.

Under Charlemagne, a revival of art was attempted, the chief building constructed by him being a reproduction of St. Vitale, of Ravenna, in which he employed sculpture and ornament torn from the original structure, and fragments from the edifices of ancient Rome; but this effort soon died away, and the period intervening between the eighth and tenth centuries was totally lacking in any architectural production of merit.

As the Roman principles of architecture had been taken Eastward and gradually transformed into a new style at Byzance, so also in the West they had been the forerunners of another method of building, but proportionately different in accordance with the character, customs, and race of the Western populations.

The basilica formed, as it had in the East, the model upon which all church architecture was designed, the nave, transept, aisles, and apse being all retained in this new class of buildings, but many of the building methods were new, and the details of their decoration differed considerably from the precise proportions and Classic graces of the buildings of Rome. The result exhibits a curious contrast between the barbaric ornament and the scientific construction, which advanced throughout the style in the genuine efforts which were made to progress in the art of building.

Starting thus at the decadence of Classic art, with a Classical building as the original type for their churches, the Romanesque architects took up each of the parts combining in its formation, and sought to improve or elaborate each, in pursuance of certain ends, arising from local necessities. There is virtually no point where Romanesque ends and Gothic commences, to give due reason for the conventional divisions of historians, for the one style melts into the other in the continual progress in the study of the principles of construction which was steadily effected throughout both styles.

They differ chiefly in that, during the two centuries prior to the thirteenth century, the pointed arch was rarely used, and that the influence of the Classic decadence is more apparent in the buildings of the earlier period. After this, the pointed arch became universal, and the whole style becoming entirely distinct from its derivation, the ornament and detail, quite unlike anything which had come before, it may be said that a new style had been created.

This new style, which has been called Gothic, continued to be developed until the fifteenth century, when its principles became exaggerated, and it died out at the extreme point to which they could be pushed.

It has been customary to call the buildings of the eleventh and twelfth centuries, built in the transition of Roman to Gothic art, Romanesque; but the pointed arch was used in both styles, though, as stated above, less frequently in the earlier one; and it should not, therefore, be taken as the distinguishing characteristic of Gothic architecture.

The chief points wherein the Romanesque churches, which were the only buildings of importance constructed at that period, differed from the basilicas were in the methods of vaulting and their consequent effects upon the whole structure, the elaboration of the apse, and the system of connected supports employed. The main characteristics of the style were the same in all Western countries, and these being known, it is not difficult to distinguish the slight differences arising from local causes.

In the old basilicas the aisles, whether of one or two stories, were lighted by windows in the lateral walls, while the nave borrowed light from them, and also received it directly from a clerestory rising above the roof of the galleries. As we have seen, these buildings were usually covered by wooden roofs, tunnel-vaults or a series of intersecting vaults thrown across the square formed by two of the columns of the nave, equidistant from each other and from corresponding pilasters in the side walls, being only occasionally used in the aisles.

The Western architects of the tenth century continued to build their churches in this manner, and we have a splendid example of a timber roof of this kind, as late even as the twelfth century, in Peterborough Cathedral; but at an early period they sought to replace these perishable roofs by stone vaults. They found the construction of the semi-dome of the apse and the vaulting of the side aisles, either by a continuous tunnel-vault, by a series of semicircular vaults perpendicular to the lateral walls, or by intersecting vaults upon a square plan, comparatively easy; but the vaulting of the nave was a much more difficult matter.

The circular tunnel-vault would have been the simplest known method of accomplishing this, but the pressure of a circular vault placed over the nave would have tended to push outward the walls upon which it rested, and this pressure being continuous, it was obviously of no avail to place buttresses at any separate point, and to place a great number, side by side, all along the vault, or, in other words, to greatly thicken the supporting wall, was to take up too much valuable ground space.

In St. Front and kindred structures we have seen the problem solved in one way by the introduction of Byzantine domes; but these churches were confined to a province of Southern France, and had but little influence in other districts. In St. Etienne de Nevers, St. Sernin de Toulouse, and in Notre Dame du Port at Clermont in Auvergne, and others, this difficulty is partially overcome by the building of a half vault over the upper galleries connecting the tunnel-vault of the nave with the outer main walls, and taking the strain continuously, the thickness of the outer wall not being considered of consequence. This system permitted the placing of roofing-tiles directly upon the extrados of the vaults, and the entire suppression of wooden rafters, which was advantageous in diminishing the risk of fire, although the pitch was scarcely sufficient to prevent leakage. The great disadvantage, however, was that the nave had only borrowed light, and in large churches it was inconveniently dark.

Another method adopted was that of suppressing the upper gallery, and bringing the arches of the aisles up to the level of the springing of the main vault, so that the summits of the side vaults and the walls erected between them, which were at right angles to the nave, served to counteract the strain of the upper vault. We have examples of this in the cathedral of Limoges and at Fontenay, but it is open to the same objection, that of darkening the nave.

Still another system consisted in binding the vault over the nave by ribs or arches thrown across to opposite piers, which were strengthened by buttresses. These buttresses, however, were built upon the top of the arches, thrown across the aisles, and did more harm than good.

[Illustration: ELEVATION.

ROMANESQUE CONSTRUCTION]

[Illustration: SECTION.]

There is an example of unusual construction at Tournus, in Burgundy, where the difficulty is effectually surmounted by the building of a number of arches at right angles to the axis of the nave, between each set of piers; but the effect is far from satisfactory.

Finally at Vezelay, in France, the tunnel-vault was abandoned and diagonal intersecting vaults were thrown across the nave, framed in between semicircular arch ribs carried upon piers spaced at equal intervals, the weight being thus wholly transferred to the four points at the angles of each compartment. It was found, however, that these piers needed strengthening, as the strain upon them was excessive, and it was thus that external buttresses were resorted to, which were connected with the piers by arches, called flying buttresses, bridging the side aisles and conveying the pressure to the outer wall. A weight was placed over each buttress, generally taking the form of a pinnacle, which stiffened it and counteracted the pressure of the arch.

An illustration of this mode of construction has been attempted in the accompanying drawing, which does not represent any special building, but in which the chief characteristics of the style at this juncture have been introduced.

The distance across the nave being usually greater than that between the columns dividing it from the aisles, the rectangular compartments of the vault were consequently no longer square, but oblong, so that while the arches crossing the nave at right angles were still semicircular those between the pillars were pointed.

The transition from this, in the thirteenth century, to the definite adoption of the pointed vault was consequently but a step.

We see, thus, that a continual progress was made in vaulting throughout the style, and the principle of concentrating weight upon isolated points was evolved in order to vault the nave and at the same time give direct light to it. In effecting this result, however, the original aim had been lost sight of—namely, that of avoiding the use of wooden roofs; for when the Romanesque architects abandoned tunnel-vaulting they had to surmount their more complicated intersecting vaults by wooden roofs, the perishable nature of which caused the ruin of many of the finest buildings. Nor was the external appearance of these roofs any improvement upon those of St. Etienne and St. Sernin, for it is a question whether any more monumental roof has been conceived than that which is formed by the natural outside surface of stone vaults.

In the old basilicas, columns taken from or modelled upon those of the temples and palaces of Rome had sufficed to support the light brick wall, carried upon an architrave or arches, which enclosed the nave. When the Western architects resumed the building of churches, after an interval of war and trouble which had proved fatal to architectural progress, brick was little used and the formation of light masonry and good mortar were lost arts. The slender Classic column was consequently insufficient to carry the load of a heavy stone wall and had, necessarily, to be replaced by a more solid pier.

These piers assumed various forms in the tentative efforts made to construct them of the dimensions calculated to occupy the least amount of floor space; some were square, others circular or formed of a number of small columns grouped together, but for a long time no very satisfactory shape was found which avoided a clumsy adjustment of the superstructure.

It came to be gradually recognized that the form of the pier should be subservient to, and made to correspond with, the arches and the column receiving the arch rib of the vault above, which it had to sustain. This was effected at first by a square pier, with rectangular projections on each side, forming abutments for the reception of the constructional arrangement above. Subsequently these were replaced by pilasters and engaged columns on each face, three of which supported the rear and side arches of the nave, the fourth being continued up to the springing of the vault, and redeemed from exaggerated effect by bands or string-courses. There are good examples in France at Vezelay, Beaune and Langres and Autun. In England the contemporary architects usually employed square or circular masses of solid masonry, carrying a heavy abacus, these pillars being sometimes ornamented with a fluting, as in the crypt at Canterbury, or with zigzag patterns, as at Waltham Abbey, Durham, and Lindisfarne.

The capitals of Romanesque columns are especially interesting, for they became constructively useful instead of simply ornamental, as were those used in the Roman orders. The section of the arch rib being square and the column round, it was necessary to afford support to the overlapping corners, the whole surface of the projecting tile or abacus being occupied by the upper masonry, instead of the line of the shaft being continued up, as had been done in Rome. The capital was therefore made to spread outward from the shaft in order to corbel the superstructure.

[Illustration: COMPARATIVE SERIES, SHOWING GREEK, ROMAN, ROMANESQUE, AND GOTHIC METHODS OF SUPPORT.

1. Greek Lintel.

2. Roman Arch, showing False Lintel. 3. Vault Springing from Entablature. 4. Arch Springing 5. Romanesque Column, with Arches Springing from Outer Edge of the Capital. 6. Romanesque Pier. 7. Gothic Pier.]

A simple form of this is found in many German, Italian, and English examples, the upper part of the capital being a cube and the lower a hemisphere. The early examples generally imitate those of the Corinthian order in a rude fashion corresponding with the poverty of talent of the period. The capitals of the twelfth century are better carved and better suited to the services they have to perform. Figures representing biblical subjects are introduced in some and in others strange animals and conventional foliage, sometimes arranged as the acanthus leaf had been in the Roman models. The proportions of the Classic column were also departed from, the capital often being a quarter or a sixth of the whole column; its height being regulated by the size of the beds of stone, which were generally low. In Germany, however, the older proportions were more closely adhered to. The quality of the stone determined in a great measure the depth of the carving, the harder kinds having less depth of incision and the style of ornament applied to them resembling the Byzantine.

In France the Romanesque column has usually a third of the diameter of its shaft engaged in a pier or wall, though isolated ones are used in the triforiums, towers, and porches; in England the latter are common, and recessed columns, that is to say, placed in an angle of masonry, are also frequently seen.

The bases of Romanesque columns, at first simple round and hollow moulds, gradually became more elaborate, until they resembled the attic base. Occasionally they were decorated with foliage or animals, and there are instances where both capital and base are similar. The introduction of an angle ornament, connecting the torus or round mould with the corners of the plinth beneath, is especially noticeable; this was effective in preventing the angles from being broken by thickening the stone at the weakest points, and in later examples added to the beauty of the base.

The arches of the period were usually semicircular and employed either separately or with a second and broader one, their contour being frequently marked by a few simple mouldings of degenerate classic origin.

Two or three arches supported by detached columns, and comprised within a larger one, were frequently placed in the triforiums; when three were used the central one was usually higher than the others. Besides mouldings: billets, zigzags, stars, and similar simple ornaments were employed in their decoration. Where Arabic taste exercised its influence, it is not uncommon to find alternate voussoirs of different-coloured stones, and variegated bands in the piers.

The Italians were especially fond of this treatment and it is seen in the exteriors and interiors of many of their buildings. To them is also due the introduction of blind arcades, the columns of which were either engaged in the wall or separated from it by an intervening gallery. The façade of the cathedral at Pisa is perhaps the most beautiful example of this.

In the West, arcades of this kind became a frequent method of decorating blank walls, and there are instances where a second series of arches intersect the first, resulting in a number of pointed arches formed by the crossing of the circular ones; from this an ingenious but unfounded theory has been deducted purporting to explain the origin of Gothic architecture.

The doors and porches of the Romanesque period are among the most beautiful to be found in any style. Starting in the earlier examples with a simple, round-arched opening, the number of mouldings in the arch became richer and of greater number, and, as the style advanced, recessed and supported by columns. These mouldings were decorated with the zigzag, billet, and kindred ornaments, many of which were probably copied from the decoration of the old basilica of St. Paul's without the walls of Rome.

As the jambs of the doorways were generally built on an angle, the contiguous shafts and arches sometimes gave the effect of an arched passage in perspective. Such effects were frequently intentional in the churches in Southern France, for we find that the walls of the nave and vault of Notre Dame de Poitiers, and of other buildings, were purposely made to converge in order to give the appearance of greater length.

It was not uncommon to give the doors square heads, supported by corbels and occasionally by a central shaft; in these cases the arch above relieved the lintel from the weight of the superstructure, and gave the character of the style to the whole. The tympanum, thus enclosed, offered a ground for rich sculpture, which was availed of to the fullest extent. The outer door of a porch was usually richer in design than the inner one; in England there are many examples of shallow porches with single deeply recessed doors. In Provence there are many beautiful examples, foremost amongst which must be mentioned the porch of St. Trophyme, at Arles (see frontispiece). Romanesque windows were but modifications of the doors; often having recessed shafts at their sides and being frequently divided by a central column.

The bull's-eye, or round window, of the early Christian basilicas continued to be used, but it had not as yet the richness of tracery which it attained in the Gothic period.

Classical features of design still retained their hold upon many details, notably in the cornices, where the modillions or brackets of the Corinthian order were frequently employed, and but slightly altered in form, although of native composition. The corona of the cornice also differed but little from the Roman models, and was occasionally supported directly by engaged columns replacing buttresses, chiefly on the exterior of apsidal chapels.

In the early Christian churches the apse had consisted of a central semicircular termination to the building, flanked occasionally by two smaller semicircular recesses containing altars. In the baptisteries and Byzantine churches these had been multiplied, and had come to be customary features in every new building. In England, the Norman architects generally ended their churches rectangularly, without even the original single apse, though there are a few examples in which it is used, as at Newhaven, Sussex. In Germany it was frequently the custom to affix apses to three sides of the square tower placed at the intersection of the nave and transept, and the result was generally satisfactory, as may be seen in St. Martin's of Cologne, and in the Apostles' Church in the same city.

[Illustration: PLAN OF STRASBOURG CATHEDRAL (Compare with Basilica, page 89.)]

In France the plan resolved itself into an open semicircular colonnade with a passage intervening between it and the outer wall which followed the outline of a series of small apses. These formed an harmonious cluster, and became a type which was matured in the thirteenth and fourteenth centuries. Those belonging to the Romanesque period, however, had a distinct and constructively excellent character which has rarely been subsequently surpassed. Among the best are those of Notre Dame du Port at Clermont, St. Etienne de Nevers, and St. Sernin at Toulouse.

In France towers were generally placed at the West end of the church, while in England and Germany the usual way was to build them at the junction of the nave and transept; in Italy they were often detached from the main structure. They were characterized by simple solidity; the openings being few and the detail bold; the angles were strengthened by stout piers; the roofs were either of timber or stone, according to the nature of the materials in the localities in which they were erected, and they were usually lighted by the round-arched double window. This round arch, ornamented with a few simple mouldings and reposing upon short sturdy columns, forms a constantly recurring feature in the composition of the several parts of Romanesque buildings.

The corridors which surrounded the square courtyards adjoining churches, and connected them with the dormitories, refectories, and other apartments of the clergy, are called cloisters. They differed but little from the Roman "impluvium" and the "atrium" of the basilica, the changes consisting chiefly in the addition of raised sills separating them from the court, and in their being usually vaulted instead of carrying timber roofs. The series of arcades forming them were treated in many ways, and the detail admitted of much elaboration and variety, as may be seen in the many remarkable examples throughout Europe. The cloisters of St. Paul's, at Rome, and the atrium of St. Ambrogio, at Milan, form very interesting historical links between the Roman and Romanesque styles and are very beautiful specimens of their kind.

It had been the custom during the struggling period of the early Church to bury the bodies of saints in subterranean chambers called crypts, a word derived from the Greek verb "to hide"; subsequently these became component parts of all churches, serving as places of interment and for the occasional celebration of masses. Their masonry was necessarily of the massive character required for the foundation of the piers of the church above, consisting generally in a grouping of columns sustaining a heavy vault.

[Illustration: CHEVET OF NOTRE DAME DU PORT AT CLERMONT.

(_From Chapuy._)]

The crypt of St. Eutrope, at Saintes in France, may be mentioned as one of the best examples, the pillars being richly carved, and the ribs of the vault of great boldness and strength.

In Germany the crypt is often raised sufficiently above the level of the ground to obtain light from windows, as at Spires, and this is sometimes carried to such an extreme that the church becomes double, that is, of two stories, as at Schwartz Rheindorf.

In England, Canterbury Cathedral possesses perhaps the best example, the crypt being very large and its details varied. Some of the capitals of the columns remain half finished, the work upon them having been arrested by a conflagration in the twelfth century.

X.

GOTHIC ARCHITECTURE.

Briefly recapitulating the preceding chapters: We have seen that the Greek temple, composed of a cella, or oblong room, surrounded by a colonnade, was copied by the Romans with but few alterations, the only one of importance being the addition of a semicircular recess to the rear wall. The columns of the colonnade having been transposed from the outside to the interior, dividing the room in three parts, longitudinally; a cross wall having been introduced dividing it transversely, and the apse retained, the building became a basilica. By extending the transept and nave the plan became cruciform and symbolically the most suitable for that of a Christian church.

The Western architects, desiring to replace the wooden roofs by stone vaults, found it convenient to substitute for columns carrying arches, piers with engaged shafts connecting directly with the superstructure.

After various attempts to obtain direct light for the central division or nave, rendered difficult by the necessity of counteracting the continuous thrust of the barrel vault thrown across it, this vault was finally abandoned and replaced by intersecting vaults, which conveyed the thrust diagonally upon equidistant piers. To avoid increasing the size of the latter to an inconvenient extent, an expedient was resorted to which consisted in propping them from the exterior by flying buttresses thrown from them to outside piers across the roof of the aisles. The result of the width of the nave being usually greater than the distance between piers was that, while the diagonal ribs of the vault remained semicircular, their lateral intersection produced pointed arches.

This form of construction was developed during the middle and latter half of the twelfth century. The pointed arch had been used occasionally before by the Romanesque architects; it had been used frequently by the Arabs, as far back as the eighth century, and

had been known and employed long before the Christian era in the sewers of Babylon. It was, therefore, not a new invention, but a known method adopted in a fresh departure in constructive architecture; for the circular arches being abandoned and definitely replaced by the pointed arch the succeeding architecture became pointed or Gothic.

This is the condensed history of the derivation of the style as generally accepted at the present day, though the subject has given rise to much controversy.

The concentration of the weight of the vault upon the piers, instead of upon a continuous wall, was more or less the key to the whole scheme of Gothic construction; for the main principle remained the same throughout its many and varied examples. The idea was improved upon gradually and finally pushed to exaggeration; the decoration of the component parts of a building increased as the style advanced and they were reduced to just the sizes needed for stability, but their construction remained almost unaltered throughout.

We have followed the steps by which the form given to Christian churches emanated from the early basilicas; this form of building, that is, its plan and divisions into nave, aisles, transept, choir, apse, etc., had become traditional and was generally accepted in all the best examples.

[Illustration: PLAN OF RHEIMS CATHEDRAL.]

The problem of accommodating large assemblies in the manner best suited to enable them to concentrate their sight and hearing upon a given point has been solved in various ways, perhaps most successfully in our modern opera-houses, but this problem was not one with which the Gothic architects endeavoured to grapple; their attention was devoted to the improvement and embellishment of the typical plan of structure, which custom and dogma had prescribed as the most suitable and in accordance with the needs of the liturgy. The plan was more or less elastic, and differed without material distinction in the different countries of Western Europe. These differences are easily noted by comparing the appended plans; the one, that of Rheims Cathedral, showing perhaps the most perfect arrangement of any in France, and the other, that of a typical English cathedral. The latter does not represent any particular structure, but is a composition including all the usual divisions and connecting buildings, taken from an old copy of Rickman.

_a_, _a_, Towers at West end. _b_, _b_, Porches. _c_, The nave. _d_, _d_, Side aisles of the nave. _e_, The cloisters. _f_, Library. _g_, North transept. _h_, South transept. _i_, _i_, Side aisles of South transept. _k_, _k_, _k_, Chapels. _l_, Chapter house with passage from the cloisters. _m_, Central tower, cross or lantern. _n_, Screen, over which the organ is usually placed. _o_, Choir, at the east end of which the altar is usually placed. _p_, _p_, Side aisles of the choir. _q_, Lady chapel.

In the thirteenth century the style was formed in all its purity; it was characterized by great simplicity and beauty, and in these respects was never surpassed. The arch had few mouldings, and these clearly defined and graceful; the shafts of columns were of slender and charming proportions, and the foliage employed for the decoration of their capitals, while conventional, departed entirely from the acanthus leaves of Classic origin, and assumed forms suggested by Western plants. Piers were reduced to the precise dimensions needful, and were formed of slender shafts, grouped together, which received the arch mouldings on either side, and rose in the front and rear to the height necessary to take the springing of the vault. In practice, the thrust of the vault was found not to be transmitted directly to a point to be received by an arch, but to two points above and below this theoretical one, which necessitated the employment of two flying buttresses, the one above the other. In Chartres Cathedral these are connected by radiating columns, and there are many examples where the intervening space is occupied by an open arcade. The French generally built their vertical buttresses very massively, but in England the pinnacle was more frequently used to counteract the thrust of the arch. For this purpose it was eminently appropriate, and might be considered ornamental, but the placing of pinnacles upon the corners of the towers and elsewhere where they served no end, which was often done, was always a mistake; and a defect which mars the effect of many beautiful English buildings.

In Notre Dame of Paris, we find the single round column still occupying the first story, with the more complex arrangement of pier and connected shafts starting above the abacus of its capital, but as a general thing, a distinct shaft was provided for each set of mouldings. In time this was replaced by a continuation of the vault mouldings down to the floor, interrupted only by an occasional string-course, or a band of foliage replacing the capital.

[Illustration: PLAN OF AN ENGLISH CATHEDRAL.

(_From Rickman._)]

Once the weight of the vault had been transferred to piers, the wall connecting them ceased to support anything but the extremity of the cross-vault comprised between the piers, and otherwise served only as a screen. The Gothic architects soon took advantage of this to widen the windows, which had been narrow in the early stages, for by throwing a discharging arch just under the upper vault across the piers the whole space underneath could be occupied by windows, which, with the improvement in the making of painted glass, became extremely desirable. This was accordingly done, the only stonework left being the network of mullions and tracery necessary to receive the panes. This tracery, probably suggested by the rich Arabic window fillings, made a great advance during the latter part of the thirteenth and fourteenth centuries, the combinations of geometrical figures, chiefly the circle, being often wonderfully beautiful. The rose window was much favoured by the French in their West fronts and transepts, but in England the large pointed window was generally preferred, and admirably suited the square termination of the apse, which was the most frequently used in that country.

The space enclosed by the pointed window had an outline to which it was always difficult to adjust geometric traceries so as to avoid clumsy joints, or oddly shaped patterns, and these were, therefore, subsequently replaced by flowing lines, which could be used with much greater freedom.

As these grew bolder they assumed a flame-like appearance, and the later period of the style to which they belong was, in consequence, called "Flamboyant." This development occurred chiefly in France, some of the best examples being in the church of St. Ouen, at Rouen.

The simplest form of the Gothic vault was that in which the compartment comprised between two piers on one side and two on the opposite side of the nave was marked by two ribs bridging it, and two diagonal ribs intersecting each other. As the system advanced the vault became more complex by the addition of other ribs, as strengtheners or as ornaments, until in some examples the whole vault became a network of intersecting ribs.

These intersections were frequently emphasized by a keystone or by an ornament called a boss, which in English work was also placed at intervals along string-courses, breaking the continuity after the manner of modillions in Classic cornices.

A keystone placed in the centre of a vault was held there by a combination of great strength, as it became a point of abutment for all the main ribs, whose thrust was distributed against four piers and hence exteriorly by buttresses to the ground. A good stone, therefore, in this position could have extraordinary dimensions, and was susceptible of a variety of treatment. In some French examples it was extended, or rather hung, considerably below the surface of the vault and ornamentally carved, while in England, in the late so-called Perpendicular Gothic, it formed the centre of a large pendant, or circular hanging ornament, which in some cases came down almost to the level of the springing of the ribs.

This construction was used chiefly in connection with the fan-vaulting, in which English architects excelled, which may indeed be said to be an English invention and monopoly, as no examples of it are found elsewhere. The name explains, in measure, the form taken by the ribs, which, spreading out from the sheaf of mouldings in the pier, trace a perfect semicircle on the upper ceiling, their intervening spaces being occupied by panels. The four semicircles thus traced by the ribs, starting from four piers of a compartment, are each tangent to a central and whole circle forming the contour of the pendant.

To be successful this requires that the compartment or space included between four piers, two on each side of the nave or choir, should be a square, otherwise the circles do not touch, and the lines are inharmonious.

The chapels of Henry the Seventh, at Westminster, and of St. George, at Windsor, contain the best examples of fan-vaulting, and are very beautiful in general effect, though it is questionable whether such constructive tricks are worthy of unrestricted praise, while the abuse of panelling in which English architects indulged in these later Gothic buildings, by which the whole wall and ceiling surface was cut up in an unending repetition, was certainly blameworthy, and tended to reduce their art to a mechanical science.

They excelled, however, in all mechanical workmanship, in which perhaps that employed in the execution of timber roofs is the most remarkable. These were in a measure, at least upon so large a scale, a feature wholly English, for nothing approaching them is found elsewhere. The roof of Westminster Hall is the most justly celebrated and is unique in general character.

The natural stonework showing all its joints was generally left untouched in the interior of Gothic buildings, and afforded the best finish as well as contrast to the stained glass in the windows.

Polychrome decoration was attempted occasionally, chiefly on the Continent, and in some instances successfully. The best examples are the restorations of the Ste. Chapelle and St. Germain des Prés, in Paris, though the latter belongs more properly to the Romanesque period. Many churches have been completely spoiled as regards their inside appearance by coats of whitewash applied to the whole interior surface, giving them a bleak and barn-like aspect fatal to architectural effect; this is especially frequent in Belgium.

This whitewash, coupled with horribly incongruous late Renaissance decoration, has gone far in many cases to ruin what would otherwise be fine buildings.

Externally all _good_ Gothic buildings showed a direct correspondence with the interior: buttresses, flying buttresses, pinnacles, etc., were all constructive and never decorative devices; there was never such a thing as a façade or false front built independently of the interior, and though the harmony of the lines of both were often difficult to reconcile, it was just in the overcoming of such difficulties that the brilliant qualities of Gothic architects were called forth.

In the arrangement of the West fronts the French were at their best, for the combination of deeply recessed porches with the rose window and gable above, flanked by the towers, which in France were usually placed here, was both judicious and effective. In England such porches as those of Rheims, or deep openings, such as the entrances to the cathedral of Paris, were not used, and the West elevations are consequently less interesting. Peterborough is an exception to this rule, but the design is so exaggerated, that the three immense arcades dwarf everything connected with them.

The custom of placing a tower and spire over the intersection of the nave and transept was always adhered to in England, and was always a happy arrangement which gave the building dignity and character, even when the Western towers were omitted. Of this the celebrated Salisbury Cathedral is a beautiful example.

The spires of Chartres and of St. Ouen, at Rouen, are the finest in France, where towers were frequently built to receive spires which were never added. The height to which the nave was carried there often prevented the towers from having their due effect, as it was impossible to carry them out on a scale large enough to give them a corresponding proportion. English architects contented themselves with moderate interior heights, rendering the proportioning of their buildings a much easier task than that which their neighbours imposed upon themselves, by attempting with each new building a more daring altitude, until the crumbling vaults of Beauvais set a limit to their audacity.

The comparison of contemporary Gothic in England and France covers the subject more accurately than between that of any other countries, for these two nations rivalled each other all along in the solution of the various problems which arose with each step in their progress, while the architects of other countries profited by the results they attained and erected their buildings on Anglo-French principles.

The cathedrals of Cologne, in Germany, and Toledo, in Spain, are as fine as any to be found in France or England, but they are neither German nor Spanish in conception and principle, and therefore do not belong to the national architecture of these countries. In Italy, Gothic architecture was never understood as it was in the North, and whenever anything was attempted in direct imitation of Northern principles of design, the result was always hard and mechanical. The true Italian Gothic was of itself often beautiful, but this was almost a separate style, in which the influences of pointed forms, Oriental colour, and the example which the Classical ruins held out so conspicuously on their own soil, were brought together by the Italians so as to form an harmonious whole.

In Venice a peculiar development of the style was attained, adapted to the flat elevations of the canal palaces. This arrangement consisted of a consecutive series of arcades, in which the mouldings of each arch were carried up and returned, forming a second and sometimes a third row of lights, replacing, in the play of light and shadow, the forced absence of projections.

These arcades were surmounted by horizontal mouldings, and the lines of the cornices and imposts were also horizontal, the Italians never having lost sight of the entablature, which had been dropped in France with the rise of Romanesque architecture and replaced always afterward by the vertical lines which are the prominent one sin of all Northern Gothic buildings.

The celebrated Doge's palace is the foremost of these and ranks amongst the most picturesque buildings in Europe. It is not free, however, from grave defects and is criticised by architects for the top-heavy and injudicious construction, by which a high and rarely pierced wall is sustained by the slenderest of arcades.

Most of these palaces are of the fifteenth century and should not perhaps be mentioned first, but as they illustrate the principle of horizontal lines more readily than by reference to the isolated parts of less well-known buildings, they are introduced now.

Although Milan Cathedral is one of the largest and most pretentious ecclesiastical buildings in Italy, it is scarcely a good example of Italian Gothic, for German architects were employed in its construction and their influence is apparent. It is rather to the Cathedral of Sienna that we should turn for a complete typical Italian structure. Here we find a beautiful building and yet one which can in no way be judged from a Northern standard. The West front has three porches, but their recessed arches are round instead of pointed, although the detail is Gothic (the church having been begun in the middle of the thirteenth century); above is a rose window, but, unlike the Western models, without dividing tracery. Both the exterior and interior are striped with alternate bands of black and white marble. The intersection of the nave and transept is covered by a dome, a feature unknown in France or England (with the single exception of the wooden one in the cathedral of Ely), and the tower or campanile is placed in the angle of the South transept. These points are all essentially different from Northern treatment, in which some of them would be considered defects. Here, however, the parts are sufficiently harmoniously united to produce a whole which is pleasing and original. The cathedral of Sienna has much in addition to these to make it interesting: attached to it is a library—a later building, beautifully decorated in a style similar to the Loggie of Raphael in the Vatican; the stalls of the choir are of carved wood, of the richest Renaissance design, and the pulpit, by Nicholas Pisano, is a gem of sculpture. This pulpit is octagonal; its sides are carved in high relief in representation of Scriptural scenes, and it is supported by polished columns carrying trefoiled arches and resting upon marble lions in lieu of bases. As a work in which both sculpture and architecture combine, it is, on a small scale, one of the most beautiful productions of its kind, essentially Italian, and rivalled only by that in the baptistery of Pisa by the same artist.

The body of a lion as the base of a column was a favourite device of Italian architects, and is frequently met with. Porches formed of columns carrying a round arch and gable and resting on lions, are often attached to the entrance of churches.

Orvieto Cathedral is, on a smaller scale, similar to the neighbouring cathedral of Sienna. The West front is designed with most elaborate detail and highly ornamented with painting and sculpture. The Duomo of Florence partakes also of the general characteristics of Sienna, although its proportions are vastly larger. Its most striking feature is the great dome, added by Brunelleschi, when the church, designed by Arnolfo, was approaching completion; but it is unsatisfactory, as its immense size dwarfs the rest of the building. The general picturesqueness of outline, the delicate design of the doors and windows, and the proximity of the beautiful tower of Giotto, go far to atone for this. The exterior walls of the church are covered with a veneering of coloured marbles, which, while judiciously treated and good of its kind, is too false to be easily reconciled to true artistic principles, and its skin-deep beauty has been painfully apparent, until very recently, owing to the unfinished condition of the West front.

It may be said in extenuation of this that plaster, while generally accepted as an honest material, is no less a shallow covering to disguise naked walls; it is, however, frequently misused, and is only tolerable so long as it is not employed in imitation of better materials, while the thin marble is really intended to deceive the eye, and give the impression that its depth is equal to that of the wall.

The interior of the Florence Cathedral is disappointing, it is insufficiently lighted, bare, and much in need of the frescos with which it was originally intended to be decorated.

The cathedral of Pisa belongs in greater part to the preceding style, but the campo-santo adjoining it has a cloister with traceried windows, which, notwithstanding its round arches, more nearly resembles Northern Gothic than anything in Italy, and by its greater height shows a novel and more effective treatment than is usually seen in France or England.

The little church of St. Maria della Spina in this town, on the banks of the Arno, is a charming little edifice of the Sienna type.

In civil architecture Italy has much to boast of. Her palaces and fortresses are amongst the noblest and most picturesque buildings of the Middle Ages found anywhere in Europe. Most of these are rectangular masses of stone, the austerity of which is relieved by heavy window-openings with pointed heads and moulded frames, and crowned by a battlemented cornice, occasionally enlivened by shields placed between alternate corbels. The addition of the campanile, used as a lookout tower rather than as a belfry, generally completes an imposing structure.

Of those in stone, the Palazzo Vecchio and the Bargello, in Florence, are among the finest of these half town-hall, half fortress buildings, while the Municipio of Sienna, with its immensely high campanile, may be mentioned as typical of those in brick. Nearly every large city possesses one of these tall towers, notably Verona, Cremona, Mantua, and Florence. In the last-named the tower

of Giotto is the most highly ornamented and graceful of this class of structure, and for general proportions unsurpassed. Longfellow, in his well-known poem, regrets the lack of a spire to complete it, but it is questionable whether such an addition could have been made in keeping with the style in which it is designed.

In France the lately restored Chateau de Pierrefonds, near Compiegne, illustrates, perhaps as well as any, the typical military building of the Gothic period, with all the usual accompanying structures. The exterior walls are high and massive, with round towers at the angles crowned with projecting battlements and conical roofs. An interior court is reached only by traversing a drawbridge and passing through an outer gate and passage defended by heavy portcullis. Around this court are grouped the apartments, banqueting-halls, the chapel, and the necessary quarters for residents and garrison.

The number of remaining domestic buildings of the period is comparatively limited. The house of Jacques Coeur at Bourges, the monastic Hotel de Cluny, in Paris, the Palais de Justice, and the Hotel Bourgtheroulde, in Rouen, may be mentioned among the few still standing, as the best examples of contemporary architecture.

Of small half-timbered houses there remain a fair number in France, though they are daily being demolished, in the principal cities, to make way for so-called improvements.

England is rich in military and civil buildings: the castles of Windsor, Warwick, Kenilworth, Rochester, and the Tower of London, are all well known and have been frequently described. Perhaps the most interesting of English civil structures of the Middle Ages, are the colleges at Oxford; as, however, they follow, in the Gothic treatment, the progress of the styles, as illustrated in the contemporary ecclesiastical edifices, they do not require special description.

The town-halls of Belgium are important Gothic buildings, and are found in all the principal cities of that country. Their flat façades are singularly rich, but as they embody only the forms and ornament of Gothic art, they are less interesting and poorer examples than any less pretentious structures showing the constructive element, which predominated in the Gothic style.

Toward the close of the style, and before the rebirth of Classic art had completely superseded Gothic architecture, a curious transitional style had a brief sway, in which both were blended. The wing of the Chateau de Blois, built by Louis XII., and the Chateau de Gaillon, built by Cardinal Amboise, in the year 1500, the façade of which is now preserved in the courtyard of the Ecole des Beaux Arts, may be regarded as the best specimens of this charming and short-lived art. The churches of St. Etienne du Mont, and St. Eustache, at Paris, may be added to these as typical of the contemporary religious edifices.

In them we see the last throes of a dying style which had become extravagant and distorted in its final efforts to survive, but retained traces of its former beauty even in its expiring moments.

The Gothic style arose in the latter half of the twelfth century, it attained its greatest purity and simplicity in the thirteenth; during the fourteenth a more extensive use of ornament was introduced, in consequence of which it has been termed Decorated Gothic; finally, in the fifteenth, its principles and principal features were exaggerated and pushed to their utmost limits, until its brilliancy, flickering in the flamboyant traceries of the latest period, expired and gave place to a Classic revival.

XI.

THE RENAISSANCE.

A not uncommon error is made in applying the name Renaissance only to the delicately treated style of revived Classic art, such as was prevalent in France during the reigns of Francis the First, and his immediate successors.

The word—derived from the verb _renaître_, signifying in French the rebirth (of the classics understood)—cannot, however, be confined to any such narrowed limits, for no new style having been substituted since, it is as correct a term to-day as it was in the sixteenth century. There is certainly a distinction between the first brilliant productions of the revival, and the more ponderous buildings which succeeded them, but Early and Late Renaissance express this satisfactorily. It did not always follow, however, that all the work which, from its characteristics, would be classified under the first head, necessarily antedated that belonging to the later period.

In Italy, where the works of the Romans were too colossal to be utterly destroyed, and too conspicuous to be easily forgotten, the first movement naturally took place to reawaken the long dormant art, by which they had been produced.

In the fifteenth century Orcagua built the Loggia dei Lanzi, in Florence, and boldly substituted round arches for the pointed ones then in vogue. This was the turning-point in the tide of Gothic architecture, for it needed but little more to induce the delighted Italians to throw off the yoke of an art which they had adopted but unwillingly, and which had never been sympathetic to their taste. Consistently with their impetuous nature, the change was effected without hesitation in a marvellously short period, and with scarcely any of the usual intervening transitional stages. The ancient forms reappeared and replaced the dying Gothic as rapidly as in the days of the French monarchy the cry "Le roi est mort. Vive le roi!" heralded at once the king's death and his son's succession to power.

It is strange that there should have been so little to connect the succeeding styles, that the revival should have been so completely independent of and uninfluenced by a style which had been steadily growing for four centuries, and which men must have become accustomed to consider the only one suited to their times. Delicate workmanship was, however, the only Gothic legacy the Renaissance architects accepted, and this was the chief characteristic of the work of the early period. The proportions and scale of their buildings were small; a whole order: pedestal, column, and entablature generally occupying and marking the height of an ordinary story of fifteen or twenty feet, and the ornament used, while profuse, was executed in the lowest relief and with most minute detail.

If the revolution in art was great, it had proportionately great exponents: Brunelleschi, Bramante, Raphael, Sangallo, Vignola, Michael Angelo are names as prominent in history as those of much-lauded victors in the battlefield.

Brunelleschi, architect of the dome of St. Mary's in Florence, was one of the earliest innovators. He designed the Strozzi and Pitti Palaces in that city, with the horizontal lines and round arches of the Classic school, although still retaining the feudal traditions in their massive stonework and in the austerity of their exteriors. The great palaces of Rome which belong to this period partake also of this external severity, and confine their brilliancy to interior display. The palaces of the Cancelleria by Bramante, the Palazzo Massini by Balthasar Perruzzi, of Sienna, the Sacchetti and Corsini Palaces by Sangallo, the Barberini designed by Bernini, and the Farnese Palace upon which Sangallo, Vignola, and Michael Angelo devoted their labors in turn, are a few among the most celebrated.

Most of these buildings, while varying in size and in accordance with the character of their sites, are rectangular in plan, and enclose quadrangular courts, the different stories being marked by superposed orders and arcades. They are planned on a liberal scale, with broad proportions and with great deference to symmetry. The beauty of the plan was, in fact, one of the best features of the new style, not only in domestic, but in ecclesiastical architecture, for the arbitrary Gothic arrangements being once discarded, it became possible to combine the circle and straight line in many novel and beautiful ways, for which the older Roman buildings furnished admirable examples. The study of these plans forms one of the most important elements in an architect's education, and their examination in these days of iron props and twelve-inch walls is fraught with much pleasure and profit.

The light and brilliant creations of the early period are abundant in Northern Italy, and were models with which the French were readily impressed. The façade of the church in the Certosa of Pavia, with its elaborate detail and delicate ornament, and such buildings as the Spinelli Rezzonico and Vendramin palaces, the church of St. Zachariah, the Logetta and Library of St Mark's of Sansovino, in Venice, and farther South the Palazzo Fava in Bologna, the Capella Pazzi attached to the older Sta. Croce in Florence, and the monument to Julius II. in Sta. Maria del Popolo in Rome are a few beautiful examples of the early treatment which has so much affinity with the works produced in France under the Valois.

[Illustration: PLAN OF ST. PETER'S AS ORIGINALLY DESIGNED BY MICHAEL ANGELO.]

The great Italian cathedral upon which nearly all subsequent churches were modelled was commenced upon the site of the old basilica of St. Peter's in Rome in the year 1506, upon plans by Bramante, and occupied a century and a half in completion. After Bramante, Giocondo, Julian Sangallo, Raphael, Perruzzi, Antonio di Sangallo, Michael Angelo and Carlo Maderno each worked upon it in turn.

Michael Angelo, who designed the dome, wished to adopt the plan of the Greek cross, that is, with equal arms, as shown in the accompanying plan. The result would have been much more monumental and would have given the dome its due effect within a moderate distance, while now it can only be properly judged from afar, and the high façade terminating the nave is both poor in composition and detrimental to the general conception. The building is essentially Classic in all its details, but differs from the general design of any particular Classical building. The nave is formed by a Corinthian arcade similar to those of ancient Rome, though on a vastly larger scale, supporting a tunnel-vault, which is decorated with sunken panels like those of the ancient Baths.

The dome is supported on a circular drum carried on four immense piers and improves on the Pantheon only in size, while it is surpassed by St. Sophia in scientific construction.

The cathedral is most richly, even gaudily, decorated within, with coloured marbles and mosaics and contains numerous tombs of great magnificence and an altar with twisted columns designed by Bernini. It is the largest church in the world, and yet its proportions are so harmoniously, or inharmoniously designed, that it does not produce a corresponding sense of its vastness upon the beholder. The single order occupying the height of two stories is a feature, the invention, or rather arrangement of which, is attributed to Michael Angelo. In subsequent buildings it was nearly always adopted in preference to the smaller orders marking each floor.

The life of this great artist forms of itself a chapter in the history of architecture. Michael Buonarotti, surnamed Angelo, the most brilliant architect of the sixteenth century, was born of noble parentage in Arezzo in the year 1575. He developed extraordinary talents at an early age, and after outstripping his first instructor, took up his residence in Florence, where he studied anatomy and the human figure until he became the most expert draughtsman of his time. In Rome, where he was summoned by Julius II., he produced several fine works in statuary, but owing to the jealousy of Bramante was forced to quit the city and return to Florence. There he aided the citizens to sustain a siege during a year, by his superior knowledge of fortification, and subsequently went to Venice, where he designed the famous Rialto bridge. At the earnest solicitation of the pope he returned to Rome and commenced the great paintings in the Sistine Chapel, to which work he had been assigned by the counsels of Bramante, who wished to prove his inferiority to his own nephew Raphael. The result of the work, completed in a marvellously short period, however, was so successful that all Rome ran to see it.

After the accession of Paul III. to the Papal see, Michael Angelo was definitely appointed architect of St. Peter's and worked on the building during the remainder of his life, although he returned to Florence several times and there executed the splendid statues which adorn the chapel of the Medicis. In his later days he was assisted by Vignola in his work, but died before its completion at the advanced age of eighty-eight.

Giacomo Barrozio, called Vignola from his birthplace near Bologna, is known for his great works, the chief of which are the Jesuits' church in Rome and the castle of Caprarolla at Viterbo, which he built for the Cardinal Alexander Farnese, and also, especially to architects, for the rules and measurements of Classical orders which he composed from the buildings of Rome with the aid of the manual of Vitruvius.

This work comprises the elements of design used in nearly all the buildings erected during the two following centuries, many of their elevations being simple combinations of different pages of Vignola's book, which to this day is the best guide for Classical proportions and the architects' A B C.

The discriminator between the various architectural styles is fond of drawing a marked distinction between Italian, French, and German Renaissance, and illustrating it by views of the typical Italian palace, with a flat tile roof and low pediments, and the typical French house, with immensely high slate roofs and pretentious dormers. Although the eye of the practised architect can distinguish between the representative work of Sansovino and Philibert Delorme, and between that of Bernini and Claude Perrault, yet such distinctions do not form separate styles, for they are but unimportant differences, caused by local influences.

The subject should be looked upon in a broader sense, for all these subdivisions tend to confuse the student and lead him to forget the sequence of the great historical style of which they form part.

The Jacobean, Queen Anne, and kindred so-called styles in England were merely eccentric streams flowing out of the one main channel, which were scarcely worthy of distinction and certainly not of revival in our times.

In France, under each reign, there was a slight difference of treatment, chiefly in the decoration of interiors, which permits of a classification most convenient to the modern upholsterer, but for our purposes it is sufficient to apply the two divisions—Early and Late Renaissance.

The Chateaux of Blois, Chambord, and Chenonceaux in the Valley of the Loire, the Palaces of Fontainebleau, St. Germain en Laye, the Tuileries and the old Louvre in Paris are splendid examples of the former, and monuments worthy of the great artists, Pierre Lescot, Philibert Delorme, Jean Goujon, and others, who laboured upon them. They are illustrative of the employment of the small orders and ornament in low relief, which characterized the corresponding period in Italy, though they are generally richer and more spirited in design than the Italian buildings, and the soft stone which is so abundant in France permitted more lavish ornament

upon the exteriors.

The skeletons of each design, that is to say, the main architectural lines, stripped of elaborate detail, are much alike and can nearly all be brought back to the ancient method of superposing orders. This is no disparagement on the value of the work, for the plans of many buildings were excellent, and the variety of ornamental design was of a delicacy and imaginative beauty which has rarely been surpassed.

It is questionable, indeed, whether the change which took place in the century of Louis XIV., in the introduction of larger proportions and greater severity of ornament, was so much a gain as it was considered at the time. To this period belong some of the great churches modelled upon or rather suggested by St. Peter's in Rome: St. Paul's in London, rebuilt by Christopher Wren; the Val de Grace, the joint work of Lemercier, Leduc, and Mansart, and the church of the Hotel des Invalides in Paris, also by Mansart, are among the finest of the period and style. The plan of the last-named church is appended as a particularly happy example in general arrangement and symmetrical variety, doing great credit to Mansart, who also built the larger portion of the celebrated Chateau de Versailles.

The publication of Stewart and Revetts' great work upon the antiquities of Athens called general attention in England to the beauty of Greek art, toward the close of the last century, and resulted in the erection of a number of buildings in imitation of Athenian monuments which were utterly inappropriate and unsuited to the English climate.

In France architecture went through two or three fashionable phases, from great extravagance of design under Louis XV. to extreme simplicity under Louis XVI., finally relapsing under Napoleon into the servile copying of entire Classic buildings: a great falling off from the principle of the sixteenth century work, which had always been original in conception although borrowing detail from the antique.

During the early part of this century, architecture sank to the lowest ebb all over the world, probably owing to the disturbing influences of the great Napoleonic wars. Within the last thirty years the spirited writings of a few enthusiasts and the liberal teachings of the French schools have caused a general revival, and better work is being done now than at any time during the century.

[Illustration: PLAN OF CHURCH OF THE HOTEL DES INVALIDES AT PARIS.]

Avaricious commerce and the predominance of the desire for display rather than quiet love of the arts are factors which stand much in the way of genuine progress, but it is not improbable that the spread of refined education will eventually succeed in planting the seeds of this love in the heart of the great masses, and enable architecture to resume its natural and elevating position in their midst.

XII.

CONCLUSION.

At the present stage of modern art we have the principles, broadly speaking, of two great styles of architecture to guide us in the design of the buildings which we may have to erect. These are the Classic and the Gothic; for we may apply the term Classic not merely to the works of the Greeks and Romans, but to their offshoots the Byzantine and Romanesque styles, the one branching Eastward and the other Westward, altered in many respects, but founded on the older systems; and we have seen that the Renaissance was but a revival of the same methods and forms.

In each of these styles the best result has always been attained where the constructional element has been held to be as important as the decorative, where the essential and useful have not been subservient to considerations of ornament or display. In Classic work much has been done that is unworthy, in the senseless repetition of columns and pilasters which support nothing, in decoration which serves only to conceal ill-adjusted architectural lines; and the same is equally true of degenerate Gothic, in which whole walls have been covered with meaningless panels, and massive buttresses built up to receive no strain.

Nevertheless, by following only what is good in the principles of each, and by avoiding the errors which experience has enabled us to perceive, especially those which have engrafted themselves upon us by bigoted custom, we can not only produce fine work but assist in the advance of architecture.

Before deciding upon what style to employ in the composition of an edifice, it is well to first consider thoroughly the programme of what is wanted in its plan, and then the special character with which we desire to invest it both exteriorly and interiorly. It is scarcely necessary to add that both should be intimately connected.

We have seen that the best period of Gothic art was that wherein the whole structure was raised on a theory of weights and strains thrown from vault to pier, and pier to buttress; it is, therefore, absurd, when a building occupies a space between the party-walls of modern street lots, to attempt an interior construction having the appearance of corresponding with buttresses and similar contrivances for which there is no room on the outside.

If, therefore, we choose Gothic for our style, let us follow no false theory, but work on the principles demonstrated in its innumerable examples, in which it may be possible to find room for further development, introducing no feature of construction which has not a full and consistent meaning.

One can scarcely go the lengths to which many venture, in saying that Gothic architecture is suited only to ecclesiastical buildings, for there are many splendid military and civil structures, from the keeps and castles of England and France, to the town-halls of Belgium. But there is this much to be said in their favour, that while the laws of fortification and domestic life have altered entirely since the Middle Ages, on the one hand, those governing the observances of religion have remained unchanged and no manner of building is so essentially religious in its character or better calculated to command the reverence and awe of the devotee, on the other.

In support of this view many will agree in admitting that there is nothing of this religious sentiment expressed in the Corinthian colonnades of St. Peter's, or, in fact, in any of the great number of Renaissance churches which are scattered throughout the cities of Europe, while it never fails to exercise its influence upon anyone entering the great Gothic cathedrals.

The great prevailing thought of Mediæval times was a religious one, and we see it reflected in the minutest details of the lives of the people of that age; it was, consequently, but natural that it should attain its highest expression when they filled their churches with the best that could be produced in architecture, sculpture, and painting. While the Classic orders seem out of place in a temple of Christian worship they are appropriate in civil buildings, and we have no better examples for beauty of proportion. They are the result of the thought and taste of generations of architects and have stood the test of time, for they are as pleasing to-day as in the days of ancient Greece and Rome.

It is their proportion rather than their component parts which we should follow, for a column, unless needed as a support, is a questionable decoration, and pilasters or engaged columns are only desirable where additional thickness of wall is required, used as the Gothic architect would have used buttresses, and never as mere ornaments, which are at once a fraudulent delusion and a retrogression in the progress of architecture.

A multiplicity of columns and entablatures does not make perfect architecture, but great leading lines, good proportion, clear detail, and appropriate ornament.

The guiding rule is to do nothing which has not intrinsic merit. It is better to have an absolutely plain wall than one covered with poor decoration; far better to have no cornice at all than a galvanized iron one, painted to look like stone.

The true definition of architecture is "ornamental construction." It is not a utilitarian science, because if so there would be no _raison d'être_ for beauty of design, for mere shelter and commodious arrangement could as well be provided by the engineer as by the architect. The art of the architect lies in the composition of buildings at once suited to their purpose and beautiful to the eye; and as such his art is one that can progress, not through a series of changing fashions which grow wearisome before they have lasted a decade, but step by step, according to the example of the great periods of the past.

This example teaches us never to copy slavishly, but to imitate old examples only so far as they may suit modern needs, in principle rather than in detail, and to eschew the reproduction of defects, however picturesque, so that architecture may be a living art instead of the mummified representation of archæological researches.

In pursuing the study of so vast and splendid an art we should do so with some feeling of reverence for its dignity, not looking upon it as a mere money-making trade, for the greatest architects the world has known have been satisfied in being only worshippers at a great shrine. Reverence is a sentiment slightly regarded in an age when delicacy of feeling in such matters is often held up as a butt for the jests and derision of the vulgar, and the dignity of the art has little foothold when it has become a custom for the vendor

of cheap furniture to style his shop an “Art Repository,” and the founder of cast-iron abortions to call his factory “The Art Metal Works.”

Nevertheless all of our work must reflect something of our inner thoughts, and if we do not place them upon a high plane it is not possible for their reflection to contain what is noble and true. We cannot become artists in the true sense of the word without loving and reverencing the beauty and principles which have made the art so great a one.

It is the custom among certain people to sneer at sentiment, and call for practical art; but the most practical art is essentially the product of thoughtful sentiments.

As an illustration, let us compare the Laocoön, of sculpture; the Halls of Karnak, of architecture; the Dead March, of music; the “Descent from the Cross,” of painting, with the “Dancing Faun,” the arabesques of the Renaissance, the waltzes of Chopin, and the gay feasts depicted by Paolo Veronese, and the contrast shows us that each branch of an universal art expresses the opposite feelings of gravity or tragedy, of joy or comedy, each in its separate manner.

In designing, questions arise every moment which can only be decided by an innate sentiment of what is good and appropriate. There are no fixed laws governing the height of a spire or the projection of a moulding; they are matters which depend upon correct feeling, or, in other words, upon educated taste.

If it were not so, art would become a mechanical science, and could no longer be called by that name. Emotion has no place in mechanics, but it has great influence in the arts. We know the Greeks were an emotional race, and it is said that Michael Angelo wept before a beautiful statue or painting; and the works of the people and of the individual were proportionate to the depth of their feelings, and have perhaps never been excelled.

Let us, therefore, commence this study—for the omega of this book is but the alpha of architecture—despising none of its delicate subtleties, and endeavour to grasp its principles, in the hope of doing our share in its further advance, laying aside the petty gratification of our vanity in a genuine affection for our art.

THE END

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Obvious typographical errors and punctuation errors have been corrected after careful comparison with other occurrences within the text and consultation of external sources.

Some hyphens in words have been silently removed, some added, when a predominant preference was found in the original book.

Except for those changes noted below, all misspellings in the text, and inconsistent or archaic usage, have been retained.

Page 21: “tenemos” replaced by “temenos”. 31: “Chilambaram” replaced by “Chidambaram”. 32: “baldaquins” replaced by “baldachins”. 40: “ababaster” replaced by “alabaster”. 111: “Adb-el-Rhaman” replaced by “Abd-el-Rhaman”. 119: “continuons” replaced by “continuous”. 126: “weer” replaced by “were”.

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Untitled

Morris Fishbein

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The Care of the Skin and Hair

And Other General Health Hints

Morris Fishbein, M. D.

Editor Journal American Medical Association and Hygeia, the Health Magazine.

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TABLE OF CONTENTS

Page

Skin Diseases and Their Cure 5

Cosmetics 7

Skin Disease Quackery 8

Magic of Plastic Surgery Replaces Scarring Knife 10

Button in Savage's Skull First Plastic Surgery 11

Beware of Beauty Doctor Who Offers Guarantees 13

Either Hair or Health Endangered by Dyes 15

Skin Eruptions Laid to Poison in Dyed Fur 17

Most Moles Harmless, But Watch Black Ones! 18

Flowers Carry Poison 20

Snow, Cold Water Best in Treating Frostbite 22

Wash Your Neck Well to Ward Off Boils 23

Psoriasis One of Most Annoying Skin Faults 25

Cauliflower Ears 26

Flopping Ear Needs Careful Operation 27

Rubber "Reducers" Are Foes of Comfort But Not of Fat 29

Be Careful in Use of Laxative Gums 30

Overeating Harmful After Middle Life 31

CARE OF THE SKIN AND HAIR AND OTHER GENERAL HEALTH HINTS

SKIN DISEASES AND THEIR CURE

There are still persons who believe that every disease of the skin can be successfully treated with a salve, a lotion or a powder. This belief and the advertisements of nostrums for the treatment of skin disease are a reflection of the actual knowledge of such conditions held even by the medical profession a quarter of a century ago.

Today the methods of treatment of skin diseases include practically every form of apparatus, every method of medical administration known to medical science. This advance is a reflection of the application of knowledge in physics, chemistry, biology and bacteriology to medicine, and of a more thorough comprehension of the fact that the skin is not merely a protective covering for the body but an organ whose condition reflects that of the other tissues and influences them definitely.

Perhaps the greatest advance has been the X-ray and the knowledge that application of its rays would affect not only tumors, whose cause is unknown, but also inflammations and degenerations of the skin produced by parasitic organisms. Not only the rays of the X-ray tube, but also those of radium, of the sun and of the ultraviolet lamps are known to have definite effects on the skin. Radium is used for destroying cancer of the skin, masses of veins, birth marks, moles and similar unsightly excresences. As Dr. Fred Wise indicated at a recent meeting of specialists in diseases of the skin, the physician is no longer limited to any single form of treatment, but may attack such growths with any of the destructive rays that have been mentioned; he may freeze them with carbon dioxid snow; he may remove them surgically with the knife; he may dry them by passing an electric current through them, or cut them with a needle whose cutting power depends on vibrations produced by electric waves. In attacking certain parasitic diseases of the skin, the specialist reaches them through the blood, injecting combinations of dyes and metallic elements or specific drugs which produce the immediate death of the parasitic organisms when they come in contact with them.

There still remain infections and diseases of the skin which are not easily amenable to treatment. Pemphigus, in which there are tremendous wheals, blisters and similar eruptions, is not known to yield easily to any form of treatment, although it may be benefited on occasion by the use of drugs such as arsenic and quinine. Generalized changes of the nature of the skin resulting from disturbances of the nervous system and of the glands sometimes resist every form of medical attack. Research in the field of skin diseases is one of the most promising opportunities for investigation to the medical man with research instincts.

COSMETICS

Since investigation has been undertaken by physicians and chemists there is less and less likelihood of the sale or purchase of cosmetic preparations, including face creams, powders and lotions, containing poisonous ingredients, although at one time such metallic poisons as lead, bismuth, or arsenic could be found as ingredients of such beautifiers. Nowadays, the difficulty seems to be that there are a multiplicity of preparations which have no real warrant, since they differ only in unessential qualities from each other. There are, for example, dozens of creams sold for application to the skin with claims that they nourish the skin, when, as a matter of fact, there is no such thing as a skin food. All of these creams essentially are cold creams, modified by varying amounts of perfumes or other thinning or thickening factors.

These statements do not apply, however, to the creams that are used as depilatories. Most of the widely advertised ointments for this purpose have as their basis a salt of the metal barium. Application of the ointment removes the hair, but does not affect the growing end within the skin. In most instances the new growth of hair is thicker and coarser and darker than the original growth removed by the depilatory. In some instances, superfluous hair is removed by the application of the X-ray. It has been found, however, that X-ray machines seldom kill the living cell from which the hair grows, unless it is applied in dosage so strong as to produce definite changes in the skin itself.

Specialists in diseases of the skin are being called on to treat thickening of the skin, or so-called precancerous keratosis, resulting from the use of the X-ray for the removal of hair by inexperienced persons. Those who give special attention to these problems are agreed that the one certain method of removal of superfluous hair is the use of the electric needle. It must be understood, however, that it is possible to remove only a few hairs at a single treatment, and that the method requires great expertness in its application.

SKIN DISEASE QUACKERY

Faith springs eternal in the human breast and credulity is not the property of any single class. One finds our best educated citizens just as easily susceptible to false and fraudulent claims as the most ignorant. Indeed, in many instances, particularly in relation to medical science, a little knowledge is a dangerous thing, since its possessor is likely to be impressed with his own ability to make suitable judgments.

Of particular interest in this connection are the many cosmetics offered to women who seek eternally for artificial beauty. According to an investigation recently made, the American public paid, in 1921, $150,000,000 for perfumery and cosmetics. There were purchased 240,000,000 packages of talcum and face powders and 18,000,000 packages of rouge.

Students of diseases of the skin constantly emphasize the difficulty of determining the nature of any eruption. Red spots and slight inflammations may be due to disturbances of digestion, to special sensitivity to various food substances, to eczema, to any one of a half-dozen infections, and possibly to tuberculosis or to syphilis.

Since the tendency of some minor conditions is to recover without treatment, persons are likely to indulge in self-treatment and thus to neglect the more serious complaints to a time when a cure is far more difficult than when they are seen early. Cancer of the skin appears in its beginning as a small and rather unnoticeable spot; if seen early, it is easily controlled, but if stimulated by the use of all sorts of caustic acids or pastes it may become so serious as to produce death.

The craze for beauty has also resulted in the tremendous rise of the beauty parlor. It is easy to remember the time when our largest cities could boast of but five or ten hair-dressing establishments. Today in the Boroughs of Manhattan and the Bronx alone there are 1,177 hair-dressing establishments. Here women come not only for massages and permanent waves but also, frequently, for the treatment of diseases of the skin and for the removal of superfluous hair, moles, warts, or tumors.

These beauty parlors are the outgrowth, in many instances, of manufacturing establishments for the sale of cosmetics. Here cold cream masquerades under twenty different names and women purchase for considerable sums preparations which cannot possibly do the things that are claimed for them.

One finds “rose leaf cleansers,” “skin fresheners,” “face moulding creams,” “balsam tissue astringents,” “skin fatteners” and “skin thinners,” cleansing creams and vanishing creams, regardless of the fact that specialists in the disease of the skin have stated again and again that all that any cream can accomplish is simply to make the skin more pliable.

MAGIC OF PLASTIC SURGERY REPLACES SCARRING KNIFE

During the World War the mutilating injuries suffered by many of the men were assuaged through the development of new features in surgical technique.

Whereas formerly it was considered sufficient merely to sew up a wound, to amputate a shattered limb or to save life regardless of appearance, surgeons then began to consider operations with a view to the most presentable appearance possible after repair.

The technique itself is difficult but the war yielded a few masters in the medical service of each of the warring nations.

Stitching and Filling In.--In addition to making wounds more sightly by fine stitching, methods were evolved for filling in defects by transplanting tissues from points elsewhere in the body.

For instance, a wound under the eye was repaired by moving some of the loose tissue from the forehead or the cheek. This was left attached to its original blood supply until new vessels had come in and then the original attachment or pedicle was removed.

In one instance tissue taken from the upper part of the chest filled in the side of the face. Here mutilations were made sightly and at least a tolerable existence given to men whose lives otherwise might have been an agony of sensitiveness.

Transplanting Muscles.--In one case a man whose arm was lost at the shoulder had not even enough of a stump to attach an artificial limb.

By transplanting muscles and tendons from neighboring parts, surgeons were able to make a stump that served well for the attachment of an artificial limb with which the man was able to earn a livelihood.

The economic aspects of the situation are, of course, even more important than those relating wholly to the patient’s appearance.

BUTTON IN SAVAGE'S SKULL FIRST PLASTIC SURGERY

Even the ancient savages used to make holes in the skull to let out the demons which they believed were responsible for disease.

Instances are recorded in which they also repaired such holes by the insertion of buttons of bone previously removed. In attempting to repair the ravages of disease, surgeons today sometimes fill in defects with substances of various kinds. At the recent meeting of the American Academy of Ophthalmology and Otolaryngology in Colorado Springs, one entire session was devoted to the newest points in this fine surgical art.

Removing an Eye.--When an eye must be removed because of inflammation or disease--and this sometimes done promptly to save the sight of the remaining eye--the cavity that is left may be extremely unsightly. Dr. Harold Gifford of Omaha told of various operations that are done to secure a good appearance. When an artificial eye is to be worn the socket must be made suitable to hold it. Sometimes paraffin is employed to develop a proper cavity, although most physicians fear this substance because its injection may produce irritations and overgrowth more unsightly and certainly more dangerous than the condition the paraffin was planned to correct.

Dr. Harry L. Pollock of Chicago told of several instances in which cancerous growths had followed the injection of paraffin by beauty doctors to relieve wrinkles or the sunken bridge of a nose injured by a blow. The appearance seemed beautiful immediately after the injection of the paraffin, but soon the irritation set in. Then the face became a mass of humpy tumors which had to be removed by surgery and which left serious scars.

Celluloid was tried for a while, but it also was discarded because the results were unsatisfactory.

Use of Ivory.--The newest and for the present apparently the best substance to use for repairing defects is ivory--either natural or synthetic. Dr. Pollock pointed out that this substance is more nearly like bone in its composition than any other substance known. Both bone and cartilage are used also, but Dr. Pollock's experience inclined him to favor ivory over either.

Obviously this work is not for the amateur, but for the experienced worker. The so-called advertising beauty doctors seldom attempt it because the conditions under which most of them work are not conducive to successful surgery. They choose rather to delude their patients with promises of rapid and easy relief that are never fulfilled.

BEWARE OF BEAUTY DOCTOR WHO OFFERS GUARANTEES

Recently there came to medical attention the case of a woman who had been the victim of the search for beauty through surgery. She was the wife of a prominent merchant in a foreign country.

When she was eight years old she was operated on for the relief of tuberculous glands in her neck. She grew up, married successfully and gave birth to a handsome son.

But in the meanwhile her life, comfortable enough otherwise, was disturbed because the scars of her operation showed when she wore evening dress.

Tours Europe.--Finally she set out upon a tour of Europe. She arrived in Paris, where she consulted several eminent surgeons, all of whom advised against operation.

Then she heard, through the press notices of the theatrical papers, that American beauty doctors were doing marvels in such cases. In this country she reached finally a beauty doctor widely heralded through paid publicity secured by publicity agents.

She was intrigued and coaxed into an operation by cleverly written pamphlets detailing the success accomplished on worn-out actresses and movie stars. She decided at last not only on an operation on her neck but also on face lifting, face peeling, wrinkle removing and similar procedures.

No Anesthetic.--These operations were carried on in the office of the beauty doctor, without an anesthetic and rather crudely in the arrangements for cleanliness. A qualified surgeon works in a qualified and reputable hospital. Advertising beauty doctors are not admitted to reputable hospitals.

The woman finally left the ministrations of the beauty doctor. She had unsightly scars, worse even than those for which she had originally consulted him.

Her skin, irritated by the caustic chemicals used to peel it, continued to give off fine scales. The lifting operations, the loss of blood, the weeks necessary for recovery in a low-grade hospital in which the beauty doctor finally placed her, left the woman nervous, melancholy--mentally a wreck.

A reputable surgeon makes no guarantees of success in plastic surgery. The disreputable beauty doctor relies on the shame of the patient and her fear of ridicule to protect him when his surgery goes wrong, as it so often does.

EITHER HAIR OR HEALTH ENDANGERED BY DYES

Ever since the first woman looked into a polished surface and decided that her appearance would be greatly benefited by certain sophisticated modifications, the feminine sex has been tampering with its natural beauty.

Among the first of the features to receive attention has been the hair, long known as "woman's crowning glory," and now merely an added source of income to the tonsorial artist. The first hair dyes were made from vegetable substances. Then came metallic, chemical compounds, and more recently the synthetic dyes largely derived from coal tar products.

Among the vegetable dyes, henna is the best known example, but indigo wood extracts, sage and camomile have also been popular. Hair dyed with henna is light red, but one hour will make brown hair extremely red and give to white and blond hair a quite peculiar orange color, extremely artificial and unattractive.

The wood extracts and camomile produce all sorts of peculiar colors. They are reasonably safe, but suffer from the disadvantage that the dyes are difficult to prepare and the result not especially permanent. Most of these dyes do not penetrate the hair shaft, but merely coat it so that their repeated use tends to make the hair quite brittle.

Metallic dyes include combinations of lead, silver, copper, tin, and other metals. All metallic hair dyes, according to Dr. McCafferty, who has written extensively on the subject, must be considered as potentially dangerous when used for any length of time. The material may be absorbed into the body and the person so saturated with metallic poison that he develops serious symptoms.

Most of the dye substances offered on the market and advertised in publications are combinations of henna with metallic substances. The dye action depends principally on the pyrogallol and on the metal, with just enough henna present to permit the manufacturer to use the name "henna dye."

The most common dye used today is the synthetic drug known as paraphenylene-diamine. Many persons are especially sensitive to this drug and develop severe eruptions following its use. In certain instances, eruptions on the back of the neck and on the arms follow the wearing of fur dyed with this substance. In Germany, the dye must always be marked with a "poison" label and most European countries have followed that example.

In this country, legislatures are only beginning to consider legislation of a similar character.

If a person is sensitive to paraphenylene-diamine, his scalp and face will begin to tingle and itch after its application, and this will be followed, in from 10 to 12 hours, by a swelling and blistering of the skin. The eyelids also may swell to such an extent that the person is unable to see.

Most of the cosmetic establishments use this dye for their work. The treatment given by most physicians consists in wet dressings of boric acid solutions and in small doses of X-ray to the region concerned. Following the subsidence of the preliminary symptoms, soothing creams are applied to the tissues. Dr. McCafferty points out that every substance used as a dye remover is a dangerous poison, which, if it does not injure the person using it, at least makes the hair extremely brittle. It is his belief that dye removers should be legislated out of the beauty shops.

SKIN ERUPTIONS LAID TO POISON IN DYED FUR

Every winter physicians who specialize in diseases of the skin are asked to see cases of eruptions around the throat and wrists resulting from poisoning with incompletely or improperly dyed furs.

The principal symptoms are blotches and swelling with itching and burning, so severe in some cases that the person cannot sleep at night.

Rabbit Becomes Beaver.--The trouble is found in most instances to result from rabbit that is dyed to imitate beaver, although all sorts of furs may be involved.

In these cases the poisonous substance is usually a compound of paraphenylene-diamine, the same poisonous substance that causes irritation of the scalps of those who attempt to dye gray hair black.

Many foreign nations have introduced laws to prevent the use of this substance in hair dyes and to regulate the fur-dying industry. Similar laws have been passed in some of our states, but there is as yet no nation-wide regulation regarding the use of this substance.

Investigate Cases.--Not all persons are equally sensitive to this dye. Some may wear furs dyed in this manner without symptoms, but those who are sensitive develop severe reactions.

Several investigative committees are attempting to secure a record of all the cases of this type that occur.

If anyone knows of such an instance, the report may be sent to the Committee on Dye Poisoning of the American Medical Association, 535 N. Dearborn Street, Chicago.

MOST MOLES HARMLESS, BUT WATCH BLACK ONES!

It has been estimated that there are five moles on an average on every person in the city of Chicago.

If all of these were to be removed, it would require more than 15,000,000 separate surgical operations.

The history of moles would be an extremely interesting topic, since they were long regarded as of great significance--sometimes considered the work of evil spirits; sometimes thought to be due to the influence of the moon or the stars, and occasionally thought to be of importance in determining configuration of the body.

Superstition.--Charts of moles were prepared so that one might tell by observation of those that were visible where to expect others that might be invisible. Needless to say, all of this was superstitious and without the slightest scientific importance.

As long as a mole does not disfigure the appearance, it is best disregarded, unless under certain circumstances it becomes irritated and subject to the unusually rapid growth that is characteristic of cancer.

If a mole is extremely brown or black, it has in it an unusual amount of a pigment called melanin, which is responsible for giving the color to the hair, the eyes, and the deeper layers of skin.

Somehow, the presence of this substance seems to be associated with dangerous possibilities, so that a severe injury or irritation of a deeply pigmented mole may cause it to suddenly develop rapid growth.

Watch Black Ones.--The most dangerous moles are those that are jet black. If these are situated where they are constantly rubbed or irritated by collars, garters, shoes or other garments, they should be most carefully watched.

The danger signs have been listed by some doctors as: (1) a gradual increase in the size of the mole; (2) deepening or spreading of the color; (3) ulceration or infection; (4) pain or soreness in the mole.

If any of these symptoms appear, the person concerned should promptly consult a physician. If they do not appear, the mole should be left alone and not teased by irritation, rubbing, picking, scratching, or half-hearted attempts at its removal.

FLOWERS CARRY POISON

Some persons are especially sensitive to contact with toxic substances derived from plants. The poison ivy, oak, and sumac may cause severe eruptions of the skin in persons susceptible.

When mah-jong first became popular, many persons had eruptions of the fingers and of the skin of the face from contact with the lacquer on the mah-jong boxes, due to a special sensitivity that they possessed to a poison in the lacquer which it was discovered had been made by utilizing the juices of certain Japanese plants.

Handling of Bulbs.--Now a British physician has discovered eruptions on the hands of some persons from the handling of flower bulbs, and has given the name "lily rash" to this type of disturbance.

It followed the cutting of the stems of the flowers, chiefly the narcissus, and from handling bulbs of the hyacinth, daffodil, narcissus and tulip.

An investigation was made in several establishments devoted to the sale of bulbs, and a small proportion of packers and sorters of bulbs were found to be suffering from an eruption extending under the nail, where splitting of the skin caused considerable pain.

The longer the nails were worn, the more severe was the condition. Moreover, the inflammation of the skin, which occurred after a few days' work in handling the bulbs, was progressive until the worker began to use gloves.

All the workers were inclined to blame the tulip bulbs. Some of the observers thought that the eruptions were due to friction from the rough sides of the bulbs, and were ready to place the responsibility on the hyacinth, narcissus and daffodil.

An investigation showed, however, that the tulip bulb is surrounded with a single layered covering which spreads easily and that it holds a somewhat acrid juice. When this juice was applied to the skin underneath the finger nail it promptly produced irritation, even without any breaking of the skin due to rubbing.

The obvious suggestion is that persons who are likely to handle tulip bulbs in any considerable numbers ought to wear protective gloves.

SNOW OR COLD WATER BEST IN TREATING FROSTBITE

When a portion of the body not properly protected is exposed to intense or extreme cold, the tissues become affected. If the cold is sufficiently intense and the exposure is sufficiently prolonged, the part becomes frozen.

When the circulation of the blood is sluggish, as in the very young, the old and the sick, suffering from cold is likely to be more severe.

In the same way those parts of the body in which the circulation is least active, and which are least protected by clothing, as the ears, the hands and the feet, are most likely to be affected.

Blisters May Form.--In mild frostbite there usually is merely tingling and slight pain. If the cold is more intense and the exposure more prolonged, blisters form with serum or blood inside of them.

If the freezing is still further prolonged, the entire part becomes gangrenous because of the congealing of the blood within. Then the tissues appear bluish, shrunken or wrinkled and are without sensation or the power of motion.

The best treatment for frostbite at first is friction with snow or cold water in a cold room, the changes to a warmer atmosphere being brought about gradually.

After the friction the feet or hands should be swathed in cotton-wool held in position by loose bandages. If there are blisters or any discolorations of the tissues, a physician should be seen promptly.

On the speed with which proper treatment is given may depend the saving or loss of a limb.

Chilblains.--Chilblains, which also are associated with a sluggish circulation, usually produce burning heat with itching and redness, and are likely to follow prolonged exposure to cold combined with dampness.

They may be prevented by wearing warm, loose woolen stockings and warm shoes. The feet should be bathed in warm water daily, and after the bath should be rubbed briskly, quickly dried and dusted with a plain dusting powder.

WASH YOUR NECK WELL TO WARD OFF BOILS

Those frequent and unwelcome visitors--boils--always are due to skin infection. The greatest preventive is constant cleanliness of the skin, particularly of the back of the neck or other parts commonly affected.

In men the back of the neck is the part most commonly affected, usually because of the constant rubbing of the collar on the hair of the lower part of the back of the head.

May Be Serious Signal.--Certain diseases, such as diabetes, seem to predispose the person to infection with boils, and the constant recurrence of boils should be the signal for a visit to the doctor.

The person who succumbs readily to skin infections lacks bodily resistance. This resistance of the skin is associated with the presence in the blood of substances that will overcome bacteria.

The constantly recurring warning to keep the body in the best physical state by proper diet, proper cleaning and prompt attention to infections in the ear, nose and throat is here of the greatest importance.

When a boil occurs the parts around it are usually shaved, since the infection spreads from one hair follicle to another. All sorts of antiseptics may be applied and fail to control the boil unless the tissues of the body wall it off and cause it to "come to a head." Heat aids this process by bringing a good supply of blood to the part affected.

Surgical Attention.--A boil should not be opened by some friend who happens to think himself a surgeon merely because he does not faint at the sight of blood. Improper opening or drainage of a boil may be exceedingly serious by spreading the infection to the body generally.

The surgeon will open the boil with proper precautions against extension of the infection and will see to it that the boil drains properly.

The germs that cause boils are small round organisms, commonly seen in clusters when stained and studied with a microscope. Some physicians build up the resistance of the chronic sufferer from boils by preparing a vaccine from the patient's own bacteria.

PSORIASIS ONE OF THE MOST ANNOYING SKIN FAULTS

Of all of the diseases of the skin that affect the human body, one of the most annoying is called psoriasis. In this disease, the skin becomes inflamed and there develop round patches which are red at their base and which are covered by dry, white scales.

These patches slowly enlarge, never developing into blisters, but continuing to give off scales. The disease usually begins on the back of the arms and the front of the legs, just below the elbows and knees, and may involve also the scalp and the lower part of the back, but seldom appears on the face.

The disease continues for months and years, sometimes better, sometimes worse. The patient is seldom disturbed in general by the condition, except by its annoying appearance and the development of the scales.

A disease of this type has been treated by all of the methods known to medical science, and the fact that so many methods have been suggested is an indication that none has proved especially satisfactory. Any good specialist in diseases of the skin is able to clear up the lesions temporarily by the use of proper drugs, and usually recommends a change in the diet involving reduction of protein substances and of meat.

In a recent consideration by the leading specialists in diseases of the skin of Great Britain, it was pointed out that the best results today are secured by local treatment, with attention to the general hygiene of the body, and that the value of the various special forms of treatment mentioned in medical literature have not yet been established.

A person who suffers with this disease will do well to select a specialist in diseases of the skin and to follow the general routine laid down.

The chronic character of the disease and its apparent incurability cause persons affected to travel from one specialist to another, and to consult all sorts of fads and quackery in their search for relief. Until some specific curative method is discovered, they will in this way merely waste funds which might better be conserved for useful treatment.

"CAULIFLOWER EARS"

Among the first of the beauty operations to attract public attention was the correction of what the pugilists call a cauliflower or "tin" ear. This term is applied to the result of a powerful force sharply administered to the appendages on the sides of the prizefighter's

visage. Immediately thereafter the blood vessels beneath the skin burst and the blood pours out into the membranes which cover the cartilage or gristle of the ear. The blood distends the tissues of the ear to the extent of the blood pressure and until the blood coagulates. The swelling thus formed may gradually be absorbed and the ear return to its normal state, but in many instances tissue forms out of the mass and when this contracts the ear is distorted into the cauliflower shape. Dr. Samuel Iglaur has pointed out that it is the left ear that is usually of the cauliflower variety, since this ear receives most of the wallops from the right fist of the opponent. Cauliflower ears are also seen frequently in wrestlers, and before the development of headgear were not unusual in football players.

After the pugilist develops affluence and is ready to retire to the stage or the screen he is usually ready to submit himself to remodeling and decorative surgical art. If he develops this vanity previous to his retirement, the revamped ear is likely to become a special target for the opposition the moment he steps into the ring.

FLOPPING EAR NEEDS CAREFUL OPERATION

Next to the cauliflower ear, no other deformity of this particular organ is so frequently the subject of correction as the outstanding ear. This is usually a congenital development and one which is likely to give much distress, particularly to a girl who is otherwise handsome. Many persons have thought that outstanding ears could be corrected merely by sewing the ear to the skin back of it. However, in practice it has been found that the skin will stretch promptly and the ear sag into a new and perhaps more undesirable position. The operation is, therefore, most intricate, involving actual transplantation of part of the cartilage of the ear to the bony covering of the skull behind the ear.

Such decorative surgery is comparatively recent in medicine. Perhaps the first operation for correction of outstanding ears was devised in 1861. Nowadays, with the increasing prosperity, publicity and vanity, such operations have become fairly frequent.

The reliable cosmetic and plastic surgeon is usually associated with a hospital that has been classified by the American Medical Association and the American College of Surgeons as a reputable institution. His work is done under the best surgical conditions, with the assistance of well trained nurses and with all of the cleanliness that is absolutely necessary if surgery of any type is to be successful.

It has been said that the persons who seek cosmetic surgery are likely to be dissatisfied with any result short of perfection, and that they submit to operation after operation, falling more and more into the net of the unprincipled surgeon, if they happen to have begun their quest for beauty with an advertising quack.

The great campaign of education about quackery carried on for many years has resulted in the development of new methods of advertising by the unprincipled surgical impresario. He is far too shrewd to indulge himself in purchased advertising space in newspapers or periodicals. He, therefore, secures a publicity agent who is as likely as not to be a reporter on some local newspaper, willing to eke out a narrow income by playing both ends against the middle. This enterprising journalist takes payment from the beauty surgeon for securing space for him in the daily press, and submits to his newspaper news items regarding weird operations performed by the beauty surgeon on actors, pugilists and other notorious persons. The result is to bring a flood of less notable but equally simple kitchen mechanics, stenographers, elderly housewives and other shallow-minded searchers for beauty into the net.

RUBBER “REDUCERS” ARE FOES OF COMFORT BUT NOT OF FAT

In the craze for reduction which agitated most of the women of the United States during the past few years, many of them undertook all sorts of exercises, diets and the use of all kinds of apparatus to remove what they considered superfluous weight.

Among the most widely advertised articles were corsets and brassières, made of pure gum rubber, which were supposed to be worn next to the skin. It was perhaps the notion of those who promoted these devices that they would squeeze the flesh into a more solid form, perhaps causing the body to eliminate the superfluous matter from inside.

There is not, of course, the slightest scientific reason to believe that such apparatus could do anything of the kind. The chief effect of wearing rubber garments next to the skin is that they prevent perspiration from evaporating. Since the perspiration is rubbed into the skin, it is likely to produce irritation.

Some persons have severe irritation of the skin from contact with the rubber itself. The rubber garment does not increase the sweat, but simply causes it to remain on the surface. Certainly it does not cleanse the skin, but rather tends to make it accumulate deposits of waste products.

The sweat regulates the temperature of the body by evaporation from the surface. It also keeps the skin soft by keeping it moist and well lubricated. Rubber garments prevent evaporation of the sweat, which produces laceration of the skin.

Certainly they cannot in any way aid the lubrication of the skin, since retention of salts and other substances is likely to make it drier and to cover it with crusts.

BE CAREFUL IN USE OF LAXATIVE GUMS

It is safe to say that more proprietary medicines of a laxative character are sold in this country than in any other.

The vogue of chewing gum is also particularly an American institution. It is not surprising therefore that a manufacturer has begun the sale and distribution of chewing gum into which is incorporated a quantity of a well known laxative drug.

Caution in Usage.--While chewing gums thus medicated may be safe as laxatives, there are excellent reasons why this drug should not be sold indiscriminately. Samples were distributed in the streets of some cities, until boards of health prevented such distribution because the samples fell into the hands of children and there were serious results.

Besides, some persons are especially sensitive, and react with severe inflammation of the skin when they take even a small dose of this remedy.

The second use to which chewing gum has been put has been to incorporate drugs alleged to have special properties for reducing obesity.

Thyroid Extract.--Anti-fat chewing gums contain thyroid extract, which is dangerous; drugs that irritate the stomach and disturb the appetite, which are also dangerous, and drugs which have no power whatever, which is foolish. The United States government has recently issued fraud orders against several chewing gums of this character.

The person who uses the gum is told that in addition to taking the remedy she should walk five miles a day, go through certain exercises, and cut down the diet. These practices will bring about a reduction in weight just as well without chewing the gum.

OVEREATING HARMFUL AFTER MIDDLE LIFE

Most of the illnesses that afflict the man beyond middle age are due to the fact that he does not realize his intestinal limitations.

The most pernicious misdemeanor after middle life is overeating. The person who works out-of-doors is, of course, able to dispose of more and heavier food than does the brain-worker.

The brain-worker who tries to eat meat three times a day will find himself, in most instances, in better condition if he eats meat only once each day, but in this condition quantity of food is more important than its nature.

Cooked Foods.--The human being gradually has been adapting himself to more and more refined and thoroughly cooked foods. Nevertheless, it is not desirable for him suddenly to change to foods that are coarse and indigestible.

These perhaps will aid elimination, but at the same time they will irritate the delicate lining of the intestines and permit the more easy entrance of bacteria into the body.

Too much starch, protein or fat is harmful because it will not be digested fully and will encourage the growth of bacteria in the intestines. As one becomes older his tolerance for sugars becomes less, and if he eats too much sweet or starchy foods, he is likely to develop disorders of sugar elimination.

Insurance Records.--All health authorities are agreed that the greatest danger for the man beyond middle age is overeating. The records of great insurance companies show that the life expectancy of the man slightly underweight at this age is greater by far than that of the man who is overweight.

As the old farmer expressed the matter, pigs would live longer if they did not make hogs of themselves.

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Transcriber's note

Minor punctuation errors have been changed without notice.

Spelling was retained as in the original except for the following changes:

Page 3: "Hademan-Julius Company" "Haldeman-Julius Company" Page 3: "UNITED STATES OF AMER" "UNITED STATES OF AMERICA" Page 19: "with dangerous possibities" "with dangerous possibilities" Page 32: "proteins or fats is" "protein or fat is" Page 32: "sweets or starchy foods" "sweet or starchy foods"

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ON ART AND ARTISTS

BY MAX NORDAU AUTHOR OF “DEGENERATION”

TRANSLATED BY W. F. HARVEY, M.A.

LONDON T. FISHER UNWIN ADELPHI TERRACE MCMVII

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CONTENTS

CHAP. PAGE

I. The Social Mission of Art 1

II. Socialistic Art—Constantin Meunier 30

III. The Question of Style 44

IV. The Old French Masters 56

V. A Century of French Art 70

VI. The School of 1830 96

VII. The Triumph of a Revolution— The Realists 107 Alfred Sisley 123 Camille Pissarro 133 Whistler’s Psychology 145

VIII. Gustave Moreau 155

IX. Eugène Carrière 166

X. Puvis de Chavannes 185

XI. Bright and Dark Painting—Charles Cottet 201

XII. Physiognomies in Painting 217

XIII. Auguste Rodin 275

XIV. Resurrection—Bartholomé 294

XV. Jean Carriès 308

XVI. Works of Art and Art Criticisms 320

XVII. My Own Opinion 336

Index 349

ON ART AND ARTISTS

ON ART AND ARTISTS

I

THE SOCIAL MISSION OF ART

There exists a school of æstheticism which laughs contemptuously at the mere sight of this superscription. Art having a mission! What utter nonsense. A person must be a rank Philistine to connect with the idea of art the conception of a non-artistic mission, be it social or otherwise. Has a work of art any other mission than to give pleasure by beauty? It strives to attain no goal that lies outside of itself. It is its own object, and whoever assigns to it another, sins against the sanctity of art.

This is, in short, the theory of art for art's sake: _l'art pour l'art_. I deem this theory false and a hallmark of crass ignorance, for psychology and the history of civilisation and art, the history of all arts, prove irrefutably the vanity and worthlessness of the concept that denies to art any other task and mission than that of being beautiful.

Certainly art is, in the main, a purely subjective activity, in which the artist wishes solely to satisfy himself, without thinking of any person or thing external to himself. The psychological roots of all artistic creation are, in fact, an exceptional sensitiveness and feeling on the part of the artist. We know that every moderately strong impression which man—and, moreover, not only man, but also every living creature, however low in the scale—receives from the external world, excites in him processes, which, in the case of man and the higher animals, attain consciousness as emotion or passion. The emotion imperiously urges in towards liberation through movements, that is to say, muscular activity, which, in many cases, is accompanied by glandular activity, _e.g._ tears, secretion of saliva, perspiration, etc. To men of the average type the usual forms of manifesting their emotion suffice. If they have wept in sorrow, laughed for joy, cursed or clenched their fist in anger, they are pacified. Their emotion has spent itself and become exhausted, and their physical life once more flows in its accustomed channels.

However, if, instead of the average man, we have before us a creature of exceptional sensitiveness and emotionality, the psychical processes assume another shape. This creature feels all phenomena more acutely; they arouse in him more violent passions; his emotions are deeper and more lasting. Their normal forms of expression do not suffice to lull them. They take possession of his soul, organise themselves, show a tendency to become compelling ideas, and oppress it with psycho-motorial incitements or impulses until it has freed itself from them by acts which stand in proper ratio to the number or violence of the emotions. A being whose excessive emotionality is of an angry, malicious nature attains relief only through deeds of destruction. Such is the case with most sub-species of born criminals. Should the exceptionally strong emotions not be of a destructive nature, they find their outlet otherwise by artistic creations, which, therefore, are a liberation and solution of emotion that has become overmastering.

But this simple, as it were, normal case, in which the work of art actually fulfils a purely subjective mission, and aims at no other object than to relieve the artist's nervous system and to unburden his mind of a compelling idea—this case is actually met with only in the earliest ages of mankind. Art for art's sake—the art which is practised purely for the relief and satisfaction of the artist—is that of the cave-man of the quaternary period. The artist who adorned the walls of the Caves of Mouthe[1] with figures of animals; who scratched the famous mammoth on the tusk of La Madeleine in the Dordogne; the draughtsman of Bruniquel, of Schaffhausen; the author of the rock-pictures in Sweden, probably did not trouble himself as to whether he was producing any effect on others. In all likelihood he did not work for society. His psychology is disclosed to us by the subjects he treated. He was an enthusiastic hunter, endowed with a particularly lively intuition and manual dexterity. On the days when he could not go hunting, either because bad weather prevented him doing so, or external compulsion—perhaps an accident met with in the chase—confined him to his cave, he thought longingly of his favourite occupation. The beasts that composed his usual booty lived in his imagination. His grotto was peopled with the monsters of the forest and plain of primitive times. He saw the mammoth with its stiff mane, the grisly cave-bear, the aurochs and giant-elk, the shaggy, thick-set horse of Solutré; he pursued, fought, slew them. He felt all the keen joys of these mighty deeds, and became so strongly excited that he could not refrain from realising the lively pictures of his fancy, by drawing them on bones, tusks, or rocks, or carving them on stags' horns and elephants' teeth. It would not gainsay this psychology of primitive human art, if the artists in remote ages (as the latest pre-historic investigations seem to attest) connected superstitious ideas with the imitation of their animals of the chase, perhaps believed by such means they cast a spell on the animals portrayed, and facilitated their capture. A superstition like this would, in its turn, become a source of fresh emotions which also seek outward expression.

Besides the hunter there was also the warrior, who liked to portray his conquered enemies, and the sensualist, who sought delight in carving female busts, the types of which, to our taste, seem very ugly, but may have appeared alluring to him.

These savage forefathers who adorned the caves of the early stone age with works of art not invariably crude; who woke the echo of the forest valleys with plaintive or yearning melodies; who excited themselves by sensuous dances in the moonlight nights of

spring; who formed, in symbolic and allegorical songs, their mystic impressions of the great phenomena of the weather and sky;—these savage forefathers were the first, but at the same time last, purely subjective artists, the only real believers in the dogma of "art for art's sake."

In order to find them once more in our own times, we must seek them in the nursery or the Board School class-room. The artist of primitive times survives by atavism in the child. But he substitutes for the rock-wall of the cave and the mammoth's tooth his slate, copy-book, school-books, often enough his desk and form, which he adorns with drawings that, if not particularly finished, are, nevertheless, always full of expression, and recognisable. The child does not give way to his artistic wantonness in order to please others. He hides it, moreover, mostly for obvious reasons, from the eyes of strangers; he only draws to portray symbolically that which has made a strong impression on him. He always notes down the important, distinguishing features which have struck him in the phenomenon. This fierce mustache, the circle drawn across which represents the head, is for the little draughtsman the characteristic of manly dignity; this right-angled broken stroke, which bristles up over a row of men, is the formidable bayonet that marks the soldier; this disproportionately big stick in another man's hand is the dreaded badge that embodies the schoolmaster's power. The young artist has obeyed genuine impulses. His art forms really spring out of the deep grounds of his emotion.

With advancing civilisation, however, this state of things quickly changes. The artist soon notices that he is differently conditioned to the rest, the average men; that his feelings are keener, their manifestation more expressive than with the latter. He becomes conscious of his superiority, fancies himself something in regard to it, and cultivates it. Other men find æsthetic pleasure in his creations, and encourage him by flattering applause which easily rises to admiration. That calls forth an energetic metamorphosis in the inmost processes of his work, in its causes and aims. What was once organic necessity now becomes craftsmanship; uncontrollable inspiration is replaced by custom and by style. The artist becomes his own imitator. In years of cool, methodical, routine work, he simply calls to mind the moment when the feverish workings of his brain powerfully drove him into the paths of art. He observes all rites of the creator by impulse, but they are now only an attitude which he has learnt. In theory he is still inspired by impulse; practically, he is a professional craftsman who performs the day's work imposed on him by intelligent volition. He is still always in search of self-satisfaction whilst engaged on works of art, but it is of another nature than that of the unsophisticated artist. The unconscious aim of his efforts is not to find relief from an emotional tension: he strives after the voluptuous feeling of flattered _amour propre_; he grows ambitious, very often, indeed, only vain. He thinks of his public. He anticipates his success. The thought of approbation takes the place of the effort to deliver himself from a painfully obsessing conception.

This also is always the psychology of the born artist, who is one because his organisation forces him to it. Beside him, however, swarms the innumerable crowd of imitation artists, of average, and very average men, who would never of themselves have thought of becoming artists—men who would never have discovered art of themselves, if they had not had before their eyes the example of the original artists, their successes, their recognition by civilised society. These individuals pursue art, not to deliver themselves from an obsessing conception, but as a means of attaining privileges, gold, and honours. For them art is an avocation like any other, a trade learnt, which is to bring them, not to subjective psychological, but to practical and social ends. They try by a sort of mimicry to become like the original artists, but they belong to another species. Nevertheless, it is not permissible to neglect them in this consideration, for, for one thing, they constitute the vast majority of artists, from the moment when the pursuit of art has become a differentiated activity, the habitual and exclusive occupation of a separate class of society; and then the productions of these imitators are always modelled after works done through organic necessity. They are, to a certain extent, the small change of originally great values; they would like to be changed for them, and everything which is to be said of any particular problem of art, necessarily finds its application to the imitations as well as to the original pictures.

These are then the origins and stages of development of art. At the outset, it is actually what the school of "art for art's sake" asserts of it: a subjective purpose, a satisfaction of an organic need on the part of the artist. Soon, however, the artist ceases to confine himself to satisfying himself in relieving himself; he also seeks to please others. In the most secret and mysterious moments of creation, the thought of other men is present in his mind; considerations as to effect and success are mixed with his productive emotions. Substitute mere craftsmanship for inspiration, then these considerations become more and more dominant, and when art has once become a regular ordinary business, and the imitators, the mere echoes and reflections, have once become the majority among those who practise it, then the artist has his eyes continually fixed on his tribunal, viz., society. In the moment his work of art is germinating, it is strongly influenced by consideration of the known or the supposed taste of the society whose applause the artist courts, and the work undergoes a development more or less remote from the form it would have acquired under the pure influence of emotion, its primary source.

Society naturally sees what place it occupies in the artist's mind, what share it has in his creations, and how important to him its verdict is. It promptly perceives its advantage. It takes possession of the artist, forces its tastes on him, and insists on his working, not for himself, but for it. Henceforward it has in him a paid servant; he has to conform his special energy to the general plan of the society organism of which he is a part, and, in this way, a manifestation which was originally a purely subjective performance becomes a social performance.

Art, engendered by individual emotion and transfigured into a social work, shares this lot which we have no right to call a degradation, with innumerable other main instincts, strivings, desires. It is the peculiarity of civilisation that it subdues to itself human emotions, and applies them as motive powers for the purpose of creating results which are not always, which are not even frequently, the natural purpose of these emotions. The whole existence of society, every organisation, every civilisation, rests on the application of this method; in fact, every attitude and action of man is affected by an emotion at its base. Without emotion, man is a sluggish mass, with which nothing can be done. In order to get anything from him, he must first have his mind excited, and after that we must be able to direct this excitement. All usages and regulations are merely a collection of channels dug in order to act as conduits to the emotions, and to utilise their force in regular employment. By the help of the emotions of love, society has been enabled to create marriage, which does not serve for the satisfaction of the instinct, but should guarantee economic security for the wife and children. With the emotion of sympathy—this preliminary condition of every social structure—with this fount of pity, altruism, and solidarity, mankind has created the political order, the State, with all its burdensome tyranny, which seems no longer to have anything at all in common with sympathy, which is, nevertheless, its emotional root. With the emotion of mysticism and superstition, society has produced practical morality and all its constraint; with self-love and vanity, patriotism and its caricature, Chauvinism; with the wicked impulses to destruction and murder, the professional qualities of the soldier, still indispensable for the security of the political organism. In short, the whole work of civilisation consists in making itself master of individual emotions, diverting them from their natural goals, applying them to the good of the whole body. The State society is a machine that is moved only by the emotions of individuals. Social life is simply the product of a very complex and skilfully conducted work of primitive emotions. If, therefore, any one exclaims slightingly at the mention of the social productions of art: "That's common, rank utilitarianism!" we are justified in shrugging our shoulders. Utilitarianism? Why, certainly. Utility is the primary law of every society, of every living organism. The lowest living creature of one cell could not support itself for a single instant, unless all its parts were continually working with the object of promoting its existence, of serving the demands of its life—in short, making themselves useful to the whole.

When men came to observe that they possessed among them beings who had stronger emotions than the rest, and made these emotions evident by creations which were calculated to make a deep impression on other men, they, according to the standing rule—I might say, according to the biological rule—of society, made haste to place these exceptional natures, these artists, in the service of the great interests of society.

Whoever can still entertain a doubt that art has always performed a task which was by no means æsthetic, even if fulfilled by æsthetic means, let him cast a glance at the history of the arts.

Let him read the poems of antiquity, gaze on the sculptures and paintings of the Egyptians or Assyrians or Greeks. Let him listen to the far-off, and doubtless sadly distorted echo of ancient music in the Hymn to Apollo, restored by over-daring scholarship. Where will he find a work—a single work—which corresponds with the psychological scheme of the origin of artistic creation and with the definitions of the party of "Art for art's sake"? Where is the work that has been achieved purely for self-satisfaction, for the relief of the artist's nerves? Where is the work that is only to serve beauty? I cannot see it; but what I do see is that all known works serve some purpose of society. They glorify the gods, the kings, the commonwealth. They extol the dignity of belief, of government, of the mother-country. Homer shows the heroes of the Hellenic race in the bloody apotheosis of their exploits. Æschylus, Sophocles, and Euripides unfold on the stage the myths and sagas of their ancestors. On the Acropolis, in the Parthenon, gleam the gods of the mother-country, the guardians of the commonwealth, shaped by the magic chisel of Phidias. The Stoa, the Poikile, the Stadium, are peopled with the monuments of athletes, warriors, archons, legislators, of all great men who are the people's pride, and are to serve them as models. Tyrtæus chants his sublime marches to excite the warriors to fight for their country. The singer of the Hymn to Apollo composes his cantatas to make the temple service more impressive. I am well aware that, besides these monuments, there are the little lyric poems of the Anthology, the charming little Tanagra figures, that is to say, very individual revelations, which sing the joys and sorrows of a single soul, which seize the graceful movements and gait of young women who had enraptured a single kneader of the clay. But these pretty little things, although _chef d'œuvres_ of their kind, are not, however, to be compared with the triumphant creations prompted by religious belief and patriotism, whose superhuman splendour fills the centuries.

If we go from pagan antiquity to the Christian Middle Ages and the free-thinking or the openly atheistic Renaissance, the _rôle_ of art remains unchanged. For whom does the artist work? Only for the Church and the palace. The pope, the bishop, the abbot demand of him the decoration of the cathedral and monastery. The priest under the vaulted arch, the monk in his refectory—these must have before their eyes images to remind them of the doctrines of which they are preachers and servants. The people, when they enter God's house, must be caught hold of by the representations of suffering and martyrdoms, of beneficent and comforting miracles, of the horrors of hell and the bliss of paradise, and be strengthened in their faith, seeing with their eyes and touching with their hands what religion teaches. The king's castle, the palace of the great vassals, plume themselves on the works of arts that are consecrated to the glory of their ancestors, of their rank, or, simply, of the dominant system. Here the stately tombs of kings or knights, here the statues showing the ancestor as hero or demi-god. Here the pictures of battles and sieges, of butcheries and victories. Here the painted memorials of great state ceremonies, triumphal entries, receptions of ambassadors, conclusions of advantageous treaties, famous meetings of mighty lords. The object of all this art is always to flatter the vanity of the great, to impose on the populace a high notion of their wealth and power, to make it feel, by all possible means of expression, the superiority of its leaders. We must go down to the Italian Renaissance in order to discover, by the side of religious, dynastic, aristocratic, and political art—for historical art was always designed to serve a political idea or arrangement—in order to discover, I say, by the side of this prescriptive art, the beginning of a purely æsthetic art. When Mantegna paints the "Muses on Olympus," or Leonardo the "Mona Lisa," they are no longer desirous of kindling faith or strengthening subjects in obedience, but they want to enrich and brighten existence. But whose existence? That of a wealthy and distinguished patron, of him who has placed the order with them. It is not before the Renaissance that we see the artist gradually emancipate himself from the rule that sternly dictates to him the choice of his theme, and even, up to a certain point, the method of his treatment. He then acquired to some degree the freedom to follow his own power of imagination, and could hope to get a return for his creations, even if he did not serve a dogma or a policy, even if he did not glorify a saint, a king, or a nobleman; if he simply tried to move a man's soul by revealing the secret movements of a human soul.

We see then that, through long centuries, art had the sole task to serve the great institutions of society: religion, monarchy, or one's native country under another form of government, the dominant castes. The mechanism by which art was held in bondage was the simplest and most naïve: the artist had no other customer for his works except the powers that be. These bound him by his necessity to eat daily, or nearly so. The Church, the king, the republic, the city, the ruler, gave the artist commissions, and paid him. If he found no patron in the castle or palace, he had no gold or honour to hope for from any other quarter. Now neither the Church, nor the Government, nor the privileged classes were in the habit of throwing their money out of the window. The money they expended had to bring them profit. They wanted the artist in their pay to become a champion for their cause, in exactly the same way as the cross-bowmen of their body-guard, their judge, their herald, steward, aye, their jailer and executioner. Art, in those days, preached the fear of God and his servants, submission to the king and the State, respect for nobles and officials. The ruling powers made the artist suggest to the people all that was favourable to them. Art was the school of the good subject, the artist the main prop of priestly and monarchical-aristocratic society. The common herd, the million, found none of their human emotions satisfied in art; the voices that rang out of these works only cried to them: "Pray, obey, tremble."

The Netherlanders, a free people, were the first to know an art other than the traditional one. In Flanders and Holland, writers, and especially painters, began to speak no longer exclusively of God and the saints, the king and the great, but of the humble, obscure, and nameless multitude. _Genre_ painting revived for the first time since ancient days. It told the everyday life of the middle and lower classes, their somewhat gross joys, their somewhat commonplace sorrows; it showed the ale-house and the mill, the sitting-room and the retail shop. This was not edifying, it is true. The philosophy of this art is low; it hardly widens the spiritual horizon, and is of poor comfort amid the narrowness and bitterness of real life. And yet this art was a forerunner. It denoted a turning-point, the beginning of great and important things. One great king, Lewis XIV., was not deceived about it. With the sharpened keen feeling of the mighty for everything that can encroach on their superhuman dignity, he perceived at once that this new art offended against his kingly majesty. How? There are painters who dare to treat of plebeian subjects! What should that mean? Does art perhaps even fancy that it can be other than a continual homage to the greatness and omnipotence of kings? And, with an annihilating wave of his hand, he banished from his august presence these daring little pictures, these democratic works of Teniers, Ostade, Dirk Hals, and Gerard Dow, whilst uttering the historic words: "_Enlevez-moi ces grotesques._"

But time stands not still; development is achieved. Modern democracy appears, and transposes all the conditions of existence of society and its members. Art cannot escape the general revolution. It experiences its influence spiritually and economically; changes its judgment hall and its mart. We do not realise the tremendous meaning of this change. The court that decided as to the worth of the artist and his work was formerly the small circle of possible patrons—princes of the Church, the great, the courtiers.

To-day this court is criticism, professional criticism. In earlier times it was enough for the artist to please a few people, perhaps only one individual, if the latter happened to be a magnate. He had not to trouble himself about the crowd; moreover, the crowd followed docilely the lead from above. When Dante said:

"Credete Cimabue nella pintura Tener lo campo, ed ora ha Giotto il grido, Si che la fama di colui oscura;"—

What did _grido_ mean? What was _fama_? It was the opinion of a court, that of Rome or Pisa, perhaps of Ravenna. We must go to Aretino to discover a specimen of an art critic who was neither a Mæcenas like Leo X. or Lorenzo the Magnificent, or even a painter like Vasari, but merely an audacious spirit who arrogated to himself the right of dealing out praise and blame, and conferring glory in the name of something absolutely novel, in the name of public opinion.

From that time it is professional criticism which suggests to the multitude, and imposes on the mighty, its judgment on the artist. But the criticism is disinterested, or at least can be so. It does not expect of the work of art a direct personal advantage, its own glorification, the vindication of its spiritual and material influence. Its measure, therefore, grows larger and broader. It brings to its office philosophical and æsthetic considerations, which the popes and kings could not know when they gave commissions to the artists, their _protégés_. In order to secure success, the artist must now please the critic—many critics—and the latter pass a verdict on him with perceptions, with taste and spiritual prepossessions that very seldom are those of the bishops and great men.

And as the artist has got another tribunal, he also comes before the public under other material and spiritual conditions, and seeks in other ways a market for his work.

In feudal times, as we have seen, the church and palace were the places for works of art. They were seen there under circumstances little favourable for a purely æsthetic appreciation. In the cathedral people were intimidated by the significance of the vast space, the acts of faith, and the perfume of incense; in the castle, by the magnificent garments of the officials, and the weapons of the guard. It was in 1673 that a "Salon," _i.e._, a regular art-exhibition, was opened in Paris; and besides the "Salon" public museums were opened everywhere, to which every one had access without invitation or introduction. The artist was now quite independent; he could work without waiting for orders. He no more needed, in order to become known, to crave humbly a visit to his possibly poverty-stricken studio. Here was a definite place where he could exhibit his work to thousands of spectators—connoisseurs, judges, possible buyers. From that time he worked with an eye to the great public which was sure not to be lacking at his regular rendezvous. If the professional critic became his judge, the mass of people became his Mæcenas. Universal suffrage has dethroned Church and royalty, and remains the artist's only patron.

I say expressly—the only. It still happens that the State, _i.e._, a high official, perhaps a monarch, orders works, assigns to the artist the task of adorning churches and palaces, perhaps even public places and walks, or even creating a monument of political import. But who receives these commissions? The artist pointed out by public opinion, _i.e._, the democratic crowd acting under the suggestion of the critics, who also belong to the crowd. The artist who has gained the advantage of an officially favoured position otherwise than by popular acclamation, who owes it to the whim of a ruler, the mere favouritism of a bishop or some other great personage, is nowadays not esteemed, but despised. He may receive some alms in the shape of money; he may collect ridiculous titles and wretched tags of coloured ribbons, but he will be branded with the name of court-artist, and this name excludes him irredeemably from fame.

The literary man in earlier times lived by the favour of a protector, whom alone he had to trouble about pleasing. Nowadays he lives, through newspapers and books, by the public at large. The dramatic poet had, for his productions, only the subsidised theatre, the theatre royal, which imposed on him its regulations. To-day this theatre is insignificant as compared with the free and independent stage, and the poet need know no other care and consideration than that of getting a good grip on his public. Then the artist had nothing to hope for, unless he served religion, the monarchy, or the aristocracy. Now subjects from these spheres have actually become laughing-stocks—_pompiers_, as they are termed with an expression of contempt; and the artist, if he would become rich and famous, must fish for his subjects in other streams of thought. This is so true that there are rulers who, from feeling that art is making itself independent of them, and will no longer serve as the herald of their thoughts, try even to produce works of art, and would impress their works on the admiration of the multitude, which, nevertheless, does not admire.

The great revolution is consequently accomplished; art now works only for the masses. It is still always the State that commissions; it is still always the few rich who buy; but it is really universal suffrage that imposes on them its own inclinations. But we do not believe that that new Mæcenas, the people at large, has other habits of mind or ways of acting than had the Mæcenas of the past. The people too, exactly like the priests and kings of old, demands that art should please and flatter it. But it further demands

something else, something more than pleasure and obsequiousness—viz., a high satisfaction, a corrective of an evil of which it is perhaps not clearly conscious, but which, nevertheless, it feels strongly. And I will now try to point out this evil.

One of the most striking phenomena of modern life is specialisation applied to all departments. Every one tills merely a very little bit of field or rather he ploughs only one and the same furrow. This is true of mental craftsmen. It is still more true of handicraftsmen. What existence does such a man lead nowadays? There is no longer one who fabricates an entire chair. One always makes the arms, another the legs, a third the back, a fourth the cane-work. A knife goes through a dozen hands, a needle, I believe, through thirty. In order to attain that extreme skill which competition demands of him and which he must supply, if he would earn his bread, the workman continually repeats the movement, becomes a machine, less than a machine, a tiny part of a machine, a single wheel, a single screw. His being shrivels up, his soul suffers. All development is denied him; all his faculties, except the one he is always employing, become crippled, and disappear. The man gradually sinks almost to the low level of a polypus, which is only an organ of a hydramedusa.

Whence comes the strange fascination that the foremost men of the Italian Renaissance exercise on us? The reason is that they were complete men. All their faculties were fully developed—all that offered a possibility in them was developed to the utmost. Nothing human was alien to them. With marvellous freedom they circumscribed the whole circle of human knowledge and faculties. Then the learned man was an universal scholar; his knowledge was encyclopædic. The poets were at the same time men of action. Men of rank were artists and writers, and the artists were all they wished to be. Michael Angelo painted, modelled, built the cupola of St Peter's, and wrote charming verses. Benvenuto Cellini handled the spatula as well as the mallet, the crayon as well as the pen, and the sword as well as all these tools. Macchiavelli governed as wonderfully as he wrote, and Leonardo painted the "Last Supper" between a musical composition, a treatise on mechanics, a plan of a fortification, the model of a triumphal car, and the plan of a canal for the purpose of irrigation. Count Castiglione's "Cortegiano" shows us the ideal of the man at the time of the Renaissance. He was probably the fairest flower ever produced by the human plant. The modern man may envy him; he can never be his peer, but must shrivel up in his narrow corner. Hypertrophy of a single, often subordinate faculty, atrophy of all the rest—such is the lot to which he is ruthlessly condemned. And there is no change possible in respect of it; no herb grown can prove an antidote to that bane. Division of labour gives to the whole advantages too great to be dispensed with out of consideration for the individual. Division of labour is the true condition of all progress, though in this case, as in so many others, progress exacts a heavy, very heavy, price for its services.

Every one is painfully aware of this reverse side of progress; many consciously take themselves to task for it. Why has the madhouse philosophy which extols the superman been able to subjugate spirited youth? Because it meets the longing for a fuller life of the personality. And anarchism? What is the secret that makes it attractive to true consciences and loving hearts? Nothing except that anarchy seems to promise unchecked development of the individuality. In all these nonsensical, wild, and criminal movements there is some little revolt against the pinching and tightening in of the personality entailed by the modern conditions of labour, and this is the ingredient that recruits adherents among those unaccustomed to rigorous examination of their thoughts. And when the workmen demand an eight-hours' day, what do they want? To find time to go and drink at the public house, to be able to idle, as the ill-wishers who calumniate them assert? No; they want to have a few hours in which to cease to be mechanical tools, in which they may again be men, and participate in the great life of the community.

But by what means can we give back to men what division of labour and specialisation—these irrefragable consequences of contemporary progress—have taken from them? By what means can we remake beings developed from them harmonic? Perhaps in a very distant future science will effect this necessary, demanded, and longed for miracle. Perhaps mankind will once more see these workers who earn their bread during a part of the day by handicraft, and during the rest of the time linger on the highest summits of human thought and knowledge; a Socrates, who is a stonemason; a Spinoza, who polishes spectacle glasses. But, as I have said before, that will be feasible only in a very remote future, for science is not easily accessible; the way leading to it is long and rough, and the full life through science is possible only to men of a higher spiritual development than the average people nowadays.

But if science is no longer the usual companion of the man of the masses, and, unfortunately, will not be so for a long time, art, on the other hand, admits him to familiar intercourse. No tedious initiation is requisite for it, nor any hard labours which the majority cannot perform. It is sufficient to have eyes and ears, and a human heart in one's breast. After an apprenticeship, which may be very short; after some habituation which one easily acquires by intercourse with beautiful works, almost every one arrives so far that, even if he cannot appreciate the technical and philosophical merits of a work of art with consciousness, yet he can feel its charm and be susceptible of emotions from it.

Art it is, then, which can give to modern humanity what it most needs—the means of attaining the full life. Here lies, unless I am deceived, the greatness, the lofty mission of art in a democratic society which rests on a civilisation, the marks of which, the real condition of which, are severe specialisation and division of labour carried to an extreme.

Art raises man out of industrialism and introduces him to a higher world. In this artist-created world the man who is bundled together stretches himself straight; the shrivelled broadens out; the fraction of a man becomes complete. Here he who belongs to his machine or observation-instrument becomes once more a free man and citizen of the world—a man participating in the life of the community, and enjoying with the rest all the beauties of heaven and earth, all the greatness of heart and soul of the pick of men. Through art a person imprisoned in his daily avocation comes into communion with all civilisation. Here is the paradise to which the astronomer descends from his constellations, to which the miner ascends from his pit, in order to participate in the same joys and raptures, to bring to flower whatever potentialities they possess. The mission of art in society present and future is, in short, to liberate the prisoner of subdivided labour, to restore the dignity of manhood to the being degraded into a little wheel of a machine.

But art, which is to fulfil this new and lofty mission, cannot, manifestly, be conventional art. On this theocracy, monarchy, and aristocracy have stamped the character that suited them. The multitude at the present day find no sort of joy in works which depict to them the bliss of paradise and the torments of hell, which extol some paste-board king with crown and sceptre, which offer for their admiration the greatness of blue-blooded privileged beings. Like the patrons of earlier times, the people, who now represent Mæcenas of old, are interested in art only for themselves. The sources of their emotions in art are the emotions of their own lives. In the work of art that is to attract them, they must find themselves again, but, as formerly the priest and king did, magnified and ennobled. The work of art must show him his own likeness, but a beautiful one; it must raise the people in their own eyes, and teach them to respect themselves.

This the common realism has not comprehended, which broke in on art with a din, and dared to call upon the democracy. The genuine people has never had a mind to realism of this sort, but has always dismissed it roughly. The rough proof of a hateful and tedious reality, such as the pictures of Courbet or Bastien Lepage, has never attracted any but the superfine, and this only, by the well-known psychological law of contrast, whereby an impression that is the exact opposite of the usual impression can impart a pleasurable feeling for a short time. The rich and luxurious like to see works of ugliness and misery; the poor and afflicted do not like them. It is the same in regard to literature. Reluctant protests have frequently become loud, in these socialistic days, against the realism which a party organ offers its readers. The working class do not wish to know anything about this realism which professes to be modern and democratic, yet is, in reality, only wretched and repulsive. It coops them up in the narrowness of their everyday existence, but their wish is to get out of it.

Pictures such as Millet's, sculptures such as Constantin Meunier's—works which seek to show the dignity and beauty of the occupations of the masses, which constitute a hallowing of work, an apotheosis of the tragedies and idylls, of all the sweet and bitter emotions of the people's life—these works, to my thinking, exhibit the type of future art.

Some great genius will, perhaps, find another formula. What one may, however, say for certain is this, that the art of the future will not be realistic in the narrow sense of the word. But it will not be mystical and æsthetic either. The people will never interest themselves in half-tone angels of boundless length, in violet-hued Virgins with lilies in their hands in a conventional bush, in enigmatical, mysterious verses. And esoteric art will never give the people what they need, viz., the liberating ideal. The art of the cultivator of the Ego, the _dilletante_, of the snobs of a Talmi-aristocracy, presumes to demand the future for itself. Is that to be an art of the future, an art of progress? One can only laugh at the notion. The art of the future will be no "little chapel," but a mighty cathedral, wide enough to admit the whole of mankind. And that will be exactly its vocation: to be the hallowed place wherein mankind will rise again to the childship of God for which religion has educated them in past stages of evolution.

II

SOCIALISTIC ART

CONSTANTIN MEUNIER

Is there a socialistic art? Can such a thing exist? So far as Socialism is an economic and political philosophy it is hardly comprehensible with the means of expression of art. If the plastic arts are to be instructive, they do not amount to more than chill

symbols and halting allegories. On the other hand, they are not prevented from digging down to the psychical roots of Socialism, and presenting the fundamental feelings and ultimate intuitions from which it springs. One of these fundamental feelings is pity for the disinherited. One of the ultimate intuitions is that of the dignity of all work done with moral earnestness and entire devotion.

The artist can show us the destitute, to whose presence amidst our civilisation applies more sharply, what the Psalmist[2] asserts of the life of man in general: "And if it has been splendid, it has been toil and labour"—toil and labour without a ray of happiness; severe physical exertion rendered more wretched by sorrow and distress. Such a picture grips our hearts, and urges on us painful questions: is this misery inevitable? Is it cruelly ordained by nature herself or a consequence of faulty institutions, capable of improvement on the part of man? Cannot we introduce into the lot of this ill-used brother something of joy?

And the artist can also show us the worker, not in want and suffering, like the beast of burden, humiliated into the slave of matter, but rather as creating eagerly, proud of displaying his strength, joyful in the conviction of success, regarding his skill as his honour. This aspect fills us with respect, perhaps with admiration. It opens to us the comprehension of the import of the workman, and the lofty reality of his achievement.

In both cases the artist fashions fully from life; he need not exaggerate, he need add nothing; he can confine himself to the plain facts of life. He need not betray any prejudice or any extra-artistic aim. He will, nevertheless, so contrive that one will be able to speak without falsification of his art as of a socialistic one. For his work will put the spectator in the mood in which he will be inclined to hail as progress every transformation which can improve the earthly lot of the worker, and increase his value in the community.

The school of æsthetes, which maintains the principle of art for art's sake, will, I grant, admit works of this sort as a form of Socialism, indeed, but not as a form of art. I do not belong to this school. I oppose it at all times and everywhere as strongly as I am able. I am convinced that art has a social mission which reaches far beyond mere gratification, that it must necessarily be moral, and, in the highest sense of the word, useful; not useful in the simple way of painted or chiselled aids to intelligence, not moral in the vulgar way of tracts; but moral through stimulating what is most human and noble in our spirit and soul, and useful through educating us to deeper and wider conceptions of phenomena. In one point, however, I agree with the heralds of _l'art pour l'art_—I demand beauty in a work of art; not beauty alone, but beauty in the first place.

In order, then, that we can speak of a Socialistic art, the works that would deserve this designation must not only excite sympathy with the disinherited, and respect for the workman, but they must also arouse æsthetic feeling, they must be beautiful. This claim, of course, excludes no kind of beauty. The tragic is absolutely beautiful. Purification is one of the most powerful æsthetic influences. Truth can be beautiful if essential and expressive. The socialist who would prove himself an artist must possess the lucky gift to see and exhibit beauty in the figures and actions of the class of society for which his heart beats.

All these conditions no contemporary artist known to me fulfils in the same degree as Constantin Meunier, the Belgian sculptor, painter, and draughtsman. Meunier died an old man in 1905. He was born in the 'thirties' of the last century. The world was slow to recognise him, not because he did not deserve recognition, but because he did not seek it. He was big and unassuming. He lived quietly in a little Belgian town as a teacher in an art school, and modestly avoided the roar of fame's mart. He had even refused to allow the reproduction of one of his noble bronzes, for business purposes, by a first-rate Paris house which was prepared to pay a munificent price for the right of sale. He was loth that his piece should become a factory-cast and a shop-window article. He belongs to the narrowest circle of the blessed, of the chosen. He is one of the Prometheus-like artists; he informs and inspires life. He feels like a Samaritan, he thinks like an apostle of the submerged, who utters a great cry of wrath over the harshness and unrighteousness of the social scheme, and he compels the bronze, like a Benvenuto Cellini, translated from what was aristocratic and classic into that which is modern and democratic.

In Meunier's work there is a unity from which he seldom digresses. He lived in a Belgian district of coal-pits and smelting furnaces, in the very midst of rough labourers who passed their lives in the galleries of mines, or in the fiery glow of furnace mouths. He found his models among these figures. There the Labour movement in Belgium arose—one of the most rapid in Europe; there Meunier's art grew up—one of the most intensive at the present time. The miner and the iron-smelter are his heroes; he admires their strength, and from the bottom of his heart he bewails their pains. And if he is unfaithful to his Cyclopses, it is only, touched and enraptured, to look after his other darlings—the country folk working in the fields, a subject which instils in him as much reverence as the burrowing of the coal-miners underground, and the powerful hammer-strokes of the iron-smiths.

One of his greatest creations, perhaps his greatest is a bronze a span high, representing an old woman, the wife or, as I would rather assume from the stormy intensity of her emotion, the mother of a miner, who, after a driving storm, has gone to the mouth of

the shaft of a coal-pit, to which the corpse of some one belonging to her has been brought.

The woman stands there, leaning slightly forward, her countenance petrified with dumb despair, her arms limp, her one hand lying in the other, yet without any convulsion, and powerless, her knees through a very slight bend betraying her trembling, her feet instinctively somewhat turned inwards, so as to give a broader support to the body, and to protect the almost crippled figure from falling down. The whole is such a frightfully expressive picture of a poor human creature who has, as it were, received a blow on the head, and in her crushed condition is not strong enough even for sobbing and wringing her hands, that it strikes the spectator with a cold shudder. Observe, the old woman wears the garments of the poor Walloons, heavy, stiff gowns and neckerchiefs, the hard angles and folds of which can express only very roughly and indistinctly the soft play of the weakly-quivering muscles. What penetrating keenness of observation does it need to recognise in an entirely self-contained form shrouded in uncouth, shapeless clothes, without gestures or play of features, and to imitate, without the slightest exaggeration, yet overpoweringly, the tenderest lines which, even in such unfavourable conditions of material, express clearly and dramatically all that is passing in this almost impenetrably veiled human soul. This little figure, no larger than the decoration of a clock, is a great monument, and, like every real work of art, it points far beyond the limits of itself. It reveals much more to the power of imagination than it manifests to the eye. This is actually proved in this very case; for Meunier has a group which supplements the work described: the same old woman, and before her, lying outstretched on the ground, the corpse of him whom she is bewailing. We might think that this more complete work would be more deeply affecting than the fragmentary one. The contrary, however, is the case. The corpse, although modelled so exquisitely, leaves us cold; it does not realise the conception we have formed of it. We had expected to feel a horror at the sight of it, at which the blood would congeal in our veins. We are astonished and disappointed at seeing lying there only an unknown man who does not concern us. When we look at the old woman petrified by grief we think of the corpse which is not exhibited to us; we see it with our spiritual eyes in the horror of the old woman, we share the feelings of the old woman, the unseen corpse is that of a relation of our own, the dead man himself is dear to us, we ourselves have suffered the loss of him. On the other hand, the completed group makes any co-operative exertion of our imaginative powers superfluous.

The corpse lies there visible; it distracts our attention from the old woman; we feel less keenly her emotion; the incident no longer occurs in the Holy of Holies of our soul, but in a forecourt, in a place of inspection. We could, in imagination, endow the corpse with the features of a dear relative, and feel sorrow for the dead man: inspection teaches us that the corpse is a stranger to us, and we have no grounds for shedding tears over it. The two works, placed in juxta-position, fully bear out the old dictum, that a work of art is more powerfully effective in proportion as it more strongly excites our imaginative faculties to creative co-operation.

A series of works brings before us the life of the coal-miners. Some of them come to daylight after their shift is ended. They are tired, but cheerful. About their wearied countenances there seems to quiver a reflection of the hearth-fire which awaits them familiarly in their poor homes. Here is a miner at his work. In a painful, half-recumbent position he handles the mattock in the narrow gallery under the seam from which he is dislodging the coal. Here another is sitting inactive, with his spade and lamp, with only a pair of trousers on, the upper part of his body naked, without a particle of fat on his muscles steeled by toil. Here a worker at a smelting furnace, likewise sitting—a reminiscence of the famous "Les Foins" of Bastien Lepage, which is at present in the Luxembourg. Like this peasant lass, Meunier's labourer is completely bestialised; he stares vacantly before him, with a jaw open like that of an animal; his hand, unused to inactivity, hangs down heavily. It is a shocking picture of the degradation of man through a one-sided exertion of the muscles; a forcible harangue in favour of the eight hours' day, which would leave more time for the human working machine, not only, as his opponents assert, to visit the public-house, but also for spiritual life.

Meunier rises to the height of the Vedic hymns when he turns towards the countryman and his heroic deeds in nourishing mankind. In the relief, "The Harvest," a band of reapers—four men and two women—are grappling with the ripe corn. One seizes violently the stalks, the second, bending forward, makes a wide stroke with his sickle, a woman binds into sheaves the ears that have been mown. In the background, one longing for rest looks at the position of the sun, and another, _rapido fessus aestu_ (fatigued by the scorching summer heat), to use Vergil's words, wipes the sweat from his brow. There is the note of the Eclogues about this work. Over it floats the consecration of the lofty act with which the rooted son of the soil, the ploughman—the creator and bearer of all civilisation—gains the bread of mankind out of the earth. A single figure, "June," is also created from this emotion. It is the realisation in free sculpture of a _motif_ from the relief. A reaper, stripped to the waist, emaciated by the heavy toil of harvesting, exhausted by his day's work, leans upon his scythe and glances, shading his eyes with his hand, at the sun—"I would it were bedtime and all was over." One would like to press the hand of this brave, good fellow, or at any rate that of the artist who has represented him to us so faithfully and straightforwardly.

All Meunier's works have not this delicacy; many are weak, some absolute failures. As an instance of such I point to "The Puddlers," though it has been particularly admired by some critics. Three iron-founders stand at the open stoke-hole of the puddle-furnace, and feed it with mighty pieces for melting. From the opening issue steam and smoke, which curl round the three men wielding rakes and tongs, and eddy upwards. Meunier has tried to represent this steam in sculpture. He has given it a concrete form, necessarily the same corporeality as the bodies, tools, blocks of metal, the flaming furnace; for sculpture possesses no means of differentiating the thickness of matter, when it abandons the mere engraved line or the make-shift of various perforations. The result is, that instead of smoke there is an amazing image which partly reminds us of an untrimmed dab of plaster, partly of a weather-beaten stalactite. Meunier was originally a painter, and took to sculpture only late in life. His "Puddlers" are formed with the technique of a painter, from which the artist did not immediately emancipate himself. Another relief, "The Bricklayers," is absolutely a mistake. Two men are standing in the loam-pit and handing up the bricks to their mates above. They do this with theatrical gestures, as if a conquered king were handing over his crown to his conqueror. The contrast between the bombastic movement and its vulgar purpose is so grotesque that the picture has an irresistibly comic effect. Here Meunier is, for the only occasion in all the works of his with which I am acquainted, insincere and affected. I have looked for a long time at this deplorable work, and it made me thoughtful. How heavy is the responsibility of the critic! Supposing I knew nothing of Meunier and only saw this work, I should find it hard to resist the impulse to abuse him in the sharpest terms, for it unites the two worst faults that can be found in a work of art: it is at the same time inanely futile and obtrusively pretentious. So far I should be acting within the scope of my perfect rights. But am I certain that I was not allowing myself to be carried away by my own natural propensity to generalise, and to condemn not only the work, but also its author, to call him a bungler and a botcher? Such a verdict would, apparently, be well-grounded and, in fact, revoltingly false. Works such as "The Bricklayers" are a warning to the critic; they admonish him to be conscientious. Their teaching is that every comprehensive verdict on an artist must presuppose a knowledge of his whole life's work, and that no single work can offer sufficient basis for the general appreciation of its author, especially of his depreciation.

In his figures of the miners and iron-founders, Meunier showed sympathy with the lot of the proletariate; in his portrayals of the countryman's life, reverence for the civilising work of the man who ploughs the soil. But he reveals in certain other works of similar subjects beauty which prevents us from wishing for one moment for those Invalides of Olympus, the unchangeable troop of academic sculpture. The "Blacksmith" wielding his hammer, the "Harbour-Workers," the more than life-sized "Smith," are discoveries which are tantamount to revelations. Especially this smith in his working garb, with his stiff leather apron, leggings, and the foot coverings that are intended to protect him from the sparks. Leaning on the tongs that are almost the height of a man, he rests his hand on his hips and waits until it is his turn to attack the work. There is a proud tranquillity, and a reserve of ready strength in him that carry us away. This artisan is every whit as handsome in his way as an antique statue in a toga of ample fold, or a noble nudity, or a knight in romantic armour. His body possesses the elegance which perfect fitness confers, his movement the energetic restraint that the workman, thrifty in exerting himself, acquires through being in the habit of avoiding every prodigal expenditure of his strength. Meunier trains our eyes to appreciate the æsthetic charm of this phenomenon of our own days, which great art has hitherto stupidly passed by.

Of what expressive poetry Meunier is capable we recognise with admiration in a statue of an animal, the mine-horse—one of those unfortunate nags which are brought to the mine as foals, in order to draw the coal waggons to the galleries, and who are condemned to spend the whole of their lives in the bowels of the earth, far from the sun. The animal's head droops, its lips are flabby, eyes half-closed, ears sunken, flanks fallen in; the whole wretchedness of an innocent creature condemned to night and woe is embodied in this shivering beast. The mine-nag has certainly no sense of its disconsolate fate; it does not miss the sun, or long for green pastures. It does not envy its luckier brothers who can skip in the fresh grass beneath the blue sky. Meunier has all these feelings for it; he infuses them into the animal's stupid soul; but doubly amazing is the power with which he himself can express through a coarse animal body humanly lofty tragedy.

What had already become clear to me when I saw Meunier's works separately in the _salon_ at the Champs de Mars, deepened itself within me, at the sight of the whole collection of them, into a certain conviction that Meunier is, perhaps unconsciously, a pupil of Millet's. He learnt from him to look with reverence on the homely men who with holy zeal, without gazing to the left or right, with body and soul in their work, wrest the works of civilisation from the forces of nature. He improves Millet's peasants and artisans into the plastic and monumental. It is the same simplicity, almost crudeness; the same contempt of pose, the same extreme energy of activity, and the same deep, inward life as in the master who painted the "Angelus." And what makes the most vivid impression on us in Meunier, as in Millet, is the ardent piety with which the sight of true and earnestly working people fills him—people who rise high in their apparently humble, yet fruitful and, through its connection with the corporate life of mankind, especially significant

labour. An artist, however, who discloses to us such outlooks on the path of civilisation, and such insight into the human soul, has some claim to a place near the acknowledged masters.

III

THE QUESTION OF STYLE

A history of style—I mean of style in general, not of one particular style—has, so far as I am aware, never been written. That I can understand. It would be a gigantic task, even exceeding the power of an encyclopædist. It would have to show from what spiritual peculiarities of the artist; from what necessities and intuitions of the time; from what requirements of the material, and from what compulsion on the part of the technique, the style develops, and it would have to measure the whole range of individual and national psychology, of customs, of material and of technology. The individual, however, whose powers do not suffice for an exhaustive and systematic exposition of the genesis and mutation of styles, can constantly register partial observations, and throw light on sections of this wide province.

Every human activity is excited by a need. We fabricate weapons, implements, shelter, and clothing, because we need them. In the earliest stages of human artistic skill, purpose and material alone control the productions of the human hand; style, so far as we can speak of such a thing, is purely constructive. It makes us recognise the influence of a small number of bio-mechanical and psychological laws—laws that have hardly varied during all the thousands of years in the history of human morals. These laws are those of the least effort and of selfishness. By virtue of the law of least effort we choose the most promising material, _i.e._, at which we have most conveniently to hand, which can be worked in the easiest way, or is most durable, and for that reason, more especially saves us the too frequent repetition of the effort. We choose the form to which the material employed adapts itself most readily. The problem which the constructive element in style has to solve is this: given a determined task which should be performed by an artistic expedient, how will this object be most readily, and yet most perfectly, attained with the material available?

The law of selfishness alters the natural course of the law of least effort, and often operates quite in opposition to it. The possessor of an object wishes to be remarked; he will distinguish himself from others, be admired and envied by them, whereby he will gain influence over their minds. He will therefore demand that for the object not the most easily procured material, but the rarest, and that which can be furnished only with the utmost difficulty, be employed, that the form require not the least, but greatest possible amount of labour. He will likewise wish the workmen to sacrifice the elegance of economy, not to represent what is alone real and necessary with the smallest expenditure of material, but, on the contrary, to lavish material, and make it quite visible and quite striking; to add to the Useful and Essential, also the Superfluous, so as to suggest the notion of wealth. The idea of elegance will alter its meaning. It will no longer signify the greatest suitability and perfect appropriateness, but, in the first place, costliness of material, difficulty of work, wastefulness—in a word, luxury.

The law of selfishness bursts the narrow frame of construction, and adds to style its second element, decoration. This, too, is still under the law of least expenditure of force; this, too, is still primarily subordinate to construction, _i.e._, utility, but it strives to render itself independent of the constructive element, and to become its own object. The history of each particular style shows this conflict between the constructive and decorative elements. At first construction rules alone; next, decoration, called forth by the _amour propre_ of the fabricator or possessor, joins it, but very timidly and very modestly. It obsequiously gets out of the way of construction, and contents itself with corners where the constructive element has nothing to do. But gradually it gets bolder, steps from its holes and corners, confronts construction, compels it to give way and take less comfortable by-paths, and finally subjects the constructive element entirely to its will and caprice, so that, in the decadent period of a style, a useful object becomes wholly unserviceable for its original purpose, and is only an excuse for decoration, which self-gloriously gives itself airs.

There is another contrast between construction and decoration. The constructive is the social element in the product of human labour; the decorative the individual one. I do not think that this dictum needs an elaborate explanation; it seems clear enough to me. In construction expression is given to a need which is, at a given time and in a given place, shared by many or all; it answers not only a condition, but a demand of the community. Decoration is—at any rate originally—the outcome of individual taste and individual imaginative power. Construction is a thing necessitated, and therefore _banal_; decoration is superfluous, and therefore charming. The former appeals to the understanding; the latter is fantastic and sentimental. The human consciousness is, however, so arranged that—for its gain? for its loss? (I have treated this question so often and so thoroughly in other places that I may here leave it undiscussed)—it derives its feelings of pleasure and aversion incomparably more from its sensuous than from its intellectual life. Wherefore, for practical purpose in style, only those who are most highly developed intellectually have appreciation;

on the other hand, for what is pleasing, all whose nervous system is susceptible to pleasurable feelings.

An individual decorative invention becomes style by the imitation of others, which can be slavish or free. A single work, a single artist, will never be felt as a phenomenon of style. There is the same difference between originality and style as between the picture of a certain person and the composite or average photograph of Galton. The feature of family likeness that runs through the works of one period and one place, however, like that which all members of a blood-relationship exhibit, is explained most simply through descent from a common ancestor.

Decoration is either organic or transferred. The former is the outgrowth of construction, and gives it a new meaning, unites to the idea of its purpose a simile that can be correct or false, pleasant or silly; the latter is added externally, and only aims at the beautification of the surface, without adopting living and necessary relations to the structure and destination of the object. Surface decoration may be pretty and rich, but it is always something subordinate, and always speaks of poor imagination and slight inventive power. Organic decoration is alone the outcome of a creative gift for art.

The psychical mechanism, which produces organic decoration, is always the same; it is the co-operation of association of ideas and anthropomorphism. I know very well that this latter is only a particular instance of the former; but I cite the really identical, nevertheless, as two apparently different ideas, so as not to become vague through too wide generalisation.

For the sake of clearness I will quote a concrete example. In collections, one not infrequently meets with a mediæval plane having the figure of a crouching lion with jaws open and a wild expression. It is easy to reproduce the psychic process through which this form arose. The joiner who uses the plane, and follows his own work reflectively, sees how the mouth of the plane, when applied, strikes the iron into the surface of the wood, and tears the splinters from it. What is more obvious than to think at the same time of jaws pouncing on the wood to flay and mangle it? The technical German expressions, _Hobelmaul_ and _Hobelwangen_ (plane-mouth and plane-cheeks) for the aperture in which the _Hobeleisen_ (plane-iron) is fixed, show that the association of ideas at once presented itself when the tool assumed the form familiar to us. The mediæval artist went further; he has logically developed the image of a rending and devouring mouth suggested by association of ideas. He has given it form; he has examined it with sufficient artistic intensity to embody materially the picture presented by the word, to raise it from the rhetorical to the plastic. But whilst the artist advanced from the mouth of the plane to a lion's jaws, and from the latter to an entire lion crouching over the board as over a victim that he has attacked and torn down, and mangling it with raging delight, he has at the same time made use of anthropomorphism, has imputed to the plane will, passion, gruesome enjoyment, and turned the planing into the tool's riotous satisfaction of bloodthirsty wild-beast instincts.

This plane in the shape of a crouching lion is the model of a good organic decoration. The construction is not injured; it does no damage to the under-surface of the plane, that it is the smooth-lying belly of the lion with drawn claws; it does not prejudice the working capacity of the iron, that it is let into a mouth of a slightly waving lip shape; it does not make it difficult to work, that the handle is shaped like a round lion's head. A sense is communicated to the tool which it did not originally possess; it does not shave and smoothe, but lives, tears, devours, and finds its joy therein. Organic decoration is thus an infusing of soul into that which possessed no soul; and not only this, but also in a higher and nobler way, a submerging of oneself in the soul that the artist has inspired into that which was soulless. He must live in the being which his anthropomorphising association of ideas has excogitated. "What should I feel, how should I act, what movements should I make, what expression should I have, if I were this object, but thinking, willing, feeling—in short, living and conscious? How should I, for instance, as a plane which was really a beast of prey, dispose myself, if I had the board—my victim—under me, and began devouring it?" The organically decorative artist is, therefore, really the dramatiser of the inanimate, for he creates beings, bestows on them character, and makes them act according to the latter and the situation, and, if not speak, nevertheless imitate.

If an artist has, from some especially vivid intuition and active association of ideas, found and embodied an anthropomorphic likeness which is very strikingly clear, imitation seizes it and repeats it with slight individual changes, which are, now and then, spirited and happy, but, for the most part, make the original picture dull, nay, through stupidity or misunderstanding may degrade it to nonsense. Such is exactly the case with the material picture as with the word-picture. At first it is the new and peculiar discovery of a poetic mind, then it is repeated well or ill so often that it ends with being a characterless commonplace. Every cultivated language is made up of such commonplaces, and, in like manner, style is made up of repetitions and tones, which are the plastic equivalent of rhetorical phrases.

The psychic sources of style—in contradistinction to those or freely devised organic decoration, which style only repeats and vulgarises—originate in very mean domains of mind. They are thoughtlessness, or, to put it more clearly and briefly, stupidity and mental inertia in their special forms as imitativeness and detestation of novelty.

It is thoughtlessness when we imitate forms that are suited to a particular material in a quite different material, simply because we are used to the sight of them. The far-famed Greek temple architecture is largely a result of this thoughtlessness: it slavishly imitates in stone the wooden architecture, the place of which it has taken; it retains the beams with projecting beam-heads and cross-braces that have neither object nor meaning in stone. To the same category belong the tablets, with manifold curled up and twisted edges, which the Renaissance and the Rococo executed in stone and wood, although they have no sense or justification except in sheet metal: the contemporary Moscow silver-work, which imitate painfully enough damask linen with Russo-Byzantine coloured embroidery, or cakes and black-bread in precious metals or enamel: the marble veils, lace garments, and knitted stockings of the North-Italian sculptors of the decadence, etc.

It is mental inertia when we mechanically persist in repeating forms which either are unfitted for a given object, or have lost all meaning. For two thousand years artists of all sorts have made a decorative use of acanthus leaves in countries where no human eye has ever had an acanthus leaf before it. The Middle Ages decorated with a whole menagerie of beasts from Asia and Africa, which they knew only from fables, foreign textures, and pictures. From imitation to imitation the outlines, which no comparison with the actual model corrected and restored to accuracy, became more inexact and grotesque. Thus arose acanthus capitals which are more like rough logs than the elegantly curled plant, and heraldic lions and leopards, in which no feature any longer reminds us of the great cats. This is then called improving upon the natural form, and people even discover a particular beauty in it: a striking proof of the ability of mankind to make a virtue out of necessity. For the so-called stylisation is conscious and intentional only in late conservative imitation. It arises, however, quite involuntarily through unintelligent imitation of a pattern that is incorrectly felt and grasped, because one has never known its living model. So, too, the whole mythology of the Greeks still haunts our present-day decoration, which mythology was to the Greek artists a part of their living feeling and religious conviction, whilst to-day it has lost all thought and feeling. What can Neptune's trident, Orpheus' lyre, the Sirens and the Centaur, the Sphynx and the Gorgon, signify to a son of this century? But whilst these bits of inherited form wander from one imitator to another, until they become hopelessly unrecognisable, they gain a beauty of another sort which they did not originally possess: the venerable spell of antiquity surrounds them, and this charm, in its turn, touches certain susceptibilities of the soul, the inclination to mystic, twilight conceptions of what is remote in time and place, the pleasurable feeling of comfortable persistance in that to which we are accustomed, the connection of the familiar and always known with the remembrance of all strong impressions, both happy and unhappy, of childhood and youth. This mystico-archaic and subjectively sentimental element, which occurs in every style handed down traditionally, furnishes it with fanatical devotees whom its original decorative value could never win. That is, if I may say so, the religious side of the feeling for, and appreciation of, style.

From the oppressive mass of material, which I must, for the most part, leave untouched, I am afraid I must deal with only one more question:—Is there a new style? Is the so-called "Secessionism" a style which characterises our time, or, perhaps, a fugitive moment of our time? He who has attentively observed the later exhibitions on this point will be bound to say "No" decisively. Household furniture and room decoration of the "secessionist" order are tortured into appearing new and original; but they are neither the one nor the other, but a patient, methodical eclecticism which aims at the influence of what is foreign and peculiar. We distinguish accurately that rooms built and painted in the secession style are patched together of Chinese motives, with an addition of Loie Fuller's serpentine twistings, and that secessionist furniture imitates, in good wood and metal, the slenderness, knottiness, and pliancy of bamboos. The secession contains a very minute percentage of independent invention and a great many reminiscences of Eastern Asia. The West European style, which should ostensibly be the expression of the latest high European tendencies, is, in reality, Chinese and Japanese style, exaggerated by absurdity of form and assumed or real delirium.

IV

THE OLD FRENCH MASTERS

We must once more change our method of study. That is the immediate result of the Exhibition of Old French artists—painters, draughtsmen, enamellers, sculptors—which, in 1904, in the Pavilion de Marsan at the Louvre, brought together several hundred fascinating, and perhaps half a dozen overpowering works. With the proofs furnished by these masterpieces full of earnestness and beauty, a chapter in the history of French and European art will have to be rewritten—not, to be sure, altogether in the sense

intended and proclaimed by those who prepared this exceedingly important arrangement.

Comparatively few mediæval French works of art have been preserved to us. The Hundred Years' War, the devastations of the League, and the Great Revolution made a clean sweep of them with fiendish thoroughness. With the châteaux, abbeys, and monasteries, their contents so far as works of art were concerned also perished. What survived has up to now appeared to a pre-conceived idea scarcely native. One historian of art wrote after another, that, up to the period of the Renaissance, the plastic artists who worked in France came partly from the Low Countries, partly from Italy, but were only quite exceptionally, if at all, Frenchmen. From a geographical standpoint, we might speak of a French mediæval art; but from the nature and form of the work, on the other hand, we should admit only a Flemish or Italian, but no French art.

This view is no longer defensible. France, too, had, in the Middle Ages, her own artists and schools of art, and if she also offered hospitality to foreign talent, she was not dependent on it. The strong, creative genius that developed in Northern France from the prosaic semi-circular arch of the Byzantine style the pointed-arch poetry of the Gothic, knew also how to make use of the chisel and paint-brush as means of expression, and to satisfy by painting and carving its impulse for depicting form. The mediæval art of France is not inferior to any other. It must no longer be treated as a mere appendage of art development in the Low Countries and Lombardy.

To be sure, if the learned compilers of the Exhibition Catalogue—George Lafenestre, Henri Bouchot, Leopold Delisle and other academicians or directors of museums and libraries—claim to have discovered, in the pictures and statues, a particular French national feature which distinguishes them clearly from other contemporary works, they are led astray by patriotic prejudice. The works bear the stamp of a period, not of a people. Nothing is more like a fourteenth- or fifteenth-century French work of art than a Flemish or Italian, and _vice versâ_. It is noticeable that people have taken Bourdichon's masterpiece, one of the gems of the collection—the portrait of the little Dauphin Charles Roland, to be a work of Memling; and of the most beautiful paintings of one and the same painter—des Moulins—have long ascribed one to Van der Goes, the other to Ghirlandajo.

No; the temperaments of the artists at this period were not differentiated nationally. They are, moreover, not so at the present day either, and if analogies are established between artists of the same origin, they may, in all cases, be naturally explained otherwise than by a common descent. The influence of strong personalities, who influence as prototypes, external successes, which form a current of fashion and incite to imitation, or simply a tenaciously held tradition of a school, in which in a long series of artist generations has grown up, suffice to impress on the art of a country through extensive epochs, a certain family physiognomy, which only a mystically inclined mind will be tempted to refer to race and blood.

Topographical and national classifications have in fact no inward spiritual justification in art, but at most a value of convenience, in so far as they render possible external groupings, which facilitate a survey. The whole art of Europe is one. It has developed from the Greek, the tradition of which has remained living through all the centuries, and has crept, from country to country, connecting inseparably all separate national developments with their common origin. The Greeks were the teachers of the Romans, and their inspirations and rules were carried down into the Christian catacombs, and from them blossomed the art of the Middle Ages.

Byzantine artists from the Roman empire of the East itself or from Italy, initiated, at the Court of Charlemagne, the barbarians of the Frankish kingdom in the mysteries of their craft, and carried the Promethean spark, however weakly it glimmered, from Attica to the banks of the Seine and Scheldt, where it did not expire, but, later on, was fanned again to bright flame by the fresh breeze of the Renaissance. The Eastern branch of Greek art withered into actual Byzantism, whose last off-shoots are the Russian icons of to-day. The Church in the East, to suit the fetish-loving views of her superstitious semi-barbarians, attributes to the picture the meaning and value of an idol, and opposes mistrustfully every deviation from the canon which, according to her conception, might weaken the power of the idol. In the West less credence was given to the picture's magical virtue, its form obtained no dogmatic consecration, the Church allowed the artist freer movement, and thus development was possible, which broke through the stiff, lifeless rule of the school, and found its way back to the inexhaustible primitive source of Greek art itself, namely, nature.

The emancipation from the Byzantine system is not the work of Cimabue and Giotto, or of an individual at all, but an effort of almost all the artists of Western Europe at the close of the thirteenth and the beginning of the fourteenth century. The portrait of John II. (1310-64) in the Exhibition, which was painted about 1359, of course _in tempera_ on a gold ground, by Girard of Orleans, is of a marvellous realism, unchecked by the slightest restraint of any studied rule. The head in profile, turned towards the left, of the melancholy-looking man in the 'fifties with the long, well-formed nose, the scanty moustache and beard, and the long hair, gleams with warm life. Girard copied his model modestly and truly, without troubling himself about a golden profit, and he could put soul

into the portrait of his king in the measure in which he himself felt the latter's inward life.

The awakening of a feeling for nature in art is generally ascribed to the Flemings, particularly to the brothers Van Eyck. That, too, is arbitrary, as a glance at the works of the old Frenchmen, who flourished contemporaneously with the Van Eycks, or even before them, teaches us. The feeling for nature was always active in the few with bright eyes and joyous consciousness of life, who dedicated themselves to art from inner impulse. The themes to which the plastic arts had for many centuries to restrict themselves were certainly as unfavourable as possible to a healthy naturalism. The only subjects the painter dared to treat were illustrations of the Old and New Testament, legends of the saints, and the symbols of faith. Scenes of heaven and hell, Biblical miracles, and personification of the dogmas of the Church could assuredly no more be painted from the model than the Holy Ghost, or transubstantiation. And yet nature herself came to her rights in this fundamental representation of the supernatural and what lay outside of nature, for she does not allow herself now to be driven out, even by the violent methods of the pitch-fork spoken of by Horace in a famous verse. Without taking particular thought about it, or with a cunning conscious of its purpose, the artists fashioned their works most foreign to actual life out of elements of reality, and achieved them by nature, truth, and life. For this reason even the earliest miniatures of the manuscripts become a trustworthy source for the history of manners. Because the art-workers of limited capacity, who wrought servilely according to the tradition of their gild, reproduced accurately all the accessories—clothes, weapons, furniture, buildings, and scenery—as they actually saw them.

The little picture, "The Virgin and Child," which is ascribed to Jean Malouel, and was painted about 1395, and can therefore have owed nothing to the Van Eycks, then in Dijon, and perhaps, too, elsewhere, certainly still quite obscure young people, is of such charming realism that one might rather class it as a _genre_ picture than as a sacred picture. The Virgin is making the Child a frock, and is just drawing the thread tight, with the needle turned in a correct horizontal direction, and the child Jesus is amusing Himself by putting His rosy little foot in His Mother's red leather slipper, of enormous size to Him, which she has taken off and placed before her. There is no reason why we should not assume that Malouel—if it was he—gave his patron—perhaps the Duke of Burgundy—his (the artist's) own dear wife and little son as a Holy Family.

In "The Death of the Virgin," of the same school of Burgundy, but about a century later, the apostle, kneeling at the foot of the death-bed and reading his prayer-book devoutly, with a big pair of spectacles on his nose, is, in spite of the pathos of the moment, so natural as to be almost comic. "The Miracle of the Saint," with his head in his hands, who is walking barefoot, by a pupil of Nicolas Froment—perhaps by the master himself—painted, about 1480, at Aix in Provence, attests the painter's most naïve indifference to probability. In the middle of the street where the decapitated saint is walking, and the executioner, leaning on his sword, stands dumbfounded, kneel, in measured symmetry, to the right and left of the saint, the founder and his consort; he with four little sons, she with four little daughters in a row, like so many organ-pipes, behind them. The picture of the city is, however, so realistic that even to-day an old corner of Aix is recognisable in it, and the gazers running up or standing in knots and laying their heads together, or hurrying to the windows, are of everlasting human verity.

Exactly the same holds good of the altar decoration, ascribed to John of Orleans (circ. 1374), a wonderful sepia painting on white silk. The sections which depict the Scourging of Christ by two brutal fellows with hang-dog faces, the Carrying of the Cross, with the Mocking of Jesus by the rabble of Jerusalem, and the Entombment, with the Blessed Virgin kissing the corpse, show that striving after truth, which has hitherto been pronounced to be a peculiarity of the Dutch. In the "Martyrdom of a Holy Bishop"—most likely by Jean Malouel (circ. 1400)—the martyr, in mitre and pallium, gazes from a strongly barred prison window, near which an angel kneels, and through the bars of which the Saviour in person administers to him the viaticum. But the castle in the Lombard style—stone rafters and corbels with red tiled spaces—on to the ground-floor of which the oval window opens, may be regarded as an architectural design.

Nicolas Froment's famous "Burning Thornbush" from Aix Cathedral (1475-6) is entirely fabulous in the middle. A soft, cloud-like, lumpy hill of rock supports a dense group of thick-stemmed trees, the tops of which unite in a kind of gigantic bird's nest, wherein the Virgin and Child sit enthroned. But this miracle, with no measure of reality to gauge it, is framed in a deep landscape with great distances; in which white towns lie by mirroring waters, and thickly-leaved trees rise up from green hills to the bright sky, and in the foreground, beside an angel of Annunciation, sits, surrounded by his drove of wethers and his quaintly posed dog, the white-bearded shepherd with his legs crossed in the most natural posture you could conceive.

In the case of almost all the paintings in the Exhibition, and chiefly of the best of them, this proposition can be repeated. The painter loyally carries out the subject commissioned, treating it faithfully according to the traditional formula; but what is not covered by the formula he shapes with sovereign freedom and an honest joyous realism which is by no means the prerogative of the Dutch and

Germans, as has been so long believed, but is to be met with, according to the evidence of this Exhibition, in the same measure in the French.

Sculpture might become crude in the earlier Middle Ages, but it did not cease to be fostered. Sculpture in stone or wood was the complement of building, that strongest expression of mediæval energy, ivory-carving, or the jewel of precious metal, the adornment of the altar or the state-rooms in the palace. Painting, on the other hand, after the collapse of the old world, went back to the adornment of books, and from this the great art of wall- and easel-painting was again developed only after the age of the Crusades. This, in many details, betrays its origin from miniature. For a long time it was nothing but an enlarged miniature. The works in the Exhibition show, at any rate up to the last third of the fifteenth century, all the features that distinguish the pictorial ornamentation of the manuscripts: the gold ground, the neat, nay, painful perfection, the gay, unqualified, almost glaring, colours, the equal clearness of objects in the furthest background and in the foreground, the puerile joy in innumerably repeated complicated decorations of the surface, the framing, with richly figured wreaths, ornamental borders, or picture margins. Even the standing formulæ of manuscript miniatures are repeated for centuries in the paintings, viz., the movements of all the personages at the Annunciation, Crucifixion, Entombment, and Ascension. Only towards the end of the fifteenth century does painting fully escape from the still clinging egg-shell of the miniature, and grow accustomed to a large, bold line, and a freedom of composition which finally reckons with considerations of distance, and prevails upon itself to neglect comparatively the subsidiary in favour of the essential. The glorious Master of Moulins has, it is clear, no longer the old inherited habit of feeling himself banished to a page in a book. He no longer shows the same somewhat mechanical respect to all work, principal and accessory. In the "Virgin and Child between the Founders," and particularly in the "Nativity" with the twilight landscape in the background, and the fat poodle in front sitting on the kneeling cardinal's mantle, the precedence of values is observed, and the painter reserves his piety and devotion for the noble parts.

The author of these pictures—one of the greatest painters that ever lived—is only known as the Master of Moulins, or the Painter of the Bourbons. His name was probably Jean Perréal, but there is no certainty about it. Only a few definite names have come down to us from the beginnings of modern art. We must search for them in the inventories and account books of princely households or cathedral chapters. The artists did not yet sign their works; they indulged in no dreams of immortality. They did not yet feel they were the supermen, that the Renaissance, later on, made of them, and that, in the estimation of the upper class, especially of its feminine and effeminate portion, they have remained till the present day. They were honest and genuine artisans, just like other respectable artisans; and in France they, for the most part, enrolled themselves in the Saddlers' Guild, perhaps because they, like the latter, had originally, as miniature painters, to do with parchment, _i.e._, a species of leather. They regarded it as a special distinction to be appointed servant,—_valet_ or _varlet_—of a prince, on whose commissions for church and palace they lived. Jean Malouel and his pupils, Jacques Cone and Jean Mignot, Jehan Fouquet, his sons Jean and François, and his great pupil Jean Bourdichon, Enguerrand Charonton and Nicolas Froment, perhaps also Perréal and King René the Good (1409-80), are perhaps the only painters whose personality stands out clearly outlined in the dawn of art history before Clouet, and his contemporary Corneille of Lyons. Perhaps a number of forgotten names may yet be dug up from archives. The obscurity of the few who have either been handed down to us, or been rescued from oblivion by industrious investigators in recent years is a heavy injustice. They deserve to shine with the same glory as the most illustrious that Vasari has preserved for us in a work of amusing studio gossip.

Jehan Fouquet stands in a line with the greatest portrait painters of all times. He may be named in the same breath with Holbein—nay, with Velasquez. His portrait of a man in the Liechtenstein Gallery at Vienna, which shone as one of the gems of the exhibition, is perhaps the most powerful work that the great master created, and the "Man with the Wine-glass," in the Vienna collection of Count Wilczek, is hardly inferior to it in significance.

Of the numerous suggestions of an artistic, moral, and psychological nature that were the outcome of this unique exhibition, the deepest and most abiding—at least for me—was that one felt the spiritual condition of the artists who created these works on commission and, for the most part, according to precise instructions from princes and prelates, lords and governments of cities. In nearly every one of them is played the great drama of the struggle of souls thirsting for freedom with the fearful oppression of intellect of the darkest Middle Ages. Secret corners and angles, easily overlooked backgrounds of the pictures, suggest already the future art, untrammelled by the world, which will overcome this art of the guilds, with its fixed, dogmatic formulæ. A Fouquet, a Bourdichon, a Clouet who, in kings and princes sees, and paints with horrible realism, poor, sick, ugly, dull fools, stands no longer under the control of royalty. He is inwardly a disrespectful rebel, and is, in his way, a prelude to the procession of the market-women to Versailles, which, two or three centuries later, was destined to overthrow the kingdom. A master of the "Mount Calvary" (1460), who makes the holy women and disciples stare with such unmoved, wooden countenances at the Body of Christ,

not because he is incapable of painting sorrow-stricken faces—all the details of the painting witness to his artistic power—but because he contemplates the incident with coldness of heart, and expresses his unbelief to the initiate as plainly as the rack and stake of the period allowed. In these early works there is a very soft and very weak rumble of thunder of a very far-off storm. They are a first indistinct announcement of the Revolutions that are slowly preparing.

V

A CENTURY OF FRENCH ART

Sincerity did not rule in all parts of the Paris Universal Exhibition of 1900, but a quickening air of freedom was breathed in the great palace of art. The temporary proprietors of this colossal building, the French artists, did not pretend to any motive that they did not possess. "Make room! Out of the way! Out!" we fancied we heard from all the dusky corners of the vast halls in a voice of thunder. "Foreigners from both worlds? To the south wing with them! In the corner! Under the staircase! That's quite too good for them. The dead? The famous of yesterday? What do the disturbers want? Haven't they had their share of ribbons, titles, commissions from the State, and other forms of the artist's ideals? Back with you! To the furthermost building in the rear! If any one wants to make journeys of discovery, he can steer away. The chief buildings, the foregrounds, the splendid halls for us, the _chers maîtres_ of to-day. We are the strongest, therefore we need do no violence to our feelings. We are alive, therefore we are right."

Certainly, certainly. I do not contradict this; but it suits my inclination to wander past the conquerors of the day to the shadows in the back premises, into the remote and also, as to equipment, significantly neglected halls of the Century Exhibition, to the great vault in which is collected that which was to make plain the development of French art from the Revolution to Carnot, the grandson. What remains when the human being who gives dinners, haunts antechambers, has cousins in the Ministry of the Fine Arts, whispers malice in one's ear, ceases to acknowledge greetings, and writes flattering letters, has fallen to dust; when rivals and parasites have disappeared; when the puffs of toadies, and the no less valuable ones of envious men and poison-boilers, are hushed and forgotten?

Not much, and there lies the melancholy humour of such wanderings through the realm of shadows. The only feature that always wounded me somewhat in the "Divine Comedy," is that Dante awards his curses and execrations on the departed according to the rank they occupied among the living. The invectives on the poor soul of a pope have three stripes, those on a prince, two, and on a lord, one. That is an inartistic forgetfulness of the frame chosen by Dante for his poem. If he remained always mindful of his programme of death and hell, he would not be able to distinguish crowns or purple mantles in the red illumination of the under-world. The laughing and sighing philosophy of Hamlet—alas, poor Yorick!—stands higher than the resentful fury of the passionate Italian, who makes the hierarchy overstep the threshold of the grave. It is perhaps the most profound usage of the French language that they deprive the dead of the "Monsieur," to which every living man, with the exception of those criminally prosecuted and condemned, has a claim. The dead has no longer a title—so much more sorry a fate for him, if, when he was alive, he was nothing more than a title.

The practice is even here somewhat different from the pure theory. The deceased is no longer "Excellency," "Professor," not even "Mr." But the usage of contemporaries to give him a title is still expressed in the respectful tone in which they pronounce his now naked name, and in which one possessed with a delicate sense of hearing perceives the rustle of all the tinsel that surrounded him when alive. In this tone, however, the name becomes familiar to the younger ones, who, without thinking, continue this veneration, unconscious that their accent expresses respect because the bearer of the name so pronounced was once a Grand Officer of the Legion of Honour and an Academician. Thus, my dear Schiller, are your confident words to be understood, you who would never perceive the weft of vulgarity in the ways of man: "He who has satisfied the best men of his time has lived for all time." Certainly, if by "best" we would understand the best placed, best paid, invested with the best office, or the best decorated. He who during his lifetime has belonged to those favoured by the grace of official newspapers, who has been gauged by them and provided with a "full" mark, will be recognised for all time as full without further test. The Pantheon is the continuation of the minister's official rooms, the golden book of spiritual history an anthology from the Official Gazette and the Army List, for the use of the children of later centuries. If I must emphasise the essential: the appraisement even of the artist, therefore of the most individual man that exists, is the outcome of social, not individual, factors, or of the latter only when they are socially successful, and, therefore, themselves become social factors. There are, I admit, always proud—perhaps only haughty—natures with an anarchistic, anti-social trait, who will not recognise any arrangement or fixing of the community, not even its hierarchy of fame, and clench their fists against laurel crowns just as they do against crowns. Their rebellion, however, is seldom successful. I know of no case of a bomb-thrower having

destroyed a Pantheon.

But as we do not take ourselves tragically, do not begin our own verdict with the threatening formula, "In the name of the Law," and do not exact any submission from others, we are always entitled to be of our own opinion, and to let the dead influence us without prejudice, untroubled by the distinctions of rank which were bestowed on them in life, and were buried with them. Such a method of observation is unhistorical, but subjectively fruitful; it leads to self-emancipation from many superstitions.

The Century Exhibition of French painting was far from being complete; it was incomparably more fragmentary than the Louvre Museum, which is also not without gaps. But it afforded a general view of the art development of the period represented, and it gave the independent man the chance of correcting numerous opinions which had taken hold of him from study and reading.

It began with the masters who created and flourished before the deluge of 1789—Watteau, Greuze, Fragonard, Vigée-Lebrun. The three first had, for two generations, sunk deeply in general estimation. Then the force of fashion raised them up again to dizzy heights of fame. I do not believe that they will maintain themselves there. It pleases the reactionaries to glorify the _ancien régime_ at the expense of the Revolution, and to this planned and deliberate toil belongs also the unmeasured overestimate of eighteenth century art and artistic work. But it is politics, not æsthetics—no taste for art, but a tendency. In reality, the darlings of the age of the Pompadour and Louis XVI. were petty masters, mere fillings of a particular frame, and, lifted out of this, they lose their best qualities.

Watteau still holds his ground most easily, for he is an amiable teller of stories that are agreeable if nothing of a more serious character occupies one's mind. He draws elegantly, although without pedantry; his colouring is cheerful, and suits admirably his hushed, silken carpets, coquettish Gobelins, and light lacquered furniture. He is the painter of joyous days wherein life seems an eternal feast. Gracious spring bedecks the earth, his men and women are all young and handsome, his ladies wear entrancing toilettes and _coiffures_, and his gentlemen silk doublets and lace shirt-frills. Even if they dress as shepherds, they are laughingly addressed thus: "I know you, fair masque; you are a marquis in disguise with your charming friend, the duchess." Rosy angels hover about them, and mingle familiarly in their pastimes. They have nothing on earth to do except pay each other witty compliments and play at love. I understand why American multi-millionaires pay any price to be surrounded by Watteaus. It is really honourable to the artists of our time that the Trust magnates have not yet succeeded in finding or rearing painters who would flatter their egotism through servile suggestions of a Watteau aspect of the world.

Fragonard appears in a secondary position besides Watteau. He is drier, and with less "swing." He is not really present in his heart at the pastimes he paints. Watteau is himself a guest at his festivals; Fragonard takes part in the _soirées_ only under a sealed order. The former amuses himself, the latter amuses the person who gives him the commission.

Greuze lives on the fame bestowed on him by the grateful Diderot. He was enthusiastic for Diderot's tearful _bourgeois_ tragedy, and Diderot repaid him with enthusiasm for his painting; but we have no longer any grounds, I suppose, for regarding him with Diderot's eyes. When he paints his eternal model of the "Broken Pitcher" in the Louvre, and of his sundry counterparts of it in the Century Exhibition, he is pitilessly pretty. When he sets great dramatic scenes in the Diderot style on the stage—the "Village Betrothal," the "Father's Curse," etc.—he is depressingly melodramatic. His young maiden is marvellously pretty and tame, and will always delight childlike spectators with the charm of her blooming girlhood. He suffered himself to be infected in Italy by Guido Reni's sweetness, and only transplanted his soft beauties, rolling their eyes, from paradise to the middle-class earth. He is simply the Bouguereau of his age. That name comprises all that can be said of him in praise or blame. Greuze is Bouguereau's superior in so far as he paints more vigorously, and forms his pretty _ingénues_ of real flesh—not, like Bouguereau, of alabaster and sugar-candy.

Beside the softness of Greuze, Madame Vigée-Lebrun seems a man and a fighter. In a century of gallantry she alone was not gallant. She painted women's likenesses, and did not pay court to her models; but she elevated them, and gave them meaning. Where the male painters of the period saw only beauty-patches, she suspected she saw a soul. If we look at these women with curiously poised heads, gazing boldly out of their frames, they say proudly and calmly: "I am no trying-on hand; I am no creature of luxury; I am no flesh for lust; I am a personage." At a distance of a hundred years Vigée-Lebrun is a forerunner of the now innumerable American painters of emancipated womanhood. This brave woman, who was beautiful, and did not overprize, nay, hardly prized her beauty, was an asserter of women's rights long before the word or the thing was invented.

Prudhon was represented by a "Zephyr," which has the same peculiarities as his "Crucifixion" and "Crime and Punishment" in the Louvre. He models a human body so that one must take one's hat off to it. He has the infallible feeling of the great Spaniards for the

value of light and shade; but what will always stand in the way of his being loved and not merely respected is his hatred of colour. He confines himself to a strict black and white style, which banishes all gladness and discourages the most willing admiration.

And now the great deluge breaks in, and, like a sea-god David emerges over the raging waves. It is really with him that the century begins, for what preceded him was the art of the _ancien régime_ and of the Trianon. He had at the Exhibition a "Distribution of the Colours," an "Ugolino," some portraits; all of the most genuine David in choice of subject as well as treatment. Everywhere the capricious "seeing yellow" which seems to have been a peculiarity of his eye; everywhere the grandly imposing, professorial infallibility of drawing which knows no first trying, no anxious searching, no hot struggle with the never quite attainable Nature. David compels with an imperious Medusa-glance the ever-stirring, the ever-flowing, so that it becomes fixed, and he can shackle the now immovable vision in brazen outlines. So his human beings appear statues, or mimes, which maintain a pose, and his most blameless anatomies acquire a tendency towards the artificial. David's mood is always uniformly high-pitched. Good-humoured people, who would like to see the majestic man in shirt sleeves for once, lurk in vain for him to unbutton himself. He never forsakes the decoration and costume of high tragedy. At first he sought the drama in ancient history or world-famed poetry. Afterwards, he found it in his immediate surroundings. Fate vouchsafed him the favour of living in a time, the pathos of which was mightier than that of Athens, Sparta, or Rome. He satisfied his deepest longings when, in the "Sabine Women," he preached to the murderous factions among his people reconciliation and brotherly love, and, in "The Distribution of the Colours" and the "Coronation," he made Napoleon the equal of the heroes of mythology. He is, therefore, always genuine, even when he may seem to the superficial gaze theatrical. It is the difference between a tone naturally sustained during moments of life at high pressure, and declamation learnt from a teacher of rhetoric.

His pupils, imitators, and rivals have, on the contrary, not succeeded in avoiding declamation. Gérard, Gros, Riesener, and Drolling were, consciously or unconsciously, the greatest flatterers that ever painted portraits. Because David represented Napoleon in the character of an Alexander of Macedon, or an ancient god of war, the others, the smaller painters, in their portraits gave to even the ordinary men of the period the deportment of Olympian gods. Only Gérard's "Letitia," who, too, bore apotheosis most easily, is a good modest human being. All the other women are Juno or Pallas Athene; all the men Mars or Achilles. The contrast between the commonplace physiognomies and the magnificence of their appearance is now and then so violent that one is led to surmise that the painter wanted to make fun of his models. "Charles X. in his Coronation Robes," by Ingres, seems, for example, virtually a parody of David's "Coronation of Napoleon."

Géricault stands an examination of his title to fame badly. He has not so correct an eye for the figures of horses as was believed before instantaneous photographs. His portraits of soldiers are really more crude than powerful. Even the sketch for the "Raft of the Medusa," reveals evidence of straining after effect which our pious admiration refused to notice in the colossal work in the Louvre. On the other hand, the figure of Louis Leopold Boilly gained strangely in the Century Exhibition. Up till then I knew only his "Arrival of a Diligence at a Posting-house," in the Louvre, and I did not rate him very highly on account of the affected _atelier_ light of this otherwise prettily studied little picture. Here he disclosed himself as a great philosopher and satirist. One picture represents a popular merry-making with wine _gratis_, another a free performance at the Ambigu-Comique Theatre. There the crowd is fighting murderously over a drink that can be had for nothing; half-grown hobbledehoys throttle bestial greybeards; bullies claw hold of furies; dreadful feet trample on faces and necks in the mad storming of the wine supplies, and the victors in this struggle have their reward: they lie on the ground bestially drunk. The scenes at the entrance of the theatre are not quite so vulgar. There is a less dogged scramble for intellectual enjoyment than for that of the palate. Yet here, too, the most brutal lack of consideration and greedy selfishness triumph; here, too, the strong man overmasters the weak; here, too, among beings who seem to belie their human form, the law of the jungle holds good; and here, too, poor people pay for a little doubtful pleasure with the sufferings, dangers, and exertions of a storming of the Malakoff. In the foreground of both pictures stands a group of well-dressed persons who, half in pity, half in disgust, look at the disorderly pushing of the rabble from a respectful distance. These rich people have the _rôle_ of teaching the moral of the fable. They express the sociological thought of the painter. Boilly deplores the low moral condition of the masses, and reproaches the dominant class with having degraded them to beasts, when it pretends to give them a feast. He rejects with utter disdain the dogma of equality, yet without haughtiness, for he has for the disinherited the somewhat condescending, yet warm pity of a genuine patrician. These are extremely modern—I might call them Toynbee-feelings—and they are expressed with an exact, judicious brush that can conjure forth the confused turmoil of a great, raging multitude, and, nevertheless, remain faithful in all details. Boilly was decidedly a master.

The Century Exhibition also gave the opportunity for a discovery, not only to me, but also to all who brought to it an open mind. There is a painter, Trutat, of whom no one had ever heard anything. Seekers who investigated the provincial newspaper of 1840-60

succeeded in discovering one or two articles about him. That is all. He once or twice exhibited in the "Salon," but the "Salon" reports of the time make no mention of him. He lived in the first half of the last century, and died at the age of twenty-four. Before his picture—one single picture—men were amazed, and women stood with moist eyes. It is a double picture; in the foreground, a fair young man, pale with sickness, with deep blue eyes and a proud, wild mane; his firm forehead full of impatient dreams of joyous creations, fame, and happiness, yet, in his hollow cheeks, faint shadows of death. Behind him, half obscured in dusk, a woman's profile, his mother's head; a good Samaritan with tender gaze, and lips closed in sadness, which once sang cradle-songs, but have learnt silence in the sick-room. In its composition there is a reminiscence of Ary Scheffer's "St Augustin and St Monica," in the Louvre. But it is incomparably more profound, for Trutat depicts himself, not saints whom the power of imagination has first to bring before him. The painting is wonderful, firm and full as that of Franz Hals—I deliberately utter this strong statement—so surely and organically matured that one traces beneath the skin all the most delicate muscles and bones. And add to this technique, of which one does not discern how he could have acquired it in a fleeting morning of life, the intensity of feeling which has raised the work to the rank of those high creations in which a soul is revealed. The picture is full as a swan's song, of foreboding and love. The great youth does not understand himself alone, without his mother—the dear mother must be with him, if he goes out to the market among people. Shall she nurse him? Shall she protect him? Can he dispense with her for a moment as he must be taken away from her so soon? All this is in that mysterious picture, and it was in it when Trutat, though he did not know it, painted his own requiem. Only nobody then understood the riddle; Trutat as little as the rest. He is another Regnault, only a still more genuine one. And no one has made lamentation about him, although his tragedy is more painful than Regnault's. For the latter attained immortality in the apotheosis of death in battle, whilst miserable consumption slew Trutat ingloriously.

The Romantic fever begins to seize the century. The painters hasten to hang round them the botanical box, and seek the blue flower. The first to go forth into the moon-illumined, witching night was Chassériau! Poor Chassériau! It would have better suited his bent to paint _salons_ with rich Empire-furniture, wherein respectably dressed citizens sit with their wives and daughters, and pleasantly tell each other the anecdotes of the day. His portrait of the two sisters in red shawls and yellow plaited dresses shows this—a neat, pretty, _bourgeois_ painting, which denies itself all enthusiasm, and all soaring. But now the tarantula stings him, and he occupies himself only with obsolete subjects such as Orpheus, _châtelaines_, fairy-tale princesses with black slaves, Macbeth and the three witches. The last picture is particularly characteristic of him. The three witches have their white beards and pointed noses, as prescribed by the romantic code; but they are merely grotesque, but not in the least weird. We have the impression that they have met in a peaceful country in order to gossip about their neighbours, and make coffee. They publicly proffer the knight, who should be Macbeth, a small bowl. The heath by night lacks every trace of mood; the ugly old women every touch of the demoniac. Chassériau painted, just as J. Fr. Kind—the ["Freischütz"] Kind—wrote poetry.

I am afraid I must likewise be guilty of heresy in respect of another great man; but Delacroix, too, fails to justify the idolatry people have displayed and, to some extent, still display towards him. I do not misjudge his joyous coloriture, although his harmonies are rather loud than grand. I am not blind to the characteristic mobility of his composition, although it is generally far more a stagey flourish than assertion of strength in the service of a will conscious of what it is aiming at. What excites in me, however, unconquerable opposition is his phrasing. If any art demands intuition it is painting. Delacroix, however, usually has not exercised intuition, but has clothed with the cool work of his brain abstract thoughts in conventional forms. For this, look at "Greece expiring on the Ruins of Missalonghi"—a picture which was once of enormous influence and highly praised. On some disordered masonry stands a young lady in the _bal masqué_ dress of a Greek, who has no thought of giving up the ghost, but is playing a part in robust health, and will change her dress, and have supper later. At some distance behind her we catch sight of a young negro in the uniform of a Janissary, climbing a rubbish heap, brandishing a flag with a crescent on it, and a curved sabre. This slightly painted Turkish warrior appears not to see the young Greek girl; at all events he does nothing to her, and does not even threaten her. There is no association between the two figures; the action is disconnected. At most the Turk is interesting as an acrobat or banner-swinger. No murderous propensities are noticeable in him. The countenance of the Greek lady is pale and weary; but a rest in bed seems the only thing she needs. It says much for the keenness of their Philhellenism that this picture could move the people of the period. Delacroix had, however, no intuition at all when he painted it; he only illustrated an unplastic, insipid phrase.

His other paintings are mostly illustrations of a text. "Comedians and Buffoons" were unmistakably suggested by Victor Hugo. Confused ideas occur to him. Thus "The Good Samaritan" was not painted to the passage in the Gospel, but to a story of chivalry; for the gentle benefactor takes the sick man on his charger—he is a mounted Samaritan!—just as a knight takes the noble lady he is carrying off.

Delacroix was a literary painter; we know that from his correspondence; but without that, his pictures would betray it. He read much more in books than in nature, and he supplied paintings that gave evidence of education and much reading, in which the art-hating, blind-souled Philistines of education delight royally. It may be that the confusion of his portrayal and the loudness of his palette was felt by his contemporaries as a deliverance from the coldness and precision of David's school. I suspect, however, his earliest admirers valued him chiefly because he fed on the same books, plays, and newspapers as themselves.

Ary Scheffer stands in the same spiritual plane as Delacroix, but lacks the keenly joyous colour and the theatricality of his stage-setting. Schubert's songs and Schumann's are music even without the lyric text, and what music! I cannot imagine what Ary Scheffer's pictures from Shakespeare, Goethe, and Byron would be without the poets and their poems. His picture in the Century Exhibition, "The Dead ride fast," is, if I exclude from my conception my remembrance of Bürger's ballad, an almost touching example of tastelessness. Leonora's dishevelled hair, blown by the wind into a stiff, horizontal position, is supposed, for instance, to illustrate the swiftness of the ride—a notion which may have seemed to Scheffer terrible, but is comic.

Horace Vernet had a "Mazeppa," of course a big modern battle, and several likenesses. He is as popular as on the first day, and will always remain so as long as children play with tin soldiers and the picture sheets of Epinal—the French Neu-Ruppin—find a ready sale. How he dazzles! He does so to a degree which deserves admiration. From a distance his pictures appear to be something; one must look at them quite closely to see that they are nothing, absolutely nothing. The colossal canvas is apparently full of men: thousands of soldiers march, encamp, storm, fight; but, as a matter of fact, not a single figure is painted; the whole pomp of war and victory is composed of little stencilled gingerbread men, without any bones in their bodies, and with scarcely the remotest resemblance to human beings. Could Horace Vernet draw? Had he really any other conception of the human form than that of an inflated india-rubber figure? In Paris and Versailles I have seen many paintings by him, but I cannot yet answer these questions. Horace Vernet is the fourth of a dynasty of painters: the first, Antoine, was great at little figures on sedan-chair panels; the second, Joseph, painted the well-known series of French harbours; the third, Carle, is a master in depicting horses; Horace, the fourth, is the weakest of them all, incomparably inferior in ability to his father, grandfather, and great-grandfather. He alone, however, has attained fame, and his renown throws his ancestors into the shade. The wheel of fortune now and then plays immoral jokes of this sort, perhaps in order to teach its own futility.

Daumier was known to me and, I suppose, most people, only as a draughtsman. We learnt now to prize him as a painter of high rank. His numerous paintings are illustrations to "Don Quixote," romantic merry-Andrews, street-singers, Molière's _Malade Imaginaire_, and a crowded group of lawyers in cap and gown. His manner is the same in oil as in lead-pencil and crayon-drawing: his lines of movement broad and firm, the outlines blunted, and now and again rubbed; all his figures mysteriously surrounded in mist, yet all so clearly and faultlessly represented that one is never led to suspect that their mysteriousness is a trick to hide carelessness or lack of skill. Even his oil-painting is really caricature, but discreet caricature. The nobler method instils into him self-respect, and preserves him from caricature; he just marks roguishly the burlesque features, but does not diverge from reality. Thus his lawyers are portraits, but they look so maliciously intelligent, so inexorably penetrating, that we can doubt of this or that head whether it is a likeness or a caricature. Let us say this: the model will take it for a caricature, but his friends will regard it as a portrait. Daumier is a solitary; he is akin to none of his contemporaries, yet an example of the migration of souls; for in him Hogarth comes to life again, but a Hogarth who for his part would be animated by a spark of Rembrandt's spirit.

Suddenly another solitary appears in the ranks of the allied men of school and tradition, viz., Millet. Precipitation would infer: the romantic is overcome; a new generation with new modes of feeling arises; the nerves of the century begin to vibrate according to a new rhythm. That is sheer nonsense; nothing has been overcome. The romantic masters still form romantic pupils, the crowd still feels in the traditional way; the range of themes and the fashion of treating them remain what they have been for a generation, but amidst the dependent, the docile ones, the imitator forms for himself, by the law of elective affinity, a divergent group—the group of the forest-folk of Barbizon—and amidst this group steps forth an individual man who forgets the master's _atelier_, who, in painting, thinks of neither the _salon_ nor the art-dealers, who looks not into books and newspapers nor on prototypes, but out into the world, and on that account falls completely out of the century.

If we follow up the development of art in the Exhibition, we may easily fall into the error of thinking that with Millet one epoch closes and another begins. Such was not the case in reality. The contemporaries who appreciated Millet were a diminishing few. Official art despised him. There were no distinctions for him on the part of the State. The critical phrase-makers knew nothing of him or mocked him horribly. The rich connoisseurs passed him by. A very small congregation of moderately well-off admirers, whose valuation appraised their most honest admiration at 1,000 francs at most, bought his pictures at prices which just made it possible for him to live in Barbizon in wooden shoes and a blouse, and to bring up his numerous family on potatoes and bacon. But as he

was a personality he succeeded—though only after his death. He made a school, like every one who has something to teach. He gained influence on the views of the creators, the critics, and the public. People began to understand his speech, nay, to feel that what he said was beautiful. But to this day there is no Millet epoch in French art, and his fame is really an optical delusion. His works did not bring him into the mouth of the masses, but the caprice of a millionaire. On the day when it occurred to M. Chauchard to pay 600,000 francs for Millet's "Angelus," snobs of both worlds took off their hats and murmured in a voice hushed with reverence: "That must be a great painter." As we see, the world's fame is but a question of money. Many more men are able to reckon than are able to feel the beauty of art, and, to the vast majority, its price is the infallible, the one key to the understanding of a work.

I must say that the millionaire who acted as Millet's herald of fame, had no sense of proportion. If the work of an artist is to be measured by a gauge, the figures of which represent gold coins, Millet does not reach the altitude of 600,000 francs, unless we estimate at least thirty of his contemporaries equally high. In technique, Millet follows the Dutch; a David Teniers without humour and without aim at humour. His landscape, never the essential with him, is poorer than that of Rousseau and François, not to speak of Corot. His greatness lies in his personality, in his simplicity, in his avoidance of pose, in the pious earnestness with which he follows the daily toil of the field labourer. That is no new note in art, but it is the manifestation of an individuality. Many are his superiors purely as painters. But souls cannot be compared and measured: they are incommensurable.

Courbet follows on Millet. Those mad on systematising have classed the two together as pioneers of Naturalism. What blindness to the essential! If anything does connect them—according to the Hegelian method—it is their very antithesis. Millet—let us think of the "Man with the Mattock," "The Gleaners," even "The Pig-Killing," and the two pictures in the Century Exhibition: the field-labourer, who, his day's work ended, is putting on his coat, and the mother feeding her little child with pap, as well as "The Angelus"—Millet indicates, in heavy painting and little-pleasing colours, in people whose coarse externals do not attract a spirituality that ennobles them and makes us forget their soil-stained smock-frocks and their hard features. Courbet, on the other hand, draws faultlessly, and is master of every knack of the trade; but, with his rich means, he never gets above the spiritual stage of photography, and he knows not how to open to us the smallest corner of the moral and spiritual being of his men and women.

But, strangely enough, this same Courbet, who never conceives human beings except as soulless forms, can put a soul into nature and her lower-conditioned life. His justly famed "Sea-Waves" breathes a dramatic will-power. His "Roes in the Wood" are spirited. Ancient, mysterious wisdom appears to possess even his trees. Animals and plants, sea and land, speak in Courbet; man alone is dumb. He is a pantheist who excludes only man from the All-Divine. That is pessimism rooted in the most profound unconsciousness, which hints at serious organic disturbance.

Rosa Bonheur, represented by a wonderful "Team of Oxen before a Hay Waggon," is in this respect akin to Courbet. She, too, is an eloquent advocate of the beauty and profound feeling of the brute; but, more logical than Courbet, she confines herself to representing animals, and does not meddle with human beings. Man fails to interest her; she takes no heed of his indifferent appearance. The animal alone attracts her attention. A Rudyard Kipling of the brush, she has painted all her life the "Jungle-Book," that tells of the wise and good and honest beasts, and the cunning men. Sir Edwin Landseer was also an animal-painter, but of quite another sort than Rosa Bonheur. When Landseer wanted to flatter the beasts, he gave them human qualities. Rosa Bonheur would have felt she was insulting her dear animals, if she had painted a picture like the "Diogenes" in the National Gallery in London. The humanising of animals seems to her like degrading their special animal beauty. Her love of animals was morbid; it was, however, a deep and powerful emotion that made of her a great artist.

Our wandering through the Century Exhibition led us finally past the great landscape-men, the founders of modern landscape-painting, to Manet and Monet, Renoir and Degas, with whom a new century of art begins. In a later section on the Caillebotte room in the Luxembourg Museum, I shall study closely the authors of the Open Air Movement. The fight against the children of classicism and romance was furious, and "free-light" was victorious in the degree in which it deserved victory. But even in those days of turmoil there were idyllists who remained undisturbed by the tumult, and did not notice it. Gustave Moreau painted his colour stories from a palette of gold and precious stones, from a palette of Limosin and the glass-painters of Gothic cathedrals, as if there had never existed an "Olympia" of Manet or a "Funeral Procession of Ornans," of Courbet. The high importance of Moreau, to whom I return in a special study, lies in the fact that he teaches us the feebleness of all classification of art development into epochs. True artists are not subject to time, and move side by side without influencing reciprocally their orbits. They are not subject to Newton's law of gravitation.

The Century Exhibition taught us something more. It sharpened our sight for distinguishing between the literary painters and the painters proper. The former, as a rule, find fame quicker than the latter, but their fame affects posterity as a bad jest. They are illustrators of the time, and what it brings, that is the worthless, art-destroying "actuality." Every attempt to put painting at the service of contemporary thought, to demand of it philosophical collaboration in the development of political, moral, and social doctrines, is a sin against an art whose essence directs it to the eternal aspects of the phenomenal world. Only those are genuine painter temperaments which can follow reflectively the play of light on surfaces in motion, and tell us what feelings this play awakens in them. All symbolism, all allegory, all graphic accompaniment of poetry, is weak. Only what has been really seen has permanence, even if it is reproduced with little skill. You cannot paint from hearsay, only from the impressions which the eye takes in, and the soul delivers. It is astonishing that so primitive a biological truth should be so difficult to grasp.

VI

THE SCHOOL OF 1830

Thomy Thiéry was a rich man of the formerly French, but afterwards English, island of Mauritius, who lived and died in Paris, and left his art collection, consisting of paintings, Barye bronzes, and some Gobelins, to the Louvre. Thomy Thiéry was a man of a single passion and a single thought; he loved only the Barbizon School and some of its artistic contemporaries who, in his opinion, stood in an elective affinity to it; but he loved them with unshaken fidelity and constant self-sacrifice. And in contrast to other more eclectic amateurs, he did not perform his heroic deeds of an undaunted purchaser in auction rooms and art-shops, but carried his money to the studios of the living and struggling as long as he was able, and appeared on the market as an ordinary collector only when the brush had slipped from the hand of the creators. In this way his gallery got the warmth and unity of an organic being, and besides its beauty, gave joy through the idea that it was not the result of _parvenu_ vanity, or of that cruel fancy that takes satisfaction in a work without troubling about the originator, but that a grateful patronage, which not only wishes to purchase art treasures, but also to lighten and beautify the artist's earthly pilgrimage, had created it. As a legacy to the Louvre, the collection has from a fraction become an integral section that methodically dovetails into its place in the frame of this incomparable museum, in which the history of art is made to live before our gaze in select examples. The management has added the pictures which it formerly possessed of Thomy Thiéry's favourites, so that the three halls of the collection now afford a good survey of the fruitful movement, which, about 1830, took place in French painting, and diverted it from the degraded classicism then dominant into the path pursued at present.

The School of Barbizon! A convenient, but, for that very reason, a meaningless, expression. The men comprised in this commonplace designation have not much in common. In age not far apart, they were bound to each other by personal friendship, and partly inhabitants of that Fontainebleau wood, in which some of them experienced Nature's revelation. They were, however, very different in temperament, genius, and impulse, and they strove for personal ideals with dissimilar modes of expression. Only one peculiarity belongs in like degree to all, viz., the burning longing with which they yearned to get out of the stupid hole-in-the-wall of the academic studio that had become to them a goal into freedom and life.

Without punning, the free air and freedom meant to them the same thing. Landscape furnished them with the means of renewing their acquaintance with Nature. Under a completely Faust-like impulse, they struggled out of the _atelier_, where, "in reek and decay, only the skeletons of brutes and dead men's bones" surrounded them, "into the far country." Their appearance about the time of the July Revolution was the Easter-morning walk after brooding in the Gothic studio.

The David tradition held painting in thrall. The master's greatest pupil, Baron Gros, and, with him, the gifted Géricault, sought to overcome the stiff mummifiedness and dryness of forms, the staginess of subject of this art, which found its triumph in the "Rape of the Sabine Women" and the "Coronation at Notre Dame." But Géricault, misjudged and undervalued, died early a conquered man, and Gros, going astray in uncertain sounding of himself, returned, after his short revolt, to the tin and paste formulary of his first epoch, recognised in alarm its hollowness, and, by voluntary death in the Seine, got rid of the pains of the sceptic who has lost his faith and his ideal. The then young generation, warned and shaken by the tragedy of this seeker who found nothing, broke with the dominant rule, and sat down at the feet of Nature, to learn from her.

The country is the great master-workshop. There Nature speaks her most eloquent language of form. There she finds the tones that awaken the loudest echo in the soul of the genuine born painter. The creation of a pictorial artist is, like each of the higher mental activities, very complicated; the most opposed organs of the brain have a variously graded and mixed share in it. The vivid reception and rendition of a phenomenon at rest, of the expressive line of one in motion, is an exercise of the motor centres. In the

representation of man, or what pertains to man, which is, directly or indirectly, through the awakening of anthropomorphic ideas, to seize on our minds, trains of thought, reason, and judgment play a part by the side of the emotions growing out of the unconscious. But the real and essential element in painting is neither the motorial production of the drawing, nor the travail of thought in the composition, but is ever the giving of light and colour. Now what counts in landscape is the effect of light and colour. Here the painter stands before the magic changes of lights and the alluring colour-mysteries of Nature, which excite him most keenly; for they stimulate his optical centre, of which the extraordinary development and particular susceptibility of light is the psycho-physical basis and preliminary condition of the primitive, impulsive gift of painting. Ever when men of talent feel the stiffened traditions of the schools to be intolerable, and want to follow their own inward impulse, they flee to the country in order, in its free light, to wash themselves clean from the dust of the schools, and bathe into health their limbs, aching from constrained positions. There is profound instruction in the fact that to Giotto, in his effort completely to burst the fetters of Byzantinism, which his master, Cimabue, had already strongly shaken, it first occurred to introduce into his work the elements of landscape. His picture in the Louvre of St Francis of Assisi is a touchingly _naïve_ example of this.

It was Corot who first uttered in the French painting of the nineteenth century the creative words, "Let there be light." Of course, he did not discover day, for there were masters before him in whose pictures the sun shone. We find in Ruysdael the keen, chilly clearness of a northern sky. Claude Lorrain gives warm, tender evening tones of the south, which have the effect of luxurious warm baths. From him, Turner directly traces his descent, who overheats Claude's pleasant tepidity to a glow, and raises his gentle clearness to a blinding splendour of radiancy. But no one before Corot has understood, like him, how to fill pictures with such discreet yet penetrating, delicate yet glowing light. It is no melodramatic, no Bengal or concocted light, no light of strange, exceptional occasions, of confusing colours, no vulgar, pompous, excessively brilliant light, but a restfully even, inexhaustibly rich, cheerful light that fills the soul with joy and hope.

Corot's light sheds its rays from a hopeful soul. It is luminous optimism in visible form. Some years ago, a Corot Exhibition took place in the Galliera Museum, and those who arranged it contrived to collect about the whole of the master's life-work. I looked attentively at one point: it contained hardly a single evening, not a single autumn note or muttering of a storm, but only morning and spring and blue sky. That is characteristic of this child of the sun. In Corot the elements of beauty are nearly always the same: pleasant hill-countries, winding paths that lead to weird distances and invite our yearning to fare thither; at a curve of the road gleaming water mirroring silver cloudlets; in the foreground delicately-leaved trees; around and over everything the wondrous air thrilling with light, animated with a thin haze of mist, in which, bewitched by the feeling of spring, by an association of ideas, we fancy we can hear the soft bell-notes of invisible church towers, the twitter of pairing birds engaged in building their nests, and the buzz of early beetles. Some of the Corots in the Thiéry rooms, _e.g._, the view of the Coliseum, are youthful productions, and do not yet show the dreamily soft, as it were, inspired style and silver glow of his maturity. They are still somewhat dry and hard, yet, even in these more prosaic pictures, the heart-quickening light falls from heaven—Corot's incomparable strength.

Corot did not belong to the forestmen of Barbizon, but he was the founder of their religion of light. Th. Rousseau shares with him the silkiness, and approaches him in the down-like delicacy of his young foliage. Daubigny has more temperament; he is sturdier, more manly, perhaps I should say: more like a peasant. What raises him to the rank of master is the depth of his pictures, and his gift of working out his subjects in almost stereoscopic relief, in all planes—in the fore-, middle-, and background. His "Skiff" is, therefore, an excellent example. The mast of the vessel stands absolutely free. We see how air is encompassing it on all sides. Dupré shares in equal degree the praise of his two friends. That is not quite just, for he has by no means so much personality as they. He does not feel originally, but imitatively. Nature moves him first through the eyes of his companions in art. He imitates alternately the softness of Corot's foliage and his silvery mistiness, Rousseau's smoothness and insinuating harmony of colour, and Daubigny's tree-poetry, but I look in vain for the feature that distinguishes him from the others.

The delicate, and at the same time reverential love with which the Barbizon-men treat the individual tree, Troyon expends on domestic animals. As to the former the tree, so long as it does not melt in the haze of distance, is never merely part of the scheme, but a distinct, living being, possessing a physiognomy of its own, of which they render a strongly individualised likeness; so the latter regards animals with the understanding of a shepherd, who is known to recognise by their countenances all the sheep of a numerous flock. He will correctly depict the physiognomy of animals, without any propensity to giving them the look of human beings, through which animal painters only too easily become, without intending it, comic.

Millet is the continuation and consummation of the great landscape painters of 1830. We are not conscious of this if we regard him only by himself; but it is at once forced on us if we see him in the Thiéry Collection in connection with his comrades. Millet is also, fundamentally, a landscape painter, only his landscapes are animated by men; but not by men who are accessories, as is the case

with Corot, but by men who are a part of the landscape, its most important and essential part, precisely as the trees and clouds are, but more dignified and spiritual than trees or clouds. With him man grows together with his rural environment, is himself a bit of nature in the midst of nature, and it is not easy to decide whether he is degrading man, or is elevating the earth with all that on it creeps and flies, when he puts them on the same level. Millet discerns in nature an all-living element that can take manifold bodily forms and be expressed in a variety of ways, but is one and the same in all different forms. This grand pantheistic feature uplifts his pictures from _genre_ to high, spiritual art. And since nature is never comic, so Millet's peasants—themselves a bit of nature—never affect us comically, but always pathetically, even when they are as sturdy, clumsy, and simple as David Teniers's boors. In one picture in the collection, "Maternal Foresight," Millet has apparently a humorous intention: a peasant woman is assisting her very small youngster at the doorstep of her house in a little necessity. Even here I cannot find anything to laugh at, unless from kindly sympathy for the hop-o'-my-thumb and his tender mother. It is just a glance at life, and at such no one who feels a reverence for the sanctity of life ever laughs.

The devotees of the great Pan—Corot, Rousseau, Daubigny, Millet, and their followers of the second rank, gain in significance side by side. Their contemporary, Delacroix, loses beside them. What I felt at the Century Exhibition of French art, I feel even more strongly in the Thiéry rooms at the Louvre. I am afraid Delacroix is one whose trial must be revised. Perhaps we shall then be obliged to confirm the unfavourable verdict that the adherents of the Classical movement passed on him at his appearance, although on quite different grounds.

Delacroix was not in love with life; he did not seek and find nature; he followed in her footsteps only in books. He was essentially an illustrator; apart from Victor Hugo he is not to be thought of. The Romantics performed a duty of gratitude when, with fanatical violence, they carried him triumphantly through his detractors. He is their henchman with the brush; he fights with them and for them. They only act according to the rules of chivalry when they protect him. His magic colouring is not to be contested, although it is often gaudy and theatrical. But out of his "Hamlet with the Gravediggers," his "Medea," his "Bride of Abydos," his "Abduction of Rebecca" ("Ivanhoe"), a dreary waste stares us in the face, which would be hardly bearable if we did not happen to know the poems from which Delacroix drew his subjects. We must put life into his dead pictures by what we remember of our reading. Delacroix stops at the externals. We have to add soul and passion.

After the men of 1830 came, on the one side, the neat painters of the Empire, of whom Meissonier is the best type; on the other, the naturalists with Courbet, the impressionists with Manet and Monet; and so the development went on to the confused struggles of this moment. That period of the July Revolution was felt by its contemporaries as an age of storm and stress in art. On us later-born children it has the effect of halcyon days, the full, rapturous life and sunny joys of which the present generation longs for in vain.

VII

THE TRIUMPH OF A REVOLUTION

THE REALISTS

In the last years of the Empire and the first of the Republic, great things occurred on the sacred hill of Montmartre, on the summit of which the Church of the Sacred Heart had not yet supplanted the Muses and Graces. A group of painters, diminishing in number, yet brave as lions, and pugnacious, arose in defence and attack against the official art of the _Académie_, the _École des Beaux Arts_, and the _Salon_, which was still an institution of the State. Their palette was a battle-shield, their brush a lethal weapon for cutting and thrusting, their easel a barricade. Uproar was what they painted, and plunder and carnage were the subjects of their conversation in endless beer and tobacco sessions. They wanted to massacre the old idols in oil-painting, and the tyrants of the plastic arts now become twaddlers. No more painting by tinker, plumber, or chimney-sweep! No soot in place of air! No Dutch dolls in tin armour, with volunteer firemen's brass helmets on their gingerbread heads! On the contrary, an honest rendering of phenomena of light and colour from actual observation, sincerity, open air, and impression.

The first to gather with fury and wild gesticulation around the daring preachers of the new gospel were literary men and journalists. They did not understand anything about painting, and would not have been capable of distinguishing a varnished oleograph for a cab-drivers' public house from a real Leonardo; whether a picture was blackened or saturated by sunlight, whether a human figure was clumsily conventional or felt and understood with truth to nature, that was to them quite as indifferent as the colour of the Empress of China's dressing-gown. They had, however, the feeling that this movement in art was, in some way or other, connected

with thought of general subversion, and attacked the government. They thought they heard the naked women in Eduard Manet's "Down with Napoleon" shriek. The gleaming, noonday lights of Claude Monet seemed to them a cry for vengeance for the _coup d'état_. They understood Pissarro's landscapes as illustrating Victor Hugo's _Châtiments_, and Renoir's dancing _grisettes_ clearly pronounced a crushing verdict on the Mexican Expedition. All the enemies of the Empire regarded open air as an item of their political programme. To be a true republican one must swear allegiance to realism. Thus Gambetta and Zola became fanatics of the new movement, not on æsthetic principles—such did not exist for either—but from a tendency to opposition.

We should be wrong to laugh at a Radical mob orator and an anarchist novelist being fervent advocates of a school of painting from party interests. It arises out of a quite correct feeling. "All is in all." A close relationship unites all the phenomena of one time, and the most opposed forms may express a single fundamental mood. About 1868 realism meant quite as much a revolt against a bit of authority as republicanism did. Were not a luxuriant beard and a soft hat in 1848 proof positive of revolutionary sentiments? And about 1895 were not a tail-coat and a flowing neck-tie the acknowledgment of belief in blank verse and Maeterlinck?

From the first moment, then, realism had the honours of the opposition press and the support of those politicians, the majority of whom, later on, were to play the principal parts in the revolt of the Commune. The artists, to be sure, despised it at first, as long as it gained no _Salon_ distinctions and had no market. For a long time—for some decades—it had none. The public regarded the works of the new movement only as expressions of unconscious or intentional artistic humour. It laughed at them as it did at the saucy caricatures in the comic papers. There was perhaps only one individual who, a generation ago, took the Manets and Monets, the Renoirs and Pissarros seriously, and was prepared to manifest his belief in them by ready money—the only genuine martyrdom in our days—and this seer, prophet, and confessor was Caillebotte. He bought their pictures; not at a big price, it is true, for we must not expect the superhuman from mere mortals, but he bought them; he poured out his red gold for them, and this sacrifice probably preserved the life of realism, or, at any rate, of its teachers.

Caillebotte himself painted, but only for himself, and that was praiseworthy; but what was more important, he had acquired a handsome fortune by commerce, and spent the major portion of his fine income on open-air pictures. He did not exhaust his enthusiasm by that. When he died, he bequeathed the most striking pieces—"the pearls," he called them—of his collection to the French State, on the condition that it left them together and accommodated them with a room in a Paris museum.

The Department of Fine Arts at first made difficulties; but finally, it resolved to accept the bequest. The Luxembourg Museum was enlarged by an additional building, and a small room in the new wing now accommodates the pictures left by Caillebotte, amongst which he also smuggled in two from his own brush. Thus the Revolutionaries attained the honours of a State museum. This triumph crowns an adventurous campaign which, after apparently fatal defeats at first, led from victory to victory, and from conquest to conquest. For a decade and a half the art of the Manets and Monets has dominated painting. Only in the works of a few obstinate old fogies is their spirit untraceable, at any rate on the Continent; for in England, to be sure, they have not succeeded in gaining the slightest influence on the Præ-Raphaelite movement. On the other hand, in countries without old and uninterrupted art traditions of their own, for which the history of painting begins at the moment in which they themselves first co-operate actively in it, therefore especially in North America and Scandinavia, there is, as a rule, no other art. When the painters in these countries awoke to art, that was the newest thing, _le dernier cri_ of realism, and they took to this latest fashion, just as, in new colonies, negro ladies, who yesterday knew no other aid to their dusky loveliness than an apron of plaited grass and a few glass beads, insist that their toilet, or, at any rate, portions of it, shall be quite up to date.

But the victory in lands barbaric so far as art is concerned, and the apotheosis in the Luxembourg Museum, do not spell the end of the battle or the conclusion of peace. Realism had even recently to fight hard battles of persecution. Whilst the crowd pressed into the Caillebotte room, which was opened in 1897, and, it must be admitted, gave expression to very mixed feelings, certain masters of the Art School, the narrow Academician, Gérôme, at their head, sent to the Minister concerned a fiercely angry warning against the desecration of the Museum's hallowed rooms by the admission of rubbish which they characterised as "scandalous daubs," the "offspring of utter incompetency or lunacy."

The warning was wrongly timed. In 1897 it came too early, or too late. Too late, because Manet and Monet have apparently held their own against Gérôme and Gustave Moreau, and protests are futile against facts, or what are regarded as such at a given period. Too early, for people then still stood—and probably they stand now—at an insufficient distance from the movement now called impressionist to regard it from the perspective of history, and to assign it its proper place in the development of painting. That moment will come, most likely very soon. Then the protest of the Academicians will be superfluous, for even the æsthetic boors will repeat the verdict, then become a commonplace, that realism had its justification; that, besides transient harm, it was the author of

permanent utility; and that, after a half-miraculous progress not uncommon in the history of art, the new men, who themselves could do little or nothing at all, taught more competent successors something precious.

The Caillebotte room will help to bring about a correct estimate of the revolutionists of "the 'sixties." Gérôme ought to have rejoiced at the opening of that room, for it really, for the first time, sets a legend in the light of history. For twenty years everybody has thought he had a right to chatter about realism, though few have really seen the documentary monuments of it, because up to now they were never conveniently accessible as a whole. The prototypical works of the Naturalist School were mostly shown cursorily in rare and little noticed exhibitions. Then they hung in their authors' studios, or in some private collections. He who had not lived in Paris for thirty years, and observed with close attention all the details of the art movement, or did not undertake troublesome journeys of exploration and discovery, could speak of them only from untrustworthy imitations, or from absolutely worthless hearsay. Now, at last, the material can be seen by all. Whoever is capable of receiving his own impressions can procure them.

Extravagant enthusiasm for the pioneers of the "Open Air" movement will now be quite as little excusable as its condemnation without mitigating circumstances. The former will, in face of the Caillebotte room, be recognised at the first glance as sheer weak-mindedness, the latter as lack of understanding. That is the great service of this room in the Museum: it adduces all that can be said on behalf of realism, and shows at the same time, inexorably, its limitations.

I should like beforehand to exclude Raffaelli from the painters that appear in this collection. He is not a labourer from the first hour. Even later on, when he joined the movement, he was no orthodox believer. People, from their superficial knowledge, jumbled him up with the realists, because he was at first always, as the latter were often, a pessimistic confessor of the truth. His peculiar temperament decided his choice of sad subjects. In his outlook on life he was wont to dwell, with self-torturing choice, on depressing sights: on the sick in lazar-houses; on the homeless tramps in the moats about the Paris forts; on poor, human wrecks that float through the street-current of the great city. He told the story of these men with heart-breaking accuracy. He depicted them in mean, miserable, mud-tints; in the dust-grey of unswept, suburban streets; the sickly lime-white and dung-brown of neglected house-walls; the washed-out greenish-blue of worn-out cotton blouses. In this mood was painted his "Convalescents in the Hospital Yard," with its livid faces beneath the white skull-caps, and emaciated bodies in blue dressing-gowns, on the dank, moss-covered stone benches, in front of the sullen lazar-house. This picture, like all of Raffaelli's, makes up for the unpleasantness of its story by the severe honesty of its drawing; and in the street picture, "Behind Notre Dame," the astonishingly effective employment of the gay red kerchief of a workwoman in the foreground, amidst the subdued tones of a murky Paris day in uncertain weather, shows what a clever and faithful colourist this painter is, who so long painted obstinately from a degraded palette. Nowadays, he has, in the main, overcome his depression of spirits, and in his soul a bright sunshine laughs, the rays of which are discernible in all his later works.

The real originator of the new tendency was Eduard Manet. Of his three pictures in the Caillebotte room, one, the "Olympia," is a masterpiece. It had already long been the property of the Luxembourg collection, and amongst the academic works of that Museum it seemed so strange that it forced expressions of repugnance from most visitors. After this comes an insipid brown lady in a mantilla, and the important "Balcony." "Olympia" is a faded, decayed lady of the class which people in Paris are accustomed to describe as "the old guard." The person, whose hair is dressed for a _soirée_, but who is entirely without clothing, lies outstretched on a bed, displaying her charms, which might convert Don Juan himself to the monastic rule of chastity. By the couch stands a pretty negress, busied with her mistress. The "Balcony" shows two ladies with a gentleman friend, and a man-servant in the background. The two pictures display Manet's purpose and method. There is nothing of impressionism and open air to be remarked in the "Olympia." The scene is a closed room filled with diffused rays of chamber-light. The figures of the two women are accurately painted, indeed in a painfully and curiously dry style. In vain would one look for the smartness and bold dashing on of colour that are now held to be the characteristics of impressionism. It is all painfully and laboriously measured, without swing or freedom, without mastery over the model or the tone. The picture is revolutionary only in its straightforwardness. When it appeared, the academic masters painted prettily. When they had to represent nudity, they painted a sort of conventional rose-coloured jelly, without bones or physiognomy, smooth, ordinary, and superficially pleasing as a china doll, inartistic, and unspeakably tedious. In his "Olympia," Manet rebelled against this prettiness in painting that so falsifies nature. He chose the most repulsive model he could find, and reproduced it with literal exactness in all its repulsive truth. He showed that there is female flesh not altogether too old that is not composed of snow and rose leaves. He taught his truth brutally and unwisely, with churlish violation of good taste and gallantry, but with ardour and conviction. The "Balcony" already announces the joyous tidings of open air. The two women are bathed in full daylight, which cruelly misuses their faces. Here, too, Manet wears the blinkers that narrow his artistic horizon. He wishes to oppose sunny brightness to the brown broth which was given out in the masters' studios as the only colour whereby one could find salvation. He therefore lavishes his light, which overcomes and disperses the darkness; but he forgets that sunshine

influences local colours; that it gives them various effects, according to their illuminative power; that it envelops and blends them, however opposite they may be, in one single underlying harmony of silver or gold tone, and with no more misgiving than a saucy child, he lays on the canvas the true colours of things unaltered and unbalanced. I do not doubt that the grey-green of the window-shutters and the arsenical green of the obliquely crossed iron bars of the balcony are painted with the very trade colours which the house-painters actually use for these objects. Of course, this truth in detail produces the greatest artistic untruth in the whole, and the picture that was to be the Whitsun sermon of holy "Open Air," becomes, through Manet's inadequacy, a speech for the prosecution of the sun.

Claude Monet, the classic of impressionism, is not to be reproached with any incapacity. His execution never betrays him. He says what he wants to say to the last dot on the "i," and if what he has said fails to satisfy, it is not because he lacked words, but solely because he had no more to say. Monet is a tippler, a drunkard so far as light is concerned. He cannot pass by any lively brilliant illumination without turning in for a painting-bout. Form, however, is to him a matter of indifference; it has no physiognomy for him, nor does it arouse in him any association of ideas. He neglects it absolutely. He does not draw or compose. In his pictures everything is without form, as in nature herself, unless we regard her with pre-existing thoughts of arrangement and meaning—in short, under the optical and logical categories. But he has not his peer in arresting the fugitive magic of sportive rays, their motes, their refractions on surfaces of every kind, on fixed bodies, liquids, and gases. His "Railway Station," with its wide opening towards the railway line, the bluish clouds of smoke and steam from the puffing locomotive transfused with light, the shimmering vapour under the framework of the iron roof, is unsurpassable as a rendering of absolutely meaningless effects of light. Pictures of this sort will become expressive only when the photography of natural colours is so perfected as to admit of instantaneous copies. Equally remarkable as painting, and more valuable as higher art, is his "Interior of a Room," with a shadowy boy and plants in the foreground, and a shining floor flooded with blue from daylight pouring in like a cataract through the window in the background. More valuable artistically, because this interior of great elegance, this outline of a child, and this blue, fairy-tale tone of the flood of light, are capable of awakening mood, _i.e._, will have an effect not only on the senses but also on the soul; will stimulate not only the optic centres of perception, but also the higher centres of conception and judgment. "Breakfast in the Open Air," and two landscapes and marine pieces, are painted after the same rule as the two panels I have described.

Gueuneutte's "Morning Porridge" draws its inspiration from Raffaelli, Degas's "Dancers and their Mothers" from Manet. I put Degas, however, above Manet, for he draws more lightly and smoothly than the latter, and when he has to depose to ugly reality under the witness's oath of his naturalistic conscience, he does it, not in an angry and provoking way like Manet, but with the divine gift of humour.

Monet's joy in light becomes with P. M. Renoir an affectation. He has not the simple love of truth of his comrade. He falls into exaggeration which betrays conscious purpose and straining after originality. His two "Young Girls" at a piano of the colour of cranberry syrup; his nude figure of a woman, on whose skin lights and shadows play so unfortunately that she looks as if beaten black and blue, in places even as if studded with the corpse-stains of putrescence in the second degree; the "Girl in the Swing," and particularly the "Ball at the Moulin de la Galette," seek rather to disconcert than to convince us by their unwonted tones. These pictures have historical importance as ancestors. From their jests of colour are descended the jokes of Besnard, from their rain of sunlight through shadowing foliage comes the piebaldness of a Zorn and particularly of a Max Lieberman, who make an eruption of yellow and reddish spots fall on their bodies. Renoir's "Girl Reading" finally is a simple aberration. He who tolerates such stumps of hands in a picture that is not meant for a mere sketch is either without capacity or without conscience—the one as bad as the other.

Pissarro is the triumph of seeing without thought. He seizes all the marvels of transformation which the light of various periods of the year and hours of the day accomplishes on objects over which it skims, with the same certainty as Monet, but he imagines even less over it than does the latter. With him the impressions which he feels from the outer world do not generally pierce beyond the back of his eyes. He is a remarkable instance of the sharpest sight with the retina in conjunction with absolute soul-blindness.

The panegyrists of impressionism assert that it was not well represented in the Caillebotte collection. That is a pretext of perplexed swaggerers who can now be nailed fast, and who should in shame and confusion crowd here, where it is easy to test their wild exaggerations. Impressionism has never produced confessed more characteristic works than those gathered in the Caillebotte room. It has never been more straightforward than in Manet's "Olympia" and Degas's "Theatre Mothers," never more bright than in Monet's "Breakfast in the Open Air" and Pissarro's landscape, never was it in a higher degree lightening-sight and instantaneous painting than in Monet's "Railway Station." Every verdict on impressionism based on this room is an adequately grounded verdict, against which the attempted higher appeal to I know not what unknown works must be rejected.

The painters who entered on the new movement are interesting as men, because they aimed at much, and at what was comparatively great. They are, from an artistic standpoint, uninteresting, because they achieved little. It is the old tragedy of the will, to which the strength plays traitor; of the mind, which subjectively and _in posse_ brings about the highest, but objectively produces nothing, because it fails in realisation. The Manets and Monets, the Renoirs and Pissarros, wanted to create a new art by returning to the old truth. It gives them a right to reckon themselves as belonging to the family of the illustrious heroes of the Renaissance, who emancipated themselves from the traditions of the Byzantine School, as the former did from the sham-classic rule of a Couture, a Cabanel, or a Baudry. The man affected by a Cimabue and a Giotto will not be unmoved in the presence of Manet and Monet, especially of Monet, for he performed a creative act. He said: "Let there be light," and "there was light" in painting. The miracle of Genesis is still being wrought to-day, and only in Gustave Moreau and the Præ-Raphaelites has the Logos proved itself powerless.

After paying them this tribute of recognition we will also take leave of them. They have pointed out paths, but they have not walked in them. In place of intricate Chinese signs, they have invented a free, brilliantly progressive alphabet, but in this script they had nothing to say. Their art is merely optical—neither emotional nor ideal. They were commonplace—nay, to some extent—unbeautiful souls. That is why, despite their honest passion for truth, and despite their precious medium of sunshine, they have not been able to produce genuine art-work.

They have meanwhile not lived in vain. Their influence has been fruitful. At first it indeed generally did harm. All bunglers flew to imitating them, and the impudent rabble of both worlds alleged they understood their teaching thus: "Drawing is superstition, and the more repulsive a hide looks, so much more beautiful and especially more modern it is." But after this scum of the artistic rabble those who had a vocation came over to the new movement, and showed what it could achieve in consecrated hands. With the open air Roll became the master he is; impressionism brought a Brangwyn to maturity; truth—the beautiful truth, not the repulsive, vulgar truth—found its triumphs in a Whistler and a Sargent. The weaknesses and mistakes of the forerunners have furnished despicable parasites with the transitory reputation, among the weak-minded, for genius, which will quickly disappear before the recognition of their wretchedness. Their lofty views, and, to some extent, the means of expression suggested by them, have, however, equipped men of illustrious talent, who permanently enrich mankind's property in works of beauty.

ALFRED SISLEY

Alfred Sisley was one of the most renowned amongst that group of realists to which I alluded in my foregoing appreciation of the Caillebotte room in the Luxembourg Museum. He, too, like his companions—Manet and Monet, Pissarro and Renouard—was a rebel against traditions, and a preacher of new gospels. He also denied old idols with fine disdain, and preached doctrines that seemed to him to embrace in themselves the whole truth. He managed, indeed, to collect a few convinced disciples, but, on the other hand, hardly any congregation about his altar or pulpit; and this was due simply to the sobriety and uncongeniality of his dogmas, which failed to satisfy the cravings for æsthetic devotion of the faithful.

Sisley was a landscape painter. He was purely this, to the exclusion of every admixture. He never introduced a human figure, and, so far as I remember, only one of an animal, into his paintings. The only life that moved and stirred in them was that of atmosphere: the play of lights, of their refractions, of their coloured dust, of their vanishing in shadows and darkness of various depths. Even the vegetable world, though one of the most important elements in academical landscape painting, he treated slightingly. He had no respect for the attractive individuality of a tree. It interested him at most as an object in his field of view, which catches and diverts the beams of the sun in a particular way. He saw nothing of the marvels of colour and form of the minute life, that is displayed in a piece of turf, a bush, or underwood, and reveals to the thoughtful and experienced eye the whole nature-tragedy of the struggle for existence: the despairing striving in the various plants for air and light, or moisture and shade; the victorious domination of one or several species; the meek supplication for mercy of single scattered flowers or plants; the defeat and flight of families unable to maintain their position against superior antagonists; the intrusion of bold strangers demanding for themselves a place among the old settlers; the confederacies of friendly groups that reside together and trust each other; the single combats of enemies seeking to throttle and uproot one another. He who has never gazed deeply into nature perhaps regards all these pictures of combat and triumph as mere phrases, corresponding to nothing real. The biologist of plants knows better, to be sure, and many a landscape painter too; so did the first English Præ-Raphaelites especially. However unbearable their vagaries and perversions may be—on these I will not enter now—this one thing must be said in their praise: they understand and love plant-life. For them every grass and herb, to say nothing of those lords, the trees, has a physiognomy, a personal mystery, which they know how to unriddle, and reveal, or, at any rate, indicate. Of all this Sisley knows nothing. For him a grassy mead is a plain of colours with gradations, starred with

varied patches; always a mere study of light and nothing else; never an expression of events of life.

Here lies the limitation of his capacity. In my book, "Paradoxes," I have tried to classify painters according to the rank of that segment of the central nerve-system, in which their talent is rooted. By this method I arrived at a distinction between painters who feel joy only in colours and their harmonies, and others who, besides delighting in colour, often even without this, have a developed sense of the proportion of things in space, therefore, of forms, reciprocal distances, movements so far as these latter can be indicated by means of the painter's fixed process: those, in short, who know how to elicit from visible phenomena an invisible, emotional significance, and to represent them so that they express, in a natural way, psychical processes and feelings, without becoming falsified through the intentional introduction of arbitrary features foreign to them. Now, Sisley is an instructive instance of those painters who are painters only through their retina and lowest centres of perception, viz., their feeling for colour, and the vivid sensation of enjoyment it affords them.

Sisley has the most delicate sense for the lightest gradations and depths of colour. If I may use an image from an adjacent intellectual domain, he does optically what an ear would do acoustically which was capable of feeling purely all the tones of a chromatic divided, perhaps, into sixty-fourths. This faculty gives him his rank as an artist, but it was also the torturing demon of his life; for he wanted to reproduce with equal clearness what he saw so distinctly. That is, however, impossible by the medium of oil-painting. Let it never be forgotten that the colours an artist uses are very different from the natural appearances which they wish to recall. All painting is a translation that falls short of the original text, and even the most refined palette only permits a vulgar groping after the subtle play of colour in the reality. It is sheer convention, to which our eyes are artificially trained, that we recognise in definite play of colours, human flesh, an evening sky, foliage, or mirroring water. In all cases we have, at most, approximations before us, and even a man's countenance by Franz Hals reproduces the true coloration of the skin on a human face, as little as perhaps the well-known _scherzo_ in the second movement of the Pastoral reproduces the true note of the golden oriole. Sisley, overlooked, like the majority indeed of impressionists, and like many very juvenile stipplers and black and white artists, this technical main condition—if you like, this main defect—of all painting with media as at present known; and he obstinately insisted on overcoming a difficulty that is, as a matter of fact, insuperable. The whole labour of his life is a struggle with the resistance of matter, intensely pathetic, but, nevertheless, finally only irritating, because its utter hopelessness is admitted. He tries to square the circle, which, as may be proved to him, is not feasible, and he aimlessly dissipates his energies in this futile effort. He is bent on arresting the most fugitive vanishing, the gentlest swaying of a ray of light, and, as it were, the fourth decimal place of a fraction of colour, and on fixing it on the canvas. And as he cannot conjure forth this feat from his colour-tubes, in spite of the most learned and complicated mixing, he tries to reach his goal by newly invented tricks of the brush. Thus he gets to dotting and spotting. Innumerable minute touches with the brush are to leave behind a chaos of colour-dots, from which the eye may come to discern, or, at any rate, get an inkling of, the play of colour in the actual object. This method is extremely laborious and risky. It postulates great patience and ability to emphasise in the minute work the firm lines of the drawing. For if one loses sight of these lines, or cannot make them ring out clearly from the colour gamut disseminated equally over the whole canvas, the picture dissolves into a shapeless daub. Sisley himself is often wrecked on this rock. By his method, however, in a few happy moments, he obtains, to be sure, effects which would scarcely be deemed possible. Then we may enjoy in his pictures a real dance of sun-motes in transfulgent air.

A single picture of Sisley's even the connoisseur easily passes by. It is insignificant. Even a whole row of pictures which represent different themes will hardly make a great impression. At most, certain delicacies of tone, a certain far-sighted clearness of atmosphere, make an impression. If, on the other hand, you see near one another panels which depict the same subjects at different hours of the day or seasons of the year, under different lights and conditions of weather, you grasp in astonishment the meaning of this artist. The subject is the same, but so altered as to be hardly recognisable. People marvel at the power with which Sisley can arrest strangely changing aspects, and gain some faint idea of the difficulty which the exposition of observations calls for, observations which are generally out of reach of any but the most acute feeling and the most painful attention. Sisley has openly admitted that his skill is unintelligible without the key afforded by comparison. That was why he exhibited, as a rule, at least two—usually many more—treatments of the same subject. Thus in the _Salon_ in the Champs de Mars in 1898, he showed a beach, "Lady's Cove," in two lights; and, in 1896, Moret Church, in transparent pale lilac just before sunset, and also in softly-veiled slate-grey in rainy weather. I remember a row of studies of the same village church, which ran through all the divisions of the spectrum, one after another, and, on each succeeding panel, was a revelation the more dazzling in proportion as one already knew its form in all its details. Sisley has hardly ever had his equal in transposing a piece into different keys.

Admiration for the almost morbidly exaggerated sensitiveness to the slightest differences in tones of colour, and sympathetic feeling for the artist's despair at the inadequacy of a technique, gross, after all, as the medium of the most delicate intentions—these are the impressions which one feels at even the most friendly consideration of Sisley's most successful works. Dreaming and longing, reminiscence and presentiment, on the other hand, they never inspire, for they are absolutely lacking in all psychic, emotional, and imaginative sense.

From the example of Sisley, we recognise the accuracy of the maxim which, when put nakedly, sounds almost provokingly paradoxical, and yet is literally correct, viz., that landscape painting, or, at any rate, a certain kind of landscape painting, is the most literary of all species of plastic art, the one from which the least is received, and into which the most is put. Landscape painting seems to reproduce nature herself, and therefore necessarily to be as objective as a land surveyor's plan, or even as a photograph. It is, as a matter of fact, incomparably more subjective than portrait, historical, or _genre_ painting, for there is throughout, not nature over again, but the features of nature which have excited the attention of the painter, and aroused in him a mood. It therefore discloses to us, more than any other kind of painting, the soul of the painter, the peculiarity of his mode of feeling, the bent of his dreams, and the object of his longing. If every work of art is a confession on the part of the artist, landscape painting is a particularly complete and honest acknowledgment. It is a portrait of the artist, which he himself has painted, transcribing all the wrinkles of his soul.

Nature in herself is absolutely expressionless. The feeling of the person who contemplates her first adds expression, just as his senses translate the movements of the atmosphere and matter, which are, in themselves, devoid of colour and sound to the perceptible values of colours and tones. The contemplation of nature awakens in us associations of ideas, and these we project into nature. Therefore we find, again, in this latter the whole range of emotion and thought of our consciousness, and nature, therefore, influences every one who contemplates her correspondingly to his education and mental habits.

Landscape painting is, then, also a continuous illustration of the literature of its time. It is anti-classical in the Renaissance and Late Renaissance up to Poussin; Ossianic and Rousseauesque in the eighteenth century, and, in Corot, is Lamartinish. It would, of course, be going too far to point out here what the relations are between each individual great landscape painter and the writings of his contemporaries; and how certain notable exceptions from the rule of parallelism between landscape painting and the fashion of the day in literature—Salvator Rosa, Ruysdael, and Turner (just to mention only three)—are to be explained. It is, meanwhile, not to be disputed that the landscape painter approaches nature with a soul filled with the literary spirit of his time, and puts into her what he has retained from his reading. A painting, then, awakens also in the mind of the spectator an echo of all the poetic melodies that have enthralled him, and it is the soft echo of these thousands of poetic voices in our soul, to which we listen when we enjoy a landscape painting.

We listen, however, in vain before a picture of Sisley's; all is still in our soul. This is because the painter has regarded nature from a wholly unliterary standpoint. She awakens in him no associations of ideas, therefore his pictures awaken none in us. He has seen the play of colour, found his delight in it, and has taken no further thought, but has merely striven to reproduce it accurately. We follow his efforts with curiosity, and approve the results if they are successful. But in this appraisement, humour and imaginative power have no part.

Is such landscape painting art, or a clever trick? The question is worth careful consideration.

CAMILLE PISSARRO

One of the most interesting artists in our times was this Pissarro, born at St Thomas in the Danish Antilles, though of a Dutch Jewish family of Spanish extraction settled in Curaçoa, who died in Paris in 1903 at the age of seventy-three. He was a born painter, of the class whose sense of form hardly exceeds the average, whose remarkably fine perception of colour, however, reacting very strongly on every optical irritation, makes the excitement of the retina the source for them of profound feelings of pleasure or the contrary, and fixes their idea and thought, to a certain extent polarises it according to colour.

It is sufficient to say few words as to his outer life. Impelled by his bent for painting, he came to Paris at the age of twenty, and had the good fortune to be taken as a pupil by old Corot. He saw Th. Rousseau and Millet working with his master, and he lived during the most susceptible years of youth amongst such originals, in the most glorious Barbizon period. His natural tendency directed him imperiously to landscape painting. This, then, is the substance of his whole life as an artist. Incited by Millet's example, in his young days he put peasants in his fields and meadows, but they were always mere accessories in the landscape, and arrested the eye less than the ground and plants. He had then also sufficient knowledge of himself to abandon, at an early stage, human figures, for

he realised that there was more life in the tiniest sod of his turf than in his conscientious but insignificant villagers. In the high school, in which it was his privilege to learn, he acquired that certainty and force which distinguished him up to his old age. When, however, he had mastered Corot's brilliant technique and Rousseau's draughtsmanship and composition, he ceased to be an imitative disciple, and with full deliberation, went his own ways, which for a time lay far from Corot's goal, but at last, by a wonderfully circuitous route, brought him back to it once more. Not long did he try modestly and laudably, with a good young man's carefully moderated works, in the _Salon_ for certificates of industry and good marks from the academical masters. At once he joined the hot-headed set; he exhibited, from 1864 onwards, only in the "Salon of the Rejected" and with the "Independents," and became one of the most prominent men in the group of impressionists.

Nothing is funnier than to read the explanation of the terms "Impressionists" and "Impressionism" of certain art-gossipers among the critics in Germany. These transcendental phrasegrinders, who have no notion how the word arose, believe it was invented by painters or æsthetics with the set purpose of characterising an artistic tendency, and of indicating elliptically a method of execution; and, with the rapturous, prophet-mien common among this brotherhood, they treat us to the deepest and most breath-ravishing explanations of the word. The truth is that the expression owes its origin to the jest of a comic paper that intended nothing special by it, least of all an æsthetic theory. In 1874 the painters who for ten years had been known as the "Open Air" artists or "Realists" exhibited a number of their works in the reception-room of the writer and photographer, Nadar. Claude Monet appeared, amongst others, with a sunset, which was quite in the manner of Turner's last years, and he entitled it "Impression." It was a remarkable and characteristic work, without form, consisting only of streaks of red and orange, in the highest degree offensive to those who will not have the contemplation of nature restricted to the observation of colours, but look also for outline and modelling. A wanton scoffer, making merry in the "Charivari" over this exhibition, seized on Monet's "Impression" as the pattern of the new style, sneered at it in the tone of a genuine back-biter, and, with the object of belittling them, called Monet's fellow-combatants "Impressionists," by which he meant only that, according to his view, their pictures were daubs, just like Claude Monet's "Impression." That is the simple origin of the word into which the German commentators have read something exceedingly mysterious and wonderful.

Pissarro belonged to Monet's circle of friends, and fell under the designation, which rapidly became current, of "Impressionist." In his case, it only means that he sought and found in nature only effects of light, only the play of sunbeams on things and around things.

In the three or four centuries that landscape painting has been raised to the rank of a branch of art—I leave out of consideration, in this place, the ancient landscape, because the modern development is unconnected with it—an enquiry, which enters into the motives and aims of painters, can distinguish three different kinds of landscape, which I would term respectively the literary, the lyric, and the optical. I do not choose these new designations for old and well-known things arbitrarily, but because, in my opinion, they mark what is essential better than do the prescriptive ones.

Literary landscape, on which I have already briefly expressed my views in treating of Sisley, is that which traditionally goes under the names of historical, heroic, ideal, or artificial landscape. It is not prompted by delight in nature, but is either the offspring of imaginative power or a piece of intellectual know-all work, in both cases, the result of reading. It is, to put it briefly, a continuous illustration of the literature in vogue. Since the Renaissance, ancient heroic materials have been specially favoured in poetry. The Spanish theatre, Corneille, and Racine lived on them. Even if they placed the lofty exploits of their heroes in a less remote past and on another stage than the ancient world, still, they endowed them with hundreds of reminiscences of the Græco-Roman mythology and history. Poussin, and even Claude Lorrain, conceived their landscapes as the frames of heroic romances and dramas. They were designed as stage decoration, which the spectator might people from his memory with figures in Roman mail-armour or Gothic plate-armour, familiar to him from contemporary poetry. In order to facilitate this play of fancy, ancient temples or ruins, perhaps even men in classical garb, helpfully stimulate the association of ideas. J. J. Rousseau substituted the sentimental for the heroic fashion; but the return to nature, which he and his innumerable imitators preached, did not to landscape painters at all mean the sinking into the contemplation of God's actual world, but only the substitution for the heroes and knights, the upright or fallen marble pillars of their predecessors, of shepherds and shepherdesses, rustic cottages and herdsmen's fires. Thus landscape painting illustrated in turn Orlando Furioso, Jerusalem Delivered, the Æneid, the tragedies of Corneille and Racine, Rousseau, Gessner, and Ossian; then, nearer to our time, Victor Hugo and the Romantics, Zola and the Naturalists, down to the latest symbolists and mystics, whose contemplation, so far as one can speak of such a thing in their gassy heads, greets us from the pictures of Burne-Jones and his continental imitators, and also from the landscape compositions of Puvis de Chavannes and Henri Martin. It may be safely affirmed that, of the pictures of literary landscape, not a single one would have been painted unless a book or some species of literature had, to some extent, commissioned them with an exact specification of all details.

Lyrical landscape is that which is perhaps also designated landscape of mood. It is more consistent with nature than literary landscape. It owes much less to reminiscence of books or plays; its only relation to literature is that through this the painter is schooled to be more susceptible of certain features of nature. Landscape pictures of this species could be painted under some circumstances by artists who had never read a book or heard a poem, if only their own disposition were attuned to poetry. For this painting the landscape itself is a poem—ballad, romance, or idyll, in many cases, perhaps, even a melodrama. It tells some tale, or hints at one, the more delicately so much the more expressively. The wrinkles of the ground, the irregularity and abruptness of the lines of mountains, the gloom of the woods, awaken presentiments; our yearning follows the paths which are lost in the blue distance, or behind hills and bends; coolness rises from the foaming rivulet; mystery broods over the motionless fish-pond. Everything unspoken, or partly unspeakable, which a keenly perceptive man of deep contemplation imports into nature, moves and reigns in and over the lyric landscape painting. It expresses a complex, subjective mood, embracing in itself many elements of sense, feeling, and thought—the joy of spring, the melancholy of autumn, the cheerlessness of winter, the shudder at the weird, the dread of eternity. It is viewed anthropomorphically. It owes its strongest effects to traits which do not exist in nature herself, but are added to her by human imagination. Japanese art knows only lyric landscape. In Europe it was first developed by the great Dutchmen, Ruysdael and Van Ostade, to attain in Corot its zenith unsurpassed up to the present time. As it lays expression into its forms, it must figure the latter distinctly. It draws and composes, therefore, with deliberation. It proceeds from the realistically rendered topographical anecdote, even if it achieves this by the transcendental.

Optical landscape, finally, is that which seeks to reproduce only the play of convergent or divergent, of reflected or broken light in nature. It is neither book-illustration nor views of places. It does not invite to the enjoyment of nature in the sense of the Sunday excursionist from big towns, or the summer tripper. It offers no scene with suggestion that we should live out our subjective moods there. The outlines, the plastic of the bodies, are a matter of indifference to it. Everything is merely a patch of colour to it; only an arena of dancing sunbeams. It wants to reproduce, as truly and fully as possible, the change and merging of lights and shades, the reciprocal influence of neighbouring and overlapping colours, the _crescendo_ of hues in the foreground and their fading away in the perspective. It systematically rates the intellectual and moral relations as foreign to its art. It is not enthusiastic for a particular season of the year or a certain architecture of cliffs and mountains. It knows nothing of the secret magic of water, heath, forest, or snow-plain. It gives light in scales, and in harmonised and dissonant chords, and will give nothing else. This landscape painting is an art of purely sensual preception, which may call pre-existent feelings and thoughts over the threshold of consciousness, but brings about no feelings and thoughts of itself. It is to be compared with the effect of the Æolian harp, which stimulates our hearing with melodious sound, but says nothing thematically differentiated to it. Debussy, latterly, consciously strives back to these origins of acoustic pleasure. The disciples of Turner in England and on the Continent enter in landscape on the same way back to a style of painting which, neglecting form, lays stress on the harmonies of light and colour.

In practice, besides the three sharply outlined species of landscape painting, manifold transitions and mixed forms are, of course, also observable. If, perhaps, G. Poussin represents literary, Corot lyric, Turner, at the time the formation of his cataract began, optical landscape, in its theoretical purity, we see in Claude Lorrain a revelling in light and a poetic mood penetrate the mytho-heroic literary painting which he owes to his artistic training, and from which, in spite of higher flights, he could never entirely free himself; and Segantini is a good example of an originally lyrical landscape that is always more strongly inclining to the optical; for if at the beginning he loved to copy high mountains, at last he busied himself only with fixing the wonder of light in thin air on the mirroring ice and glacier snow.

Camille Pissarro was mainly, in separate periods of his artistic development exclusively, an optical landscape painter. The attunement with nature which is afforded by the meeting of mountain and wood, water and reed, by the forms of trees and cliffs, the peculiarities of plant-life, and the movements of open country, he evidently did not feel and he cannot arouse. He was nothing, and he wanted to be nothing, but a priest and poet of light. When light fell, what objects it illumined and played on was a matter of such indifference to him that this landscape painter painted city scenes just as often as those of open country. Views of the Paris Boulevards, the Avenue de l'Opéra, the Seine seen from the bridges, the streets and squares of Rouen, occupy quite as large a space in his work as studies of the valley of the Marne and the hills of Southern England. Thanks to the good school from which he came, he never, like so many of his rivals, melts away into formlessness. He could not refrain from drawing distinctly. It was the movement of his bold and skilful hand that pervaded his will; but the sole hero of his pictures, to whom he gave his love and attention, was light.

After he had outgrown the formulæ of the Corot type of landscape, he sought with persistent, hot endeavour to find a method that would qualify him to draw into his picture as much light as possible, as intense light as possible, even the whole sun. What he

himself found failed to satisfy him. When Seurat, who suffered undoubtedly from eye troubles, came forward with his stippling, Pissarro at once took possession of the new manner, and became a stippler even unconsciously. Seurat, it is well known, taught that the painter, if he would give truth and force to colour, must not mix the shade on his palette and transfer it ready-made to the canvas, but must dissect it into its primary colours, which are known from the spectrum, and insert them in little dabs by one another, so as to leave it to the eye to put them together again on the retina. This optical proceeding professes to have been learnt by listening to nature, which also offers us only as single colours what we feel as a synthesis of colour. The theory is sheer nonsense. Nothing of the sort happens in nature. When we see green grass we do not see yellow and blue grass which our eye mixes into green, but we see a body proceed from the æther-vibrations of the undulations, which call forth on the retina a sensation of green; and to imitate this influence of the grass we have to employ only one colour stuff from which atmospheric vibrations of similar undulations proceed. Unscientific painters were, however, impressed by the sham-scientific jabber of Seurat, who tried, in his wonted manner, through a subsequently discovered theory, to convert a defect of sight into an advantage; and they applied themselves the more zealously to stippling as the innumerable specks really made bright a twinkling, whirling impression, which superficially reminded one of the vibration of hot air on a sunny plain at midsummer noon.

Only superficially. Pissarro soon discovered that stippling really did not bring more light into his pictures, and he gave it up. He resigned the Seurat method to rivals who rush after eccentricity because they hope to astonish by it, and to whom a style of painting was particularly suitable, which blurred the line with colour and saved them that tedious drawing that always gave them the greatest affliction. He himself, however, returned again to the honest style of wielding the brush, which he had learnt of his great masters.

The stippling episode of his life, which he got over, throws light, however, on the painful, fundamental mistake of Pissarro and his companions. They wanted to paint light, and by that wanted something impossible, for light is not to be represented by colours which do not themselves emit light, and are neither phosphorescent nor fluorescent. All that is attainable by colour is awakening the reminiscence of light, and, by means of the memory-picture illuminating the brain, to cheat our consciousness with the idea of a directly received impression. The very great masters of optical landscape painting soon acknowledge, or feel, that the brush can indeed conjure forth the illusion of illumination, but is unable to paint light, and they turn from a hopeless Sisyphus-task to create pictures of mist and dusk, from which sunlight—a thing inimitable—is absolutely banished. The most instructive example of this is James Whistler; but he who does not possess the instinctive certainty of genius will not be conscious of the limitations of human capacity, and ever rolls the round stone unweariedly up the mountain.

Pissarro would have saved himself many hours of tragic quest, struggle, and sense of powerlessness, had he known or recognised the primary fact which Friedrich Hebbel seized in his theological but lucid epigram:

"He who the sun has created will ever remain quite another Than the industrious wight who for us prospects shall paint."

WHISTLER'S PSYCHOLOGY

"Do you think, prince, that Raphael would not have been the greatest genius among painters if he had been unlucky enough to be born without hands?" Lessing makes the painter Conti say to Prince Gonzaga. A century and a half ago that seemed paradoxical, and was, probably on that account, one of the most quoted maxims of Lessing's. It has, meanwhile, experienced the fate of many paradoxes, viz., become a commonplace. Nowadays, every dabbler in psychology knows that not arm and hand—_i.e._, execution—make the painter, but his optical brain centres, _i.e._, his sensitiveness to impressions of sight, his specific reactions on colour and form. One is a born painter—a painter from organic necessity and natural bent preceding all education—only by special development or susceptibility of this centre.

In painting, however, there are two elements to be kept distinct—drawing and colour. Both these are traceable to the centres of sight, but they correspond to different sensibilities. Optical centres, which perceive with particular keenness and delicacy the distinctions between intensities of light, are the real, organic hypothesis of the talent for drawing; for what we perceive with the eye, without the aid of the senses of touch and muscle, as outline or form, is purely distinction of intensity in light. Optical centres, on the other hand, which are particularly sensitive to the variations of undulations of light, form the basis of the sense of colour and the talent for colouring. As a rule the talents for drawing and colouring appear coupled, even if one or the other preponderates, for highly developed or particularly sensitive optical centres are naturally receptive beyond the average of optical impression of every sort, of differences both of intensity and of undulations of light. This is, however, not always the case, and there are dry, sharp draughtsmen without sense of colour, and some who revel in colour without the ability to grasp the idea of form and render it

plastically.

In a brain that is characterised by a special morphological or functional development or sensitiveness of the optical centres, this dominates all functions of the brain, especially memory and association of ideas. The entire thinking faculty has an optical or visual character; it stands in a dependent relation to sight. Memory clings almost exclusively to reminiscent pictures of the sense of sight, and association of ideas connects mainly pictures of this category. Every perception of form calls up in the consciousness representations of form. The fancy is "inwardly completely full of figures," as Albert Dürer quaintly and with wonderful intuition expresses it in his "Diaries." The world-picture of this brain, always disposed to intense observation, is neither loud nor excited, but bright, flashing, and radiant like a mosaic work of precious stones and enamel. All the inner connections between the different domains of the brain are sharpened towards the optic centres, and all the activities of the brain, all emotions, all processes on the threshold of consciousness also release central optical excitements.

Whistler's life-work reveals more than that of any other artist in our times the deep, organic primitiveness of his genius as a painter. We can observe in him, as in a school text, the psychology of the born painter. His signature is at once a fine example of the association of ideas on the part of a visionary. It consists, as everybody knows who has seen Whistler's works, of a butterfly with evenly outstretched wings. People have insisted on seeing heaven knows what symbol in this, and have consequently sought the wildest and remotest explanations of it. If any one asked the master for an explanation, he laughed, and made a mysterious gesture of refusal. It gave him vast entertainment to see his admirers tormenting themselves with profound attempts at interpreting it. They just had no eyes; they could not see. The butterfly is nothing but the first letter of Whistler's name—a big W. A Gothic, ornamental W with the two side lines bellied out and a bar in the middle reminds one strikingly of a soaring butterfly with its cylindrical body between its outstretched wings. The definite association of ideas from similarity of form made Whistler, as he painted the W of his signature, think of a butterfly, and he henceforward formed this picture that was fuller in expression, disregarding the original letter, which seemed to him balder and more meaningless. The butterfly came to the front more and more as the W went further and further back, and it is possible that at last Whistler himself forgot the point from which he started.

Whistler was, when he liked, in the front rank as a designer of forms. From the severe, painfully upright school of Gleyre he went forth a master of drawing, as of the outline of corporeality of three dimensions seen stereoscopically. One glance at his wonderfully plastic portraits, especially of his first period, teaches this irrefutably; but, on the whole, as his individuality made itself felt, he neglected form and became more engrossed in colour. In the second half of his life the outlines of subjects hardly any longer interested him at all; he only dwelt on their appearances in colour, on the harmony or discord of their tones. That means that his optical centres were much more sensitive to the differences of undulations than to those of the intensity of light. From this there necessarily resulted a contradiction between him and the average individuals which was not to be got over, since it originated in differences in the constitution of the brain. He who has not Whistler's special hyper-sensitiveness to colour is simply unable to see things as the latter saw them. He can just as little imagine the impressions that Whistler feels through his sense of sight as perhaps those which are supplied to a hound by his nose. When the blissfully but painfully supersensitive appreciator of colour and the dull seer of outline, _i.e._, the perceiver of light, sought to explain themselves to each other, inexplicable misunderstandings were bound to arise, which make his celebrated law-suit with Ruskin an excruciatingly comic jest. Ruskin appreciated only draughtsmanship, his mind never went beyond contour. For him a picture was a writing that should express thoughts and feelings in the most concrete form. He demanded that it should be a definite communication, reducible to plain words, as of a narrative, a record of travel, or a treatise on natural science. A picture that differed from an exact representation, just as music differs from articulate speech—a picture that attempted to convey only a general, not a concrete stimulation of the sight-centre sensitive to colour, and the pleasurable feeling accompanying and emphasising it, not only was to him necessarily incomprehensible, but, as he was a dogmatist of strong feelings, seemed to him an impertinence—nay, a profligacy and personal insult. Ruskin's criticism of a "Nocturne in Black and Gold" was a new version of the fable of the stork and the fox who invited each other in turn to dinner, improved to the point of libel. It was childish of Whistler to bring an action against the angry-minded art-inquisitor who required, as the first duty of a painter, the accuracy of a geologist, botanist, or engineer. He should not have expected justice from judges who saw and felt, not like himself, but like Ruskin. Judge Huddleston was of good faith when, in the immortal trial—which Whistler himself has preserved for posterity in his charming book, "The Gentle Art of Making Enemies"—he exchanged with the artist remarks like these: "Which part of the picture, then, really represents the bridge? Do you mean to say that this is the proper representation of a bridge?" (The question referred to "Battersea Bridge by Moonlight.") "I had no intention of giving an exact copy of the bridge." "Do these daubs of colour on it represent human beings?" "They represent what you please." "Is that thing under there a boat?" "It is a consolation to me that you recognise it. My whole object was only to produce a definite harmony of colours." He could hear this harmony of colours: Ruskin and Judge Huddleston could not. It was utterly futile to try to make them feel it.

His peculiarity of giving his pictures fine and pretentious names, such as “Black and Gold,” “Blue and Silver,” “Ivory and Gold,” “Purple and Gold” is also generally misunderstood. People read “Silver and Blue,” and saw indistinctly intricate brush-strokes of blue with elevations in dead white, representing, by way of indication, the high seas by night and in a mist. People hurried to the picture labelled “Ivory and Gold,” expecting to gaze at something like an ancient chryselephantine marvel, or a Florentine masterpiece of splendour belonging to the days of the Medici, and what did they find? The lightly executed sketch of a woman in a yellow and white harmony, in which one looked in vain for the costly materials promised by the title. Not Philistines alone have shaken their heads over this, and evil-disposed critics have talked of hoaxing, foppery, and American bluff. They have wronged the artist bitterly. He was absolutely honest; his optical hyper-sensitiveness felt the colour with so heightened an appreciation of tone that he really saw gold, silver, and purple, where a less susceptible sense could only see dull yellow, deadened white, undecided reddish-brown. In all probability, it was long before he realised that others failed to observe, in the appearance of the actual things and his pictures of them, the rare metals and precious stones, the pearls and ivory, which gleamed from them to him. The common phrase, which is a precipitate of the universal thought and feeling, speaks of sun-gold and moon-silver. Sun and moon consequently make such a strong optical impression on even the average man that he thinks of gold and silver with the accompanying higher notes of ideas of splendour and magnificence. In Whistler’s consciousness, however, these ideas began to be felt with gentle excitations, as whitish foam on dark waves in the night, or a woman’s pale complexion in cream-coloured raiment yielded them. These delicate charms affected his sensitiveness just as the force of the sun or moon affects others. In maniacal excitation, of which the acutest form is madness, the brain of the sick person becomes so supersensitive that it reacts on the ordinary impressions of the senses just as on intolerably violent irritations. Moreover, certain poisons, of which hashish is the best known, derange the central nervous system into a condition of supersensitiveness, in which the person poisoned feels himself inundated with floods of light, and sees a blinding brightness everywhere. The sensitiveness to which only illness or poison raises the average brain, was from nature the peculiarity of Whistler’s sight-centres. He was conscious that in certain respects he had more than others, and he felt as superior to them as the Indian hunter does to a pale face of the towns on a game-beast’s track, which the latter does not notice at all, whilst it gives the former a thousand clear indications. As an artist he was amiably modest, as a man amusingly arrogant. He did not flatter himself on his work, but on his finer organisation, _i.e._, that he was kneaded out of better dough than the majority.

His supersensitiveness is expressed not only in his revel of colour; it is also curiously and graphically revealed in the impressions which he feels of the appearance of women, and which he conveys in his best portraits of women with an intensity no longer restrained within physiological bounds, but positively touching on the morbid. The intensity with which he feels young, high-bred, nervous women has quite an uncanny effect on me. I think of his “Lady Meux,” and other capricious femininities, which were exhibited, in the last fifteen years, in the Paris _salons_ and in London. He plants his model before us in some wonderful position. One stands with its back towards us, but turns its head, as if in a sudden caprice, to us. Another shows us its full face, and looks fascinatingly at us with pinched mouth and impenetrable eyes that think troublous thoughts. These perverted, whimsical beauties wear remarkable and personal toilettes which, except the face and often the hands, reveal not a finger’s breadth of skin, yet, in spite of the interposition of silk and lace, cry out for the fig leaf. They are bundles of sick nerves that, from the crowns of their heads to the tips of their fingers, seem to thrill with Sadic excitement. It is as though they wanted to entice men to wild attempts, and at the same time held their claws ready to tear, with a loud cry of pleasure, the flesh of the daring ones. Everything madly Mænadic, or inexorably Sphinx-like, that Ibsen was incapable of incarnating convincingly in his Hedda Gabler speaks distinctly from Whistler’s female portraits.

They have become typical—typical for copying painters who exaggerate his neurotic women into the pornographic; typical for hysterical women, to whom they suggest poses and psychological states. Félicien Rops perhaps owes him nothing, although often enough his female demons seem Whistler-portraits divested of clothing; he has, from analogous organic hypotheses, independently attained to analogous conceptions of woman; but Zorn’s, Boldini’s, Alexander’s women point to Whistler’s demoniacs. The woman of a given epoch likes to form herself on the ideal which the art and poetry of the time give of the “interesting” woman. Thus Whistler, by means of his female portraits, became an educator of the æsthetically superfine woman of the present day; but Whistler, as an educator of woman, is to me incomparably less sympathetic than Whistler, the delicate appreciator and symphonist of colour.

VIII

GUSTAVE MOREAU

The house in which Gustave Moreau spent the seventy-seven years of his life (1826-98) has been turned into a museum which contains nearly all his life's work, according to the catalogue 1132 items, from the copies and sketches of his youth, through the great finished paintings, down to the promising sketches, unfulfilled promises, of his old age. This collection falls little short of being complete. Perhaps, with the sole exception of the incomparably less interesting Wierz, there is no contemporary artist less often met with in public and private galleries than Gustave Moreau. He never sold his pictures, for he was lucky enough not to be obliged to do so; and, in the time of his maturity, he did not exhibit, for he shunned contact with men who were strange and unfamiliar to him. He who wishes to get to know him must, then, not shirk a pilgrimage to his house, which he inherited from his parents, inhabited by himself, and left as an unencumbered legacy to his native town. And the journey will be found worth the trouble, for Gustave Moreau is a curious phenomenon, affecting to melancholy and depressing, at least for men enamoured with life and action, but nevertheless full of mysterious, strangely pathetic allurement, even for those who prefer to breathe in air and sunshine under a bright sky.

Gustave Moreau stands apart from the mighty procession of French art in the nineteenth century, which was headed by the classic cohort, continued by the powerful band of the knights and squires of romanticism, and then unrolled itself before our eyes, in the legion of the bourgeois National Guard of Philistine academic routine-art, in the blouse-wearing troop of Realists, and, lastly, in the vacillating and oscillating sun-flower groups of Symbolism. He is not to be classed in this line of development. He went his way alone, deaf to the strains of the world of which he heard only those with which he himself was in harmony from the beginning. He had some few kindred spirits among contemporary painters, but he did not know them, and they did not know him either, and they exercised no influence on each other, but grew up independently of one another from the same conditions of like temperaments and peculiar moods that in the middle decades of the nineteenth century dominated narrow, exclusive circles, without being characteristic of this or any other time. For these temperaments are purely subjective, and accord with the external only so far as civilisation, when it has reached a certain grade of intensity and artificiality, always produces men with widely preponderating development of fancy, who are continually looking into their inner selves, and cannot withdraw their eyes from the fascinating spectacle of the wonderful events being enacted therein.

Moreau was just such a visionary. Remote from life, remote from actuality, he ever remained engrossed in his dream, and his noble art served him to retain his apparently multifarious, but, in reality, little changing dream-pictures. His museum is, then, a world by itself, with which the objective outer world has no more in common than have dreams and ravings with pictures of the actual which serve them as a stimulus, and furnish them with the elements of their subjective combinations.

Since the earliest stages of development of the spiritual life there have existed, side by side with men of observation and action, thinkers and dreamers who turn away from actualities, and build up around them a world of ideas which their excessively developed power of imagination could fashion, and endow with romantic life according to their own inclination and necessities. Thus arose all symbols, mythologies, fables, and superstitions that were enshrined in folk-lore, traditions, and, more especially, in all arts. Civilisation brings with it, by this means, besides its recognition of nature, a world of shadows invented by men freely—even if according to fixed psychological laws—like a ghostly double, the astral body of the real world; and our prescriptive education, which comprises in itself more æsthetic than positively scientific ingredients, renders us all double citizens of the real and the imaginary world. The majority of us chiefly live in the former, and visit the latter only in rare moments, which to some mean only recreation, but to others consecration and exaltation. A small minority, however, renounce their citizenship of the actual world and withdraw wholly to the world of imagination, which has been conjured up by the artistic fancy of mankind in thousands of years of creative activity.

Moreau was a citizen of the shadow-world, wherein he spent, an eternal Phæacian Sunday, and he never grew weary of lingering over its beauties. We learn by his representations to know it thoroughly in all its parts. Its landscapes are curiously jagged rocks which seem to be formed of corals; chalk plains with moon-glimmering reflections; mountain steeps in cumulous clouds; lakes and seas of oil, opalescent or charged with indigo. The animals that people this hypnotising paradise are unicorns with silvery coats, amazing dragons that are too curly to inspire fear, milk-white flying-horses, seven-headed hydras standing bolt upright on the tips of their tails, Stymphalian birds with women's faces, sphinxes, chimæras, and phœnixes. Even the flamingos, which come nearest to the terrestrial fauna, are here with the tips of their wings dipped, as it were, in blood, immeasurably more oddly pathetic than we know them. The flora exhibits (besides monumental marvels of Peru, which remind one of the rose windows in Gothic cathedrals) a "mystic blossom," a somewhat calla-like creation that sprouts forth from a luminous rock in the blue, mirroring mere, and on its slender summit, between great high leaves, bears the Blessed Virgin surrounded by a dazzling halo. The spiritual beings that move amidst these marvellous animals and plants, are gods, heroes, and poets: Tyrtæus, Orpheus, Hesiod, Sappho, Jason, Helena,

Odysseus, Penelope, Pasiphae, Hercules, Dejanira, Œdipus, Jupiter, Apollo, the Muses, Semele, Leda, Europa, Prometheus, the Oceanides, Moses, Buddha, Jesus Christ, the Good Samaritan; the acts or, more correctly, the states in which these gods, demigods, and genii are represented are taken from all mythologies and theogonies. Every mysticism that has at any time or place arisen, like a silver haze, from the chaotic brain of man, has found admittance into Moreau's soul and flows up and down in it in changing pictures. As to orthodoxy of any sort or kind, he is quite unconcerned. His mind, when stirred, clings with the same delicacy to the saint of every origin, and he kneels, like the large-hearted heathen of antiquity, at the threshold of the most varied realms of divinity. The Pallas Athene in the hall of the king's palace at Ithaca, who enjoys the massacre of the suitors, is formed after the same type as the Blessed Virgin of the "mystic blossom"; hovering in long, trailing, white garments, radiant with a halo, ecstatic in look and mien and the clasping of her hands. The statues of the Chaldæan gods in the triumph of Alexander the Great imitate hieratic repose, and the Eastern posture of the Buddha-Amina statues. Prometheus on the Caucasian peak, palpitating beneath the vulture's beak, is allied by a family likeness to Christ scourged at the pillar. Jason on the poop of the _Argo_, and the fair man among the "Three Magi from the East," are cast in the same mould. Moses, looking down from the frontier hill on the blue plains of Canaan, and the great Pan, gazing at the spectacle of the procession of the spheres, seem brothers. Jupiter, with Semele on his bosom melting away with its heat, has the unapproachable sublimity of the canonical, the orthodox God the Father. For Moreau there are no dead religions; with a humble shyness and feelings of awe, he approaches all that has ever been reverenced by man.

Moreau's transcendental imaginations necessarily reveal themselves to the senses in other colours, as in other forms than those familiar to us by experience. An eerie light fills his pictures with the shimmering radiance of mother-of-pearl. The rarest, and, therefore, as jewels, the most treasured exceptional forms of the planetary world are the material of which everything in these pictures consists; the buildings are of gold and precious stones; there is a twinkle of rubies, sapphires, and emeralds everywhere. Moreau's amazing art produces from his palette of oil-colours effects that lie far outside its technique; they are huge Limoges plates with rivers of transparent enamel; paintings on glass with sun-illumined, jewel-like fragments of colour; Byzantine mosaics of bits of _lapis lazuli_, jasper, and cornelian. With this palette certain Quattrocentists such as Mantegna, certain Flemish artists as Van Eyck and Roger van der Weyden, as also Holbein, have in their pictures produced a small number of beauty-spots. No one prior to Moreau has painted big pictures entirely with it.

The first impression received from the Moreau Museum is that of having entered an enchanted castle, which has about it something of the treasure cave of the mountain sprites, something of the palace of the Elf-queen, as we know them from the "Thousand and One Nights," and German folk-stories. And if we have tarried longer, and our eyes have grown accustomed to the ripple of pearls and precious stones, of enamel and gold, we are astonished at the strange, weird stiffness and stillness of all these splendid creatures, and really feel we are surrounded by ghosts and spectres that have assumed only in pretence the guise of men.

Moreau formed his views on Baudelaire's rules. In the rooms of his museum we fancy we are looking at a series of book-illustrations for the _Fleurs-du-mal_.

"Je hais le mouvement qui déplace les lignes, Et jamais je ne pleure et jamais je ne ris."

"I hate the movement which displaces the lines, and never do I weep and never laugh" would, as an inscription above the entrance, most fittingly convey in words the main feature of Moreau's art. For nearly all his pictures, but most of all for the "Triumph of Alexander the Great," "Penelope's Suitors," and the "Daughters of Thespius," the verses of the _Paris Dream_ would suit as a deliberate description.

"J'avais banni de ces spectacles Le vègétal irregulier . . . . . Babel d'escaliers et d'arcades, C'était un palais infini, Plein de bassins et de cascades Tombant dans l'or mat ou bruni. . . . . C'étaient des pierres inouies . . . . . Et sur ces mouvantes merveilles Planait.... Un silence d'éternité."

This _silence d'éternité_ is the characteristic of Moreau's art. Here nothing moves; all is as stiff as Lot's wife after she was turned into a pillar of salt, as the men in the fairy-tale after the wizard has, by a wave of his magic wand, made the warm life stagnate in their veins. Moreau succeeds in reversing Pygmalion's miracle. His brush takes the life out of every human body he paints, and turns it into a statue. In none of his figures do we feel that he painted from a model. They all give the impression of being copies from statuary, and we are, for instance, not surprised that his manifestly unfinished "Moses Looking at the Promised Land" has a long bearded head as white as marble on an almost flesh-coloured body. We assume that Moreau has here simply reproduced the natural colour of his stone prototype. Among all his thousand works, one alone has really struck me as having something like a stir

of passion traceable, viz., his "Messalina." The abominable empress, slave of her animal passions, is ascending the dirty couch at a den in the Suburra. The young vulgarian whom she has beckoned to her clasps her waist with both arms; the attendant torch-bearer of the crowned slut turns her head away from the repulsive sight. One can very well understand the movement of this slave who is ashamed of her mistress, but has only to obey and hold her tongue. The eagerness, too, with which the youth kneeling before the couch creeps up to the body that is offered him, is true and warm. Here is real life, even if in one of its lowest manifestations. But Messalina herself, though the protagonist of this tragedy of Cæsarean madness, is again entirely Moreau. With her stony repose in a situation with which it is so inconsistent, with her Assyrian fish-bladder-eyed profile, she resembles an idol in a Babylonian temple, and one wonders how the passion of the favoured one can endure the icy coldness gleaming from this idol.

His temperament indicated to him, from his earliest awakening to artistic impulse, the course of his education, just as it did, later, the choice of his material. As a youth in Italy he copied Pompeian mural paintings with fervour, and later revelled at the sight of the Quattrocentists. Here he recognised at first sight kindred souls; here, as it were, his blood spoke. He tries, by imitating them piously, to keep them for reminiscences later on. His mystic bent to the old, the obsolete, the risen as from a grave, is a trait connecting him with the Præ-Raphaelites, who were almost his contemporaries. With them he has in common, too, the uncommonly exact and accurate technique. He is a cold but unerring draughtsman. All his accessory work, his architecture, ornaments, implements, and clothing, are marvels of archæological learning or, when this fails, of invention and patiently, painfully achieved execution. His conscientiousness went so far that he painted perhaps twenty or more far advanced sketches of each detail of his large compositions ere he proceeded to the main work, and this, nevertheless, he often left unfinished, because he felt he had not done enough to satisfy his conscience.

Those empty, or merely vaguely filled-in spots instead of faces in big pictures, in which all besides—the patterns of the garment stuffs and carpets, the decorations on the splendid vases, the finery, weapons, capitals of the pillars—are precisely rendered as complete productions, give suddenly to the sympathetic an idea of the pains of this struggling spirit. Moreau shunned life, which was too stormy, noisy, and bustling for his morbid need of repose and quiet, but it did not cease to attract him as a mysterious riddle. He would gladly have understood it, comprehended it, and held it fast, but he had to admit to himself that he was powerless to reach it. A homunculus artificially generated in the retort, he can live only in his glass vessel, and must die if he ventures out of it; but through his prison walls he gazes at the great, broad, free nature, replete with tempestuous life, and in the cold of his glassy den he shudders with longing for this world, so near and yet beyond his reach. His longing is, however, never to be appeased; he will never feel the joys of the warm breath of life.

IX

EUGÈNE CARRIÈRE

How much better off are painters and art-lovers nowadays than in earlier times! Formerly, if you wanted to enjoy a picture you had to own it; if you wished to know a picture you were obliged to make a journey to it. If you liked an artist sufficiently to wish to surround yourself with his chief creations, or the whole of them, you had to have unlimited wealth and set up a gallery of your own. Copies are a mere aid to remembrance, and not a good one either. Executed by a dauber, they are worse than nothing; by a gifted artist, they give the copyist's, not the original creator's, personality. The older methods of multiplication also either furnish clumsy attempts at transmitting them, or they are peculiar, independent, artistic creations of another order than painting, which have their special beauty, but are unable to seize the most inward and subtle of the charms the painting possessed.

Since the latest developments of photography and the copying processes dependent on it, the case has been altered. If you would convince yourself of the almost marvellous perfection with which oil-paintings are transferred to paper nowadays, so that every stroke of the brush, however fine, every movement of the painter's hand, every paste, every unevenness in the colour plane, every effect of the canvas, ground-coating, and varnish, is reproduced in a life-like way, and you have actually before your eyes the whole personal work of the artist, then look at the handsome folio entitled: _L'œuvre de E. Carrière, Texte de Gustave Geffroy_, that has been published in Paris by H. Piazza et Cie., and contains the copy of 150 paintings and sketches by Carrière, 75 of which have been printed on Bristol paper, and 75 incorporated in the text. They lack colour, I admit. Only when photography renders this too, will the last word of genuineness in copying be pronounced. Meanwhile, we must be contented that we find again in the photograph the tonality of the colours and the effects of light and shade in the original relatively graded in respect of each other. With Carrière, however, the absence of colour is really of little importance, for he painted chiefly from a grey and brown palette, which can be very accurately reproduced by means of photography.

A hundred and fifty Carrières! Who could pride himself on possessing such a treasure? One would have to be an American multi-millionaire to enjoy such an æsthetic satisfaction as that. Now it is within the reach of every well-to-do individual. The 150 reproductions comprise about the whole of the great artist's life-work up to now. They disclose to every beholder, who is of good faith and possesses a sensibility for the beauties of painting, the key to the law of art which Carrière laid down for himself. They render it possible to follow the course of his development, which, at the beginning, is hesitating, then becomes decided and weighty, and carries the artist from the school to mastership, from tradition to uncompromising individuality.

Eugène Carrière was born on 17th January 1849, in the village of Gournay (Seine-et-Marne). His father was a Fleming from the north of France; his mother an Alsatian. His appearance corresponds to this probably pure Germanic origin. He is a big, broad man with strong bones and portly stoutness; white-skinned, blue-eyed, and fair-haired; slow of speech, thoughtful and reserved in his movements; dreamy when listening, unintrusive when silent, raising his voice little when saying modest, sensible words about things which he understands. He was still a child when his parents settled in the mother's home. He grew up in Strassburg, and was intended for an artisan. When he was eighteen he went to St Quentin, and had an opportunity of seeing the La Tours in the museum there. His talent was kindled by this unsurpassed, perhaps unequalled master. The beautiful crayon faces of La Tour taught him to feel the velvety splendour of youthful human skin, and meditate on the mystery of the artistic creation of plastic effects through merely intensifying or subduing the play of light. He began to draw and paint eagerly, and aroused sufficient belief in his vocation to be sent to Paris to the Academy of Art. What it offered him was practically nothing. Drawing copies of plaster models chilled him; even the professional life-model in the prescribed studied attitudes seemed to him futile and absurd. What meaning for him had this comedy of gladiatorial positions, ostentatious muscular development, clownish distortions expressive of no natural feeling or rational purpose, in which no human being would, if left to himself, indulge, and which, often enough, the body can assume and retain only by the artificial help of rests and props? What he longed for was life, warm life, such as pulsates in men of strong feelings, and is expressed by them in a straightforward, convincing way by looks and gestures.

The depression produced in him in the pupil-rooms in the _École des Beaux Arts_ made him doubt himself. Luckily for him, amidst his general ill-luck, this spiritual crisis of his coincided with the great crisis of his country. The war broke out, and Carrière hastened as a volunteer to the front. He did his duty bravely in several battles and engagements, was taken prisoner at Sedan, and, as such, reached Dresden. The months of his imprisonment proved decidedly fruitful to him, for he spent his days in the picture gallery, and was shown by the Rubens pictures there, the ways which, up to that time, he had not clearly seen.

After the war was over, he resumed his orthodox studies at the Academy, and became a pupil of Cabanel. It exhibits a good testimony of the power of resistance in his nature that this most inaccurate portrait-painter of the Empire could not influence him, although he had for five years his misleading example before his eyes. In 1876 Carrière competed for the _prix de Rome_. He did not get it. That might have been predicted to him; the prize is the reward of the meritorious industry of the pupil, which flatters the teacher's _amour propre_. Carrière had then, however, emancipated himself from tutelage as an artist. He felt nowise humiliated or cast down by the failure of his purpose. With brave heart he drew from the occurrence the only true moral, viz., that not the approval of teachers, _i.e._, of those who have succeeded, but the satisfaction of his artistic conscience must henceforward be the goal of his efforts. He renounced official recognition, and that was wise, for it preserved him from the pain of disillusion. From 1877 he exhibited annually in the _Salon_, but it was not before 1884 that the prize judges awarded him an "honourable mention," which can hardly, however, be called a reward. A year afterwards, he received the medal of the third class, which is "the last kindness," but at the same time the Baschkirtsew prize of 500 francs, which is awarded, not by the prize-committee, but by the Society of Artists by universal suffrage. In 1887 the Jury rose to the medal of the second class, and, at the Universal Exhibition of 1889, to an insignificant silver medal. With this the series of distinctions vouchsafed to him by the masters of his guild closes. His later honours—the ribbon and rosette of the Legion of Honour, the room reserved for his works at the Universal Exhibition of 1900, the purchase of his "Maternal Love" for the Luxembourg Museum, the commission to paint twelve bays in the Banqueting Hall of the Paris Hotel de Ville—were forced for him from the public authorities by independent opinion. They were the scanty revenue of fame, which the lonely man found when he ceased to seek it. It is characteristic of Carrière that of all the nonsense of medals and decorations there is not a word to be found in the monumental work dedicated to him. They were formerly regarded in France as the great events in the life of an artist. Carrière's proud independence does not admit that they have any meaning at all, or deserve the most casual mention. The book enumerates all his works, even rough drawings, unfinished sketches, attempts at lithography. These are the deeds and events of his life. There is no room in the book for official certificates of industry and his elevation in the _Tchin_.[3] Moreover, Carrière was one of the co-founders of the Salon of the Champ de Mars in 1890, which on principle repudiated the system of rewarding meritorious youths by testing and directing superior officers, and rebelled against turning artists into an hierarchy by means of conventional marks of rank.

Carrière has formed a manner of his own, which he discovered by himself, and asserted it victoriously despite of all kinds of opposition. Every layman sees at the first glance that his pictures are full of grey vapour. A sometimes transparent, at other times thick mist envelops his figures, and makes their different parts stand out with unequal distinctness. "A whim," exclaims superficiality; "a dodge to astonish," grumbles the _blasé_ man-of-the-world, who thinks himself cunning. It is neither the one nor the other. The origin of the curious exhalation hovering about his figures is to be sought in his own need for representing the æther in which all planetary life is displayed. His sense of truth took umbrage at the painting in vogue, even that of the masters, which sets beings and objects in space, without giving any suggestion that it is not empty, but filled with a gas possessing optical and kinetic qualities. It is all very well trying, by established toning of the local colours, and blurring of the contour lines, to make the fact perceptible that the figures are surrounded by air; but these customary means of expression failed to satisfy Carrière, and he is not the only one they left dissatisfied. A whole generation of painters, about 1870, had the annoying feeling that air did not get its rights in art, and made obstinate efforts to find a formula for announcing the presence of air with an emphasis that could not be neglected. Sisley, Monet, Pissarro, thought to solve the problem by refraction and iridescent radiation which would render apparent in the painting the visible motion of the air, its vibration under definite relations of illumination and heat. The object is only very imperfectly attained. The attempt is justified, and deserves respect. Carrière sets about the matter differently, in a more direct and _naïve_ way. The decomposition of white light into its spectrum, as the dotters and stipplers practise it, proves, I admit, that the rays of light move in a material medium, as they would otherwise have no reason for resolving themselves into their component parts; but, in order to infer air from the prismatic colours, a man must be a physicist, and it requires a labour of thought that has nothing in common with an immediate impression of the senses, such as must, first and foremost, proceed from an optical work of art. Carrière, then, found even the impressionist rule too learned. He preferred simply to exaggerate, and, as it were, to make palpable, the properties of air, which is neither absolutely colourless nor absolutely transparent. Thus arose the thin grey air in which his figures are bathed, ranging from the most delicate mist to the thickest smoke, but always transparent.

Directly he found his method or manner, it became alive in his hands. In that his peculiarity consists, and in that he shows himself a great artist by the grace of God. Smoke is to him a medium of expression of amazing range. He employs it almost as the engraver on copper of mezzotint does the "burr." It is a layer of veils which he diminishes or increases as the effect proposed demands. Here he withdraws the covering. There he suffers it partly or entirely to remain, and by such means obtains, by the most natural and, apparently, the least troublesome way, a recession of the non-essential, an amazing relief of the essential, a clearness in the expression of his thought, such as not one of his contemporary painters possesses. At the first glance at a picture of Carrière, one is very forcibly directed to what was important to the painter. One positively cannot wander into what is unimportant, or be diverted from the main thing. It sounds paradoxical, but is literally true: Carrière understood how to make vapour the medium of the highest clearness, to make mystery the gate of an unreserved revelation. That, I admit, his imitators cannot discern in him. It is easy to daub smoke in a picture, but that is not all. Vapour must not be an excuse for bungling draughtsmanship; it must not mercifully cover defects in form. In order not to favour any fraud, it makes a masterly accuracy in modelling a primary condition. To permit oneself such noble economies and condensations one must be as accurate a draughtsman as Carrière. The veiling of the greater part is only, then, admissible, when the lesser left unveiled is perfect.

The subject of Carrière's portrayal is always life of deep feeling—self-forgetting maternal love, childhood's gracious innocence, pathetic tenderness of father, brothers, or sisters. He has never worked from the peddling model who can be hired at five francs an hour, and who poses only with the body, not the soul. His model is his own family, with the whole range of idiosyncrasies which their existence by night and day comprises. What the tender husband and father observed with delighted eyes at all hours, that the painter has uniquely fixed on canvas: the mother resting in bed with her baby at her breast; that sweet, shapeless little lump of human flesh which is a wee boy that the elder sister fondles; the children eating or being fed at table; the washing and dressing of the little one, which the mother and elder sister carry out as a pleasant game with a doll; the mother's anxiety as she cradles the fever-stricken child in her arms, and tries to quiet it; dressing the eldest girl for her confirmation—a prelude to that affecting moment when the mother, with trembling hands and streaming tears, will place the bridal wreath on her head; the pride of the parents when marshalling all their five children in a row; the gloomy seriousness of the tiny school-girl puzzling at the work-table over her first task. Carrière, when painting his family life, painted the life of mankind. His large, epic style of feeling preserved him from falling into _genre_. He remained monumental even when painting details. He is as little sentimental as Goethe in "Hermann und Dorothea"; nevertheless, tears rise when we gaze on his pictures. The incident disappears, and we stand before the Eternal, which it comprises; before Love, which keeps the world together.

The same feature is distinguishable also in his portraits; they ennoble the model by spiritualising it. He gives only just enough of the anatomy to reveal the soul. And when he sets himself greater and more highly differentiated tasks ("The Gallery of the Belleville Theatre," the "Holy Women at the Foot of the Cross"), he accomplishes them by bringing forth the feelings and thoughts which have brought together the persons concerned, and determine their bearings and movements.

What individual works scattered in exhibitions and museums have not proved to every one is made indisputably clear by the 150 reproductions in the Piazza book, viz., that Carrière is one of the noblest, chastest, most deeply-feeling artists of to-day, who has created for himself a peculiar technique, particularly dangerous for imitators, but natural to himself, and, therefore, in his hand, justified.

SOME OF CARRIÈRE'S PICTURES

"The Belleville Theatre."—The light, mystic vapour which fills and exhales through Carrière's pictures, like delicate bluish-white clouds of incense, does not, as a rule, exert a disturbing influence. In this picture, quite one of his most important ones, his brush seems to have betrayed him. He has grown more material than is usual with him. The "Belleville Theatre" is so densely enveloped in smoke that hardly anything can be distinguished amidst the clouds. Yet what splendid discoveries are to be made if you make a violent effort to penetrate the darkness, into which a venture may only be made with a diver's helmet and an air-pipe! We see—or, rather, we surmise—the third and a part of the fourth gallery of the People's Theatre. The suburban audience that fills these rows, gives itself unrestrainedly up to the magic of the spectacle. It lives not its own life, but that of the heroes in the piece. To this audience Hecuba is everything. The wide-opened eyes lost in reverie, the cheeks sunk sorrowfully in their hands, the shoulders contracted by fear, the bodies almost helplessly leaning on one another, betray the intensity with which these poor people have fled out of themselves into illusion. What is truth, what is deception, if a poetical word, and that, too, most likely the word of a wretched melodrama, can snatch away small trades-people and artisans—probably sore oppressed by the needs of existence and more than full of their own troubles—so far from all their griefs that they forget their misery and think they are vividly experiencing a new lot? That would be the Buddha philosophy of this amazing picture if we could but distinguish all it contains. Carrière has painted the profound doctrine of Maia and Nirvana. It is a pity he has covered it with so thick a veil that it remains impenetrable even to the eyes of the initiated.

"Christ on the Cross" will give to those capable of feeling the impression of a great, artistic experience. The mystical tragedy, from which a world-religion draws its emotion, is presented with the simplicity and suppressed pain with which a father reports to his son the tragic death of the mother. All subsidiary work that might prove distracting is avoided. No thieves, no Captain Longinus, no Roman legionaries, no fanatical spectators; not one of the aids in men or things with which the classics of painting are wont to complicate the event of Calvary, with the object of making it more impressive. Nothing save the life-sized figure of the Saviour, who has ended His sufferings, and Mary, who leans against the Cross so as not to break down altogether. On the face of the corpse the peace of consummation has sunk; unutterable grief wastes that of the Mother. The form floats in a soft, unearthly light; on the latter expressive shadows strive. The repose of the dead Christ, which would appear painless and almost cheerful were it not that a slight trait of suffering was fixed around the mouth, dawns like a consolation over the dark despair which fills the soul of the living mother. If she suffers humanly, as a mother, so that she would fain die of woe, still redemption and exaltation also arise for her from the act of salvation. If one has ever heard Palestrina's "Stabat Mater," it re-echoes in his soul at the sight of Carrière's picture. It has issued from the same deep emotion as the tear-soaked _terzine_ of Jacopone da Todi and Palestrina's sobbing hymn. Carrière abandons himself to his feelings with the same earnestness as the Franciscan friar and the choirmaster of St Peter's. It is hard for me to admit that he shares their pious belief. I assume that the Mother's grief has, in the main, inspired him. This strong feeling has, doubtless, made him susceptible of the sacredness of the symbolism in the death on the Cross; through the human he will have raised himself to an inkling of the superhuman. Let us not forget that Carrière is the painter of that "Motherhood," the gem of the Luxembourg Museum, which depicts a young mother with a child on her lap and another beside her, revelling in the sight of her little ones—her treasures—with adorable tenderness in look and mien, in the pose of her body and the movement of her arms. Carrière has a wonderfully deep feeling for maternal love, in joy as in sorrow. Unconsciously and involuntarily, he has conceived his subject not with the spirit of a believing Christian, but with the broken heart of Mary. He might confidently have called his "Christ on the Cross," too, "Maternity," like his masterpiece in the Luxembourg; the one is a companion-picture of the other; the tragedy of maternal love, according to its idyl.[4]

There were cases in which the employment of Carrière's plan of the delicate grey veil of enveloping mist was not successful. I have, for instance, been obliged to make reservations in respect of his "Theatre in Belleville." In the "Christ on the Cross" it is

organically developed from the subject. The veil of mist shrouds the incident in the weird twilight which is the prescribed atmosphere of miracle and the mysteries of faith. Beyond the figures in the foreground of the Crucified and the Blessed Virgin we divine, in the semi-dark distance, a great city, at the back of which, on the horizon, a twinkling white light, like the still uncertain brightness of a young dawning day, arises. Our powers of imagination may fill with life the whole of this profound space wherein dawn is at odds with night—with the life of a whole townsfolk enjoying their revenge or weeping for woe, oppressed with foreboding or hopefully confident.

Here is symbolism in that high sense in which every true work of art is symbolic. The picture is at the same time intellectual and transcendental; the rationalistic beholder, who neither seeks nor wishes to find a mystery, has before him the humanly affecting drama of the mother who bewails her son who has died unmistakably in a noble task. He sees sights he can understand—the peace of death and a mother's deepest pain—presented with unsurpassable truth. He enjoys the charm of perfect form, marvellous warmth of colour, produced with the simple means of _gouache_ toning and a very faint heightening by touches of red, and an extremely interesting distribution of soft light glimmering from the dark background. The mystically minded beholder sees all this, and he sees, besides, the divine element in the Crucifixion and the sorrow-stricken Mother, the terribly threatening subversion of the natural order in the darkness brooding over the city and fields, and the promise in the light arising in the distance. What the rationalist sees in the work of art is sufficient to arouse his feeling and admiration. The mystic's wonder and feeling will be powerfully strengthened by religious emotion.

"Portrait of my Wife."—He who is guilty of the error of confounding gaudiness with coloration might find a guide in this work. A few bright tones in the spiritualised, almost transparent face; a fur collar of a warm, rich brown; a gay, red flower in the girdle, comprise all that Carrière employs as colour media, in order to conjure up a harmony of lulling melody and, at the same time, of all but hypnotising intensity. That is precisely the whole mystery; it is not a question of the noise, but of the harmony. Three colour values, chosen with exquisite taste, placed on the right spot in the floating white and pearl-grey cloud which constitutes Carrière's manner, and the impression of the colour mystery is produced with greater success and depth than by a palette on which all the seven colours of the rainbow are keeping a witch's festival.

"The Kiss before Going to Sleep."—A painting of marvellous range of feeling. A mother with her daughters, from the grown-up one to the suckling infant at her breast. The big girl bends over her mother's shoulder, as the latter is sitting, and takes her good-night kiss from the lips of the head turned to her. The baby has fallen asleep whilst feeding at the maternal bosom. The third, half-grown-up, has likewise been overcome by sleep, as she leans helplessly, with her whole weight, on her mother. The last twines her fondling fingers in her mother's hand outstretched to her. The mother is the central point of the picture. From her gushes the force that penetrates, encompasses, attracts, and holds together the rest of the figures. Love it is which collects these beings and unites them in a marvellous circle. Thus they become a symbol of the force that has built up the universe itself, and keeps it in its eternal order. And this self-same love, which knits these hands in each other, bends these bodies to each other, brings these lips together, which is visibly the motive and attractive force, in all these simple but incomparably eloquent lines of movement, has also guided the magic brush capable of expressing so great a theme. He who at the sight of this lofty work does not feel all the hardness in him melting in joy stands outside humanity. Moreover, there is not a trace of declamation, or purpose, or _tremolo_ in its execution; no prettily pietistic rhetoric. Not a single adjective, but only neuter substantives, as in Roman inscriptions. That is precisely the receipt, which holds good in all times and in all places, for monumental works: eternal feelings expressed in eternal forms.

"The Engaged Couple," like "Maternity," like his portraits of a married couple, a young maiden, etc., etc., are unapproachable works. His grasp of the essential in phenomena, his economy of form, are of supreme craftsmanship. It is in this direction, I think, that the future development of painting lies. It will soon be over with mere transcription of nature, however clever; certainly, on the not very distant day when colour photography will be handed over from the experimental laboratory of the physicist, to professional use. Then the individual standpoints of observation will alone hold good. People will want views, not as the mechanically reproducing, dead object-glass, but as the inspired eye of the artist sees them. Pictures will have to be a selection, an interpretation, an emotional excavation of the optic phenomenon; every picture an anthology of vision; and the personality of the artist revealing himself in it, will be the fascination of his work, its value and its beauty. Let no one say: "These are trivialities. It has always been so since plastic art existed." The plastic artist was hitherto always in the first place a depictor. His soul revealed itself only discreetly in his works. Carrière goes far beyond what he sees: he paints souls; he paints feelings. In his representation the inexpressible becomes an incident. A fugitive movement, a pose, a line of head, neck, shoulders, or hand in which unconsciousness is manifested, when self-control is relaxed for a moment; these treacherous means of expressing mood, which

the will is not always able to influence—these are the elements with which he works. He discloses the impulses, up to their most delicate moods, which are the causes of movements and deportment. To such a spiritual art must painting be developed. And this is why I call Carrière's pictures the art of the future.

X

PUVIS DE CHAVANNES

Puvis de Chavannes is dead, and his influence is dying; his School is desolate, and I see now hardly any stragglers worrying themselves to paint with his palette of pale moonlight. So it is no longer necessary to attack him. It is enough to explain his spiritual transformation and his successes.

When he attained the maturity of his powers, that Naturalism was the trump-card in painting, of which Bastian Lepage's abominable "Reaper," whose brutalised grimace grins at the visitor to the Luxembourg Museum, was admired as the highest achievement. The young critic had eyes only for this art. The multitude dared not question the fulsome praise squandered on the works of the naturalists; but their inner voice was not mute. They had qualms of conscience about their culpable cowardice, and were quite well aware that naturalism, which was lauded to them as Progress and the Future, was in reality the negation of all art. Then Puvis de Chavannes stepped forward with his big wall-paintings, which put symbolism, sacred legend, and history on the stage, on a literary background, and reunited them to tradition, which had been disowned or scoffed at by naturalism, out of barbaric ignorance or vulgar arrogance. The multitude, whose inward feelings partisan criticism outraged, turned forthwith to the painter who seemed to them a deliverer and an avenger. He was a living protest against the art of the vulgar, the hideous, and the commonplace; against the art of the mechanically dull copying of a soulless reality. He took pains to serve beauty. He showed unmistakably the object of his spiritualising his figures and actions. Before his pictures one could once more dream. After prose, after vulgar, slangy prose, it was verse. People did not even ask if the verses were good; people were satisfied with mediocre verses, provided they were verses. To Puvis de Chavannes his fundamental, academic instincts had given the direction; but whilst he followed his bent, he became, without intending it, and without previously knowing it, the file-leader of the right-about turn, which began in "the 'eighties" and has now long ended.

In a period of idealism he would have been one of the many. People would not have noticed him or would have found in him much to take exception to: the banality of his symbols, the impersonality, smoothness, and polish of his draughtsmanship, the intentional incoherence of his compositions. During the predominance of naturalism, his academic banality itself seemed a courageous act, and seekers after the ideal even accounted his most obvious faults and weaknesses as excellencies in him.

He got his faded, spectral colours by imitating the fresco painters of the Quattrocentro. His ideal of picturesque beauty united in inseparable association the stateliness of the old monumental wall-paintings with their fadedness; and when he wished to paint in their style and produce their æsthetic effects, he at once gave his pictures the faint coloration which had never been intended by the Quattrocentists, but which their works have suffered through the devastating force of five centuries. The obliterated, remote, ghostly qualities of this faded type of painting came to meet a morbid mood of the time. This mystic coloration harmonised with the prevalent mysticism. The decadents were thankful to him for his moon-stricken colouring; those athirst for beauty for his conversion to classical tradition; and so he became a great man through the sins of the naturalists and their critical heralds.

Puvis was the first academical and recognised master in France who began to paint the morbid. His whim is chalk-wash. He covers, on principle, his pictures with a white, semi-transparent broth that extinguishes all the colours. His eye detests colour. His glance has a sort of chloridising effect; it takes the colour out of everything it ranges over. With him, however, morbidity is natural and not an affectation. He has that horror of all that is loud, full, and impressive, which marks the nervous man, whom every rough touch pains. It is well with him only when nature whispers, when her looks are veiled in a fine mist, when all life in her is motionless. In his soul reigns a melancholy absence of sound, and he likes to carry this into the outer world also. Moreover, the multiplicity of living forms confuses and repels him; it is too full of motion and gaudiness. He simplifies, therefore, all lines which thus lose their distinctive individuality. He retains only what is typical of the phenomenon; he infuses his style into all that his brush and pencil touch, and this cold stylisation is then called by people his "idealism."

Has Puvis laid himself open to the reproach that all his figures are awkwardly typical because he cannot draw? We might almost think so. It is only as a reply to such a reproach that we can understand his exhibiting in 1896 several hundred drawings, preliminary studies for all his chief works. After a minute inspection of these smaller and greater sheets of sketches scarcely

indicated or industriously executed, of figures scarcely outlined or carefully shaded in lead-pencil, Indian ink, red and other coloured chalks, we are bound to feel every respect for his industry and conscientiousness. For the originality of his talent, too? That to me is questionable. If I gaze on the studies of Leonardo and Albrecht Dürer, I am, in a very short time, over-mastered by an inexpressible emotion. A holy of holies is revealed: the most secret feelings of an artist's soul which would fain become conscious of itself whilst seeking to give shape to the emotion that is urging it. You can see the struggle with the resistance of the material, the mustering of all his forces, in the majority of cases the artist's victory, ofttimes his despairing confession of impotence. A feature of the phenomenon—a fugitive yet expressive movement has made its impression on the artist. He hastens to fix his conception. At first in a few hasty strokes, which are then strengthened, deepened, emphasised, and developed. Five times, ten times, till the artist desists disheartened, or till the vision is overcome and fixed by a spell in its whole force and verity, in its distinctive character that is never to be repeated. In Puvis I observed with astonishment the contrary process. The first sketch has always the greatest individuality, every later state of the figure shows it less differentiated, and more reduced to an average type lacking expression. He never ascends, he goes down. The artist's emotion in face of the phenomenon—the impulse to produce in the rapture of an intuition is never traceable in him. None of the sheets is the arena of that awful fight waged by talent against the hostile demon of the material, which reminds me of the night-long struggle of Jacob with the spectre at the ford Jabbok. The starting-point of the work is correct, ice-cold _métier_. It progresses to simplifications that are just so many evasions of difficulties, and it finally arrives at insignificant puppets. "That was intentional," cry the painter's eulogists. So much the worse if it was intentional. But was it really intentional? That is the question. Often enough, as an afterthought, a person imagines he is exercising volition, whilst, as a matter of fact, he is constrained. For him who has learnt to see in all works documents bearing on their creator's psychology, the drawings of Puvis are proof positive that this highly famous man never glanced at the world with an artist's eye, but that he was originally a cold, academical technician, who, later on, by pure reason and without attaining the slightest fervour, has subtilised a peculiarity: the imitation of faded frescoes in colour, archaic indifferentiation in drawing, abstract literary symbolism in his subjects.

In fact, what is unreal and dream-like about his vision is not only determinative in regard to his archaically simple, almost poor drawing and his pallid colour, but also the choice of his subject. He likes best to portray allegories, in which the figures are reduced to the _rôle_ of symbols. When he cannot be allegorical, in his famous wall-paintings at the Pantheon, for instance, which tell the legend of St Géneviève, he satisfies his craving for spectre painting by spiritualising the given historical figures into fleshless, bloodless denizens of the ballad of the land of Thule. In individual and very rare instances, he finds a material organically suitable for his moon-struck style of painting. In such cases, of course, he strives after extraordinary effects; for instance, with his "Poor Fisherman" in the Luxembourg Museum. This dreadfully poor, emaciated man—more a shadow than a human being—who, sorrowfully but resigned, stands in his old patched boat, drops his wretched net into the sluggish, greyish-yellow water, and is surrounded and, as it were, fixed by the dead lines of a flat melancholy landscape, breathes a disconsolateness and abandonment that, at the sight of him, "humanity's whole sorrow" seizes the beholder.

Once again, in his last period, Puvis lighted on one of those rare subjects which not only bear, but demand his peculiar methods of execution, and out of this lucky encounter came forth a masterpiece, viz., the fresco which concludes his Géneviève cycle.

St Géneviève has stepped out of her cell on to the balcony of her convent and lets her glance roam over Paris. At her feet lies the slumbering city; in the foreground surge the red-tiled roofs, between which soar a few tree-tops in the luxuriant verdure of midsummer; in the distance stretch the soft hill lines of a cheerful landscape, the green of whose meadows is interrupted, here and there, by the white mass of a convent or abbey. Slender lilies and _gladioli_ bloom in noble vessels on the balcony. In the bare cell, the door of which is wide open behind the saint, the smoking flame of a lamp of antique pattern smoulders. At the summit, in a deep blue sky, hangs the full moon, which softly illumines city and landscape, and casts an eerie gleam on the curled leafage of the tree-tops. Immersed and bathed in its soft radiance, the saint stands there, unearthly with her thin, ascetic countenance and her white nun's habit, which from her headcloth to the trailing hem of her garment flows down in unbroken, perpendicular lines, and seems to lift up her soul in a quiet, ecstatic prayer for the slumbering town, whose peaceful prosperity is a work of her solicitous love. Here Puvis's peculiar method triumphs in every feature. Here his temperament needed only to give itself its natural scope to attain the highest artistic result. What elsewhere is intolerable affectation becomes here the honest revelation of a mood. The subdued harmony of violet and blue in different gradations of intensity that blend softly into one another is legitimate in the picture of a summer night, which takes its sole spectral light from the moon and an oil-lamp. The paleness of the flesh is understandable in the aging nun who mortifies herself by prayer, vigils, and fasting. The simplicity of the drawing, which is reduced to a few straight and slightly though expressively curved lines, finds its defence in the dusk of the semi-transparent night which suppresses all individualities of forms; and leaves only for us general, essential features, and these rather surmised than clearly seen. Thus here a special subject finds its special and fully adequate means of expression, and the work becomes a model of what is termed style in

the highest sense.

A rejuvenation seemed to come over Puvis when he seized once more on the Géneviève theme which had occupied him from the days of his youth. This theme was to him what the theme of Faust was to Goethe: while the octogenarian was engrossed in it, something of the flame that glowed in the young man of twenty fired him, and the last cry of _Una pænitentium_[5] is still an after-thrill of Gretchen's passion. Puvis, too, appears to have thought or felt "_Ihr naht euch wieder, schwankende Gestalten!_" when he set about painting this concluding picture of the Géneviève cycle; and for the last strophe of his ballad, which dies away so sadly, he found again some of the power and unction which secures to its predecessors their glorious place in the century's Art.

If the brazen foreheads of the babblers who have the chief say in the art criticism of the time were at all capable of a decent blush, they would turn red with shame at his series of frescoes in the Pantheon. People had the audacity to claim Puvis for some "modernity" or other, in which certain moods of our time were said to be incorporated. The only time when one can wholly surrender oneself to him, he is absolutely of no time. What, in that instance, fascinates in him is nothing relating to the present, and still less to the future, but the past and the remote past, the atavistic. His life's great work is a legend of a saint, which he has treated after the manner of a legend with the feelings of a primitive who, in the manner natural to him—the manner of about the fourteenth century—tells a story that is to him a living verity, in which he believes, as those souls believe it for whose edification he presents it, and which moves and touches him as it does the beholders who will fold their hands devoutly before his work. Puvis cannot reckon on such a reception from his contemporaries, for whom he designs his creation. To us the legend is strange; it is a bit of learned literature which we look at critically, and in which we cannot be expected to plunge believingly. If Puvis, nevertheless, overcomes our opposition, and can suggest to us for moments the child-like faith and all the emotions of dead and gone times that are connected with that faith, he has achieved something more difficult than the primitives, for whom the spirit of their time was no opponent, but a confederate.

Blessed are the ignorant. Their lack of suspicion secures them, whenever they glance at the world, the enthusiasm of discovery and invention, and every phenomenon delights them as something unprecedented. During the lifetime of Puvis de Chavannes his peculiar style was particularly extolled by his eulogists. They exhibited him as a God-sent foundling; as a Moses of painting, without ancestors, himself an ancestor; as a great solitary wandering apart from the multitude through the history of contemporary art. Such phrases can be uttered only by one who rejoices in the most refreshing ignorance of the historical continuity of things. Puvis is of a family. The expert can name his forefathers and relations; he finds their lineaments repeated—often coarsened and disfigured—in him.

Puvis, this great, original genius of his admirers, is an impoverished descendant of Cornelius. He represents the worst aberration in art that this century has seen, viz., thought-painting. Nowadays it is no longer necessary to prove that abstraction is the negation and abrogation of plastic art. This maxim, fortunately, has become an æsthetic commonplace. Painting has to do only with sensuous phenomena; abstraction distils from the sensuous one quality, which, since it is common to many phenomena, is reminiscent of many phenomena, yet is itself not phenomenon. He who feels the impulse to paint not views but thoughts, proves that in his innermost soul he is not a painter, but a rhetorician, and that he has deceived himself marvellously as to the method of expression natural and organic to him. Cornelius's painting presented thoughts, religious, philosophical, and historical dogmas, in a picture-language considerably less clearly than might have been done in well-ordered words. It pleased all those whose soul was seven times sealed against understanding what really constitutes painting. As long as the Cornelius tendency was dominant in Germany, that country was depressingly behind in the art life of the period. As soon as Cornelius and his school were overthrown, a sound development of German painting began. And now, at the close of the nineteenth century in France, in the France which has produced, in landscape, Corot, Rousseau, Diaz, Harpignies: in figure-painting, Millet, Courbet, Bonnat, Roll: from which has come the return to nature and the renaissance of art, the allegorical thought-painting of a Puvis has been praised as the greatest advance, as the latest step in development! The snake biting its own tail still remains the truest symbol of human activity that the self-knowledge of the race has as yet discovered.

And how far, in his special direction, Puvis lags behind his obsolete predecessors! A Cornelius, Kaulbach, and Stilke, displayed, after all, in the invention of their symbols, a rich power of imagination which might have been worthy of better things. Their two-legged abstractions were so honestly drawn that they deceived with regard to their phantom-like nature, and could give themselves out to be real creatures of flesh and blood. Puvis's invention, on the other hand, is so poor that it whines pitifully for alms. The representations which kindle his imagination seem derived solely from an illustrated handbook of mythology for girls' schools. For an example of this, one has only to look at the wall-paintings for the Boston Library, which are among the most important work that Puvis has done, at least so far as their range and claims are concerned. The first represents the inspiring

Muses “greeting with acclamations light carrying the Genius.” From a schematic landscape with sickly pale meadows, a sea of ultramarine blue, and spanned by a sky the colour of autumn foliage, nine female figures are flying to meet a delightfully insignificant naked youth striding on clouds of wadding. This youth holds in each hand a powerfully brilliant electrical lamp, evidently the Teslasch alternating current light, as wires are nowhere visible. The least fault of this picture is that the Muses are not aspiring in voluntary, independent flight, but hang motionless in the air in a passive attitude, like Giotto’s angels and saints, who have not yet learnt to fly. Its mortal sin is that it wishes to represent in painting a vulgar, rhetorical arrangement composed of a number of abstractions.

Beside this allegory, Puvis opens five windows on his world of dreams. Naked shepherds observe, in a southern night, the course of the stars, and are themselves observed by a young woman who is creeping out of a lowly leafy hut. A man in a sort of Roman dress looks thoughtfully at some bee-hives, whilst peasants in the distance are busy working in the fields. A greybeard is sitting by the sea, from which a steep cliff emerges. On its summit a man is chained almost in the attitude of the Crucified. The shadow of an approaching vulture falls on him. Maidens emerging from the sea hover round him with disconsolate gestures. We must necessarily recognise Prometheus and the Oceanides in the scene. Another old man, who is blind, receives laurel branches from two young beauties. A haughty dame stretches her arm with magic gestures over a mysterious abyss that has engulfed mighty marble buildings, pillars, and woodwork. Behind the woman stands a youth with a torch and book in his hand. I have described in brief what one actually sees. Puvis means the star-gazers for Chaldæan shepherds; the Roman for Vergil; the greybeard in front of the Prometheus-rocks for Æschylus; the blind man for Homer receiving the laurels from the hands of the Iliad and Odyssey personified; the enchantress for history conjuring up the past. We are to read still more into it. The Chaldæans signify astronomy; Vergil bucolic poetry, Æschylus dramatic, Homer epic; the conjurer up of the dead and ruined, Clio. Thus we have before us five polished planes of the prism of man’s spiritual activity, five domains of the Muses—a fitting decoration for a library. These abstractions are painted in an abstract style. The human beings are schematic drawings as if taken from statues for illustrating an academic canon. They live psychically only through their artificial gestures—not through their mask—visages without mien of glance. The landscapes are geometrical combinations of rocks which a Cyclopean stone-mason has hewn in ancient style; of mountains whose ridge stretches in architectural lines; of evenly-coloured masses of deep-blue sea, pale-green sky, and sap-green grass country. The land is called Utopia, and is inhabited by Outis: in English, Nowhere and Nobody. The indigo, emerald, and turquoise tone is pleasant to the eye, especially as Puvis has here, contrary to his murderous habit, not massacred the living colours. But nothing except the harmony of colours appeals to me in these pictures. It is not painting: it is writing. It does not presuppose in me any feeling for art, but only a decent, classical education. It taps on my school satchel. Before these five Puvis de Chavannes pictures, I think of a highly-educated Japanese, learned in all the wisdom of his country, with the most delicate feelings for line and harmony of colours; an appreciator of Hokusai and the other great masters of Japan: he will receive no impression at all from Puvis’s works; he will look upon the figures as phantoms, the scenes as so much childishness; he will not have an inkling what these forms, remotely resembling human beings, are doing, or what they mean. For he is not acquainted with the Greek and Latin classics, and without this hypothesis the works of Puvis are dead symbols, incomprehensible to any one unprovided with the special key, and without the natural constraining power of plain human truth and beauty. The provoking over-estimation of his work by corybantic critics justified every severity against Puvis de Chavannes in his lifetime. Now his appreciation no longer requires polemical pricks, and we can say that his Géneviève cycle secures him a permanent place in the history of art; that his great allegorical frescoes are cold, dead, sprawling, pretentious subtleties; and that neither his drawing nor his colour sanctify him as a master and model. His importance consists in this, _i.e._, that in his time the longing for beauty took him as a cloak for a passionate confession. The Puvis cult was, in the main, a reaction against Realism. By the exaggeration with which he was honoured may be measured the greatness of the disgust which his contemporaries felt for naturalistic art.

XI

BRIGHT AND DARK PAINTING

CHARLES COTTET

A generation ago opposition arose against gloomy painting. Down with the twilight cellar painting! Down with the studio sauce! Hurrah for the open air! Long live free light! With this war-song a brave, hot-blooded band stormed art academies and studios of masters, and, shouting for joy, planted their silver and violet banner on the posts they had taken. For two whole decades the art exhibitions presented a cheerful, festive aspect. It was always Sunday. The glow of a southern noon rested over whole walls. From the hundreds and thousands of canvases, big and little, streamed the gleaming sunlight in its full glory. Men, beasts, things,

landscapes—all swam in luminous splendour which, at most, patches of violet shadow subdued timidly. Nature seemed to know no other conditions of light than those of Capri in July. About the turn of the century this suddenly began to change. In some pictures the light went out. Certain painters again discovered the darkness of evening, of leaden-clouded winter's day, of thickets, of rooms. On some palettes the eternal white and violet was replaced by the old brown, black, and olive-green of our fathers. The phenomenon became, year by year, more marked. To-day the change is accomplished. Free light is thrown away after the old moons. Painting has grown sick of noonday. There is an atmosphere of twilight in all the pictures. The young painters—the victors of the day—use as much asphalt, mummy, and umber, as did the old ones thirty years ago. Whole ranges of walls in the Paris _salons_ lie as in deep shadow, and we may go through several rooms before finding a creature represented as "breathing in rosy light."

What satires these _salons_ are on the consequential, high-stepping, deep-thinking drivel of professorial and other chatterers, who, to hide their dearth of thoughts, turn out new words, discover in our days a particular "charm" in painting as in other arts, and prove by _a_ + _b_ the necessary, logically offered expression of new spiritual needs of the present generation.

Now what has become of the "charm" that calculatingly demanded "free light" and nothing else? And how is it, then, with the spiritual needs of the present generation, to which free light and nothing else corresponded? And how does it stand with the new way, in which favoured artists have taught us to contemplate and to feel nature? Was the "charm" four or five years ago inclined to brilliancy, and is it changed during the night to an insatiable longing for gloom? Did white and violet correspond five years ago to the spiritual needs of the present generation, and does this generation now need black, brown, or olive-green tones? Have we just as quickly again unlearnt to contemplate and feel nature in sun-gold and violet, as favoured artists have taught us to do?

Living art goes her way according to her own laws and impulses, and leaves in the lurch the babbling empty heads, with their pretentious threshing of phrases, who tramp after her, expounding and talking wisely interpretations and clever chatter. Not by a particular "incentive" of the period, not from its alleged spiritual needs and currents of thought, are the changes of art creation to be explained, but solely by the psychology of the artists, by their very human, very weakly prosaic needs, by the material and moral conditions under which they are nowadays condemned to work.

The _salons_, the art exhibitions, are in our time the annual marts of success for painters. In these they have to seek fame and its train-bearer—payment in cash. In these they must strive amongst a thousand or two thousand competitors to astonish at any price. By special beauty or special nobility? This means will be chosen by the very fewest. Firstly, not one in a thousand has it in his power. In the second place, even an artist not in the front rank has enough Philistine contempt to be convinced that nobility and beauty are the last things for which the crowd has a taste. His hunger for success—a fitting form of his instinct for self-preservation—gives the artist sense and understanding of the psychology of the multitude, whose elementary law is that it is obtuse to that which is common and reacts on what is uncommon. The artist who works with an eye to exhibiting where his work will be one of two thousand, has only one endeavour, viz., to be as different as possible from these, and by this means possibly to make a striking impression amongst them. The contrary is the greatest difference possible. That is the polar line, the angle of 180 degrees. Logic, which unconsciously proceeds geometrically, brings the artist to this. He also looks sharply at what the others are doing; puts himself to trouble to find out what they have in common, and in what respect they resemble each other; and when he has discovered this, or thinks he has done so, he proceeds to do the exact reverse.

If he has properly recognised the predominating element and has hit the exact opposite, the victory is gained with a weight that overthrows all before it. Professional associates, critics, and public stand in front of something new. The novelty-hating majority feels the disturbance in their lazy mental habits as an insult and discomfort, and sets up a yell. The minority of unsatisfied gainsayers, morbid bread-hunters, vain coxcombs, and enthusiasts longing for the glorious Unknown and Unprecedented, passionately take side for the novelty. This serves as an excuse for a conflict of those eternal conservative and radical tendencies, whose battle may be seen throughout the whole history of human development; and the artist who unchains these tempests sees himself honoured as one of the embodiments of contemporary thought, as a power in civilisation. Only quite exceptionally is a cool analyst found to say with smiling tranquillity amidst the bluster of the war of minds: "Dear children, don't excite yourselves like that; the word 'new' is no verdict. To be different does not necessarily mean to be better. An old tendency may contain beauty in itself; a new one may, of course, do so too, but not necessarily. He who grows excited on behalf of the old, simply because it is old, is commonplace. He who grows excited for the sake of something new, merely because it is new, is commonplace with a negative prefix. Only wait a little while. In a short space of time the new will have become old, and you will recognise that there was no grounds for raising a noise about it. The man of the new thing, whom you hail as the bringer of a new salvation, is no better than the ancients; but he is right, for he wishes to be noticed, to inherit from the ancients, and that is wholly justified from his selfish

standpoint."

The would-be aristocrats of intelligence—the "intellectuals"—would find a speech like this intolerably homely. It is not in the least "deep." It is not at all applicable to the mystic inclinations of vaporous brains. It discovers no single unsurmised and astounding relation between phenomena that have nothing in common with each other; but I believe it is literally true.

The "Impressionists" of the Caillebotte room in the Luxembourg painted brightly when the _salon_ was correspondingly dark. The one light picture among the dark paintings acted like a window that opens in the gloomy wall to the sunny air. When the other painters saw that the multitude flew towards this bright point, like moths after the flame of a taper, they hastened to paint also in bright colours. "Free light" was discovered. It corresponded to no mood of the period. Free light is joyous and satisfied. The spirit of the age was, during its predominance in painting, pessimistic and sick with longing as it had hardly ever been in the past. Nor was it a new way of seeing and feeling nature. Turner, Corot, Claude Lorrain, Ostade, Salvator Rosa himself had seen and felt nature quite as brightly as Manet and Monet had done. The truth is that the "Impressionists" were turbulent young people who got angry at vegetating in obscurity whilst Gudin and Schnetz, Signol and Müller, Pils, Cabanel, Dubufe, and Robert Fleury had all the honours and successes; and that impelled by envious loathing of these celebrities of that day, they found, as it were, in a negative chemo-tropical way, the exact reverse of their dark style.

Five years ago the same incident was played off exactly in the opposite direction. Everybody was painting in a bright style. The Schnetz and Cabanel, Delaunay and Cogniet of the day were called Puvis de Chavannes and Roll, Besnard and Cazin. Then, again, some young people got angry about their being unknown and unheeded, and they entered, consciously and of set purpose, into opposition against the celebrities of the day. Charles Cottet exhibited a black picture which, in the middle of a blinding white exhibition wall, struck just as glaringly as did, thirty years ago, the bright picture in the middle of the black wall. Cottet had hit the bull's eye. He instantly created a school, and to-day the _salons_ look once more as they did thirty years ago, to be once more flooded with free light, probably, some twenty or thirty years hence. It is an orbit without beginning or end, an eternal beginning over again, and only posing fools seek, in this monotonous, periodical return of the same effects under the influence of the same causes, to ferret out connections with definite phenomena of the times.

Charles Cottet is developing into the undisputed leader of the young race of painters. He deserves the recognition accorded to him, yet it is a serious matter that he provokes to imitation; for what in him is uncouth, though justifiable, independence, will become with the imitators a manner that may rapidly pass into intolerable aberration. Cottet loves dark harmonies of colour. He paints night, closed rooms illumined by artificial light, candle and fire effects; unlike Rembrandt, whose glooms are delicate and transparent, whose men and things are particularly self-luminous in sunless space; and unlike his pupil, Schalcken, who treats flames and their reflections roughly after the manner of a blacksmith, without mystery or harmony. Cottet paints it apparently more from joy in darkness than joy in light, for with him darkness is generally the principal thing, and the sources of light are there chiefly to call attention to the sinister stir and movement in the unillumined dusk. His imitators do not see the intense life of his shadows. They only see his black, brown, and dark-green palette, and dimly brush away at it again as in the worst days before the dawn of "free light."

Painting goes out into the night, and will remain there a while. Then once more a cheerful and free artist will come, and discover light for an astonished and enraptured world, and he will be deified or damned as a revolutionist just as Monet was thirty-five years ago when he did the same, and as Cottet was five years ago when he did the reverse. And thus it will ever be so long as in the human apparatus of thought a change of impression will relax conscious feeling, and art creation will have to serve, not only the utterance of strong impulses of emotion and the relaxation of the nervous system, but also the ambition or vanity of the artist, which means, I suppose, to the end of time.

Cottet's execution is somewhat brutal. He works in the style of Ribot, who was himself a curious mixture of reminiscences of Franz Hals, Ribera, and Velasquez, with an admixture of personal self-will. He lays great, dark, almost dirty spots on the canvas, and treats human skin with boorish coarseness—I might almost say, with the curry-comb. But what truth and energy in all the movements! How economically and yet how exhaustively he can reveal the thoughts and feelings of his subject. There is little in the whole of modern painting so pathetic as his three-panelled picture, "Sea Folk," that now adorns the Luxembourg Museum. In the middle, the parting meal of the Jack Tars before starting, round the village table fifteen people, strapping young men with their womenfolk—mothers, wives, and sweethearts. Through the open window dark-green night looks in; from the petroleum lamp there gleams a sharp streak of yellow light; the men sit close to each other in silence; forebodings and the sadness of leave-taking exalt them and raise the souls of these horny-handed toilers to the regions of poetic thought and dreams. On the right, the boat that is

conveying the sailors to their ship; some are rowing or steering, the rest are in a reverie. All go carelessly to meet their fate, which perhaps will mean merely prosaic seaman's work on a voyage without any adventures, but perhaps even heroic tragedies of struggle and destruction. On the left, the women remaining behind, who watch from the shore the departing men, their lovers, their bread-winners, with sorrowful love and prayer in their looks, their mien, their hands, and their attitudes.

Possibly this profound picture moves me so much only because it illustrates completely what I meant when I described the social mission of art in the future in these words: "In a work of art which is to attract the people, the people must find themselves again, but just as formerly the priest and king did: magnified and ennobled. The work of art must show them their own likeness, though a beautified one. It must raise the people in their own eyes, teach them to respect themselves.... Works which can show the dignity and beauty of the occupations of the multitude, which are a sanctification of labour, an apotheosis of the tragedies and idyls, of all the sweet and bitter stirrings of emotion in the common life—these works, I believe, constitute the type of the art work of the future."

Cottet's triptych is one of these works. It renders my abstract deductions concrete. He is a great painter who can extract with so sure a hand from the stone of everyday life all the gold of beauty it contains.

Cottet gets his suggestions for the most part from Brittany. Almost all his works, in any case his most famous ones, tell of Breton nature and the life of the Breton people. His "Midsummer Fire" is very affecting. The holiday fire is kindled beneath the clear sky of a midsummer night; around it assemble the Bretons, ever faithful to their traditions. The smoke ascends vertically; the flames glow on the countenances gazing on them. Old women and children they are, for the most part, who celebrate the solstice according to ancient custom; there are hardly one or two men among the devout multitude. The sterner sex, the middle-aged, laugh at the superstition; but the grandmothers foster the custom of their ancestors, and entwine it into the earliest childhood of their grandchildren as a dear remembrance that grows up with all the joys and sorrows of their infant years. Thus what is old is retained and is handed down from generation to generation. Cottet has expressively illustrated this rule of folk-lore, not because he intended it, but because he was true. Far and wide, as far as the eye can reach, other fires are burning, and mirroring themselves in the sea, and you can guess that, even around the furthest, which are hardly visible in the night, the villagers are making a circle, just as round the flame in the foreground. One single note hovers over the whole of this landscape; one single feeling dominates the soul of all this population. Each one of these old women whose glances are submerged in the holy flame feels herself at this instant a unit of the whole race inhabiting the hereditary granite soil, and part and parcel of her forefathers who have long rested beneath the sod. Thus a real work of art, without straying into literature, points far beyond its own boundaries.

The "National Fête at Camaret" is celebrated so earnestly by the Breton peasants that, in spite of the bright paper lamps on the tree, it has the effect of a church solemnity. In "The Old Breton Nag," Cottet has translated from bronze into less severe painting one of the never-to-be-forgotten coal-mine horses of Constantin Meunier. "Mourning by the Sea" is one of his masterpieces. Grandmother, mother, and daughter are sitting together on a stone bench on the shore. They are all three wearing widow's weeds. They are speechless and motionless, abandoned to their thoughts, which abide with their dead. The sea, which has swallowed their husbands, and to which they turn their backs, lurks behind them in insidious calm behind two storms that depopulate the coast, and leave behind the granite cliffs only old and young widows and children, who, in turn, also will be trained for the sea—the merciless sea, on which the poor devoted fishermen and sailors seek their living and find their death. The existence of a population, its truceless fight with hostile nature, is comprised in the black figures of these three modern Niobes. To-day, too, as in its beginnings, true art is myth-making.

To this series of pictures from Breton peasant life belongs also an "Early Mass in Winter," which at present hangs in the "Little Palace," at Paris. In the early dawn, beneath heavy clouds, a few Breton peasant women, of whom we get a back view, are proceeding across the flat, damp heath to an insignificant village church. They wear the round mantle with a hood, which is usual in that country. On first glancing at these short, broad, black figures without human form, which look like wobbling, tightly-filled coal-sacks, I could not help laughing aloud. But I observed in the mien of other observers composedness, piety, and admiration. These evidently saw in the picture only the walk to church, not the clumsy sacks, always a proof how powerfully Cottet can conjure up a mood.

Once or twice Cottet has in some measure proved faithless to his usual dark style of painting, and allowed himself to revel in colour. Thus in his portrayal of a family of Breton fisherfolk, when the corpse of a baby is laid on its bier. The dead child lies in its little open coffin, around which four tapers are burning. On both sides of the bier the seven or eight relatives stand grouped: the parents, aunts, little brothers and sisters express, each in his or her way, their grief, which, in the case of the still unconscious children only, sinks to the level of mere curiosity. From the coffin proceed two vividly red ribbons which stream across the bier down to the

ground. Flowers of a similar furious red are strewn over the bier. These shrill values do not produce exactly a fine and harmonious effect in the dark-toned general atmosphere with the opposite warm yellow spots of the taper-flames. Moreover, the composition here is also not a happy one. It is an error to make the pale little corpse of the child the centre of a large picture. Death does not attract the eyes, but repels them. It does not endure the rivalry of life unless it can compel attention perhaps by means of special melodramatic circumstances or symbolical value. The glance turns naturally to the living, feeling, acting human beings, and thus the centre of the picture, which should be the keystone of the arch that holds the composition together, seems to be a gap. Christ's dead body may be made the centre of a picture. This dead Saviour will always be, in the beholder's imagination, the most living, the only living thing in the picture. So, too, the dead Lazarus and Jairus's little daughter are suitable for the main figures in a composition, because these dead persons are virtually living, and what makes them interesting is not death, but returning life. But the innumerable "Lessons in Anatomy," which were a favourite subject with the Dutch painters (Aart Pietersen, M. van Mirevelt, Rembrandt, Adrian Backer, Van Neck, Cornelis Troost, etc.) show how unsuitable a corpse, to which no suggestions beyond its visible condition are united, is for arresting the attention. Even a master such as Rembrandt is unable, in what is, I suppose, the most famous of all "Lessons in Anatomy," to direct attention to the dead body. In spite of the large space occupied by the corpse, we do not see it, but only Dr Tulp and his audience. Cottet's picture is the most convincing proof of the impossibility, in a composition containing living persons also, of laying the chief stress on a dead one. The psychic element, _i.e._, the mourners' pain, Cottet has, however, expressed with gripping force and truth. It is his strength and glory that the inward, emotional life preponderates with him so far beyond all externals.

At the first glance his "Breton Festival" is even more repellent than the "Dead Baby." The line of hills on the horizon, the stern heath, the church, the breakfast laid on the white tablecloth in the foreground, are certainly masterly achievements; but the Breton women grouped in the open air round this still life wound us with their silk bodices of the crudest blue, green, and violet! It is said that Breton women actually dress in such shrill colours. This may be so; but that does not really justify the crude reproduction of such brutalities. It is asserted that time will subdue the overloud tones of these violent colours and effect a reconciliation of them. On this subject our children or grandchildren will have an opinion. What we see now is, anyhow, unpleasant. Has Cottet wished to show that he is able to deal with something besides asphalt and umber? If so, let him be told that his dark harmonies of brown, grey, and black are more agreeable than all these shrill penny-trumpet tones.

Cottet stands at the zenith of his life and artistic capacity. It would be rash to predict his further development. Whether he keeps to the dark style of painting, to which he owes his reputation, or lets himself be led away by the strong, bright, full colours; whether he remains faithful to Brittany, which seems with the young race of artists to take the place of the classic Italy of their predecessors, or seeks another soil and another landscape to serve as frames for his men and women of deep emotions—in any case, Cottet has already secured himself a place in the History of Art; deservedly, too, but chiefly because the change in the valuation of tones is bound up with his name. It was day; it became night. Manet and Monet had denoted dawn; Cottet introduced evening twilight.

XII

PHYSIOGNOMIES IN PAINTING

John W. Alexander, an American, possesses an enviable skill and certainty. He is master of the means of expression belonging to his art, and has a trustworthy feeling for the harmony of those light, subdued colours called in Fiance "Liberty" shades, after the name of an American tradesman in the Avenue de l'Opéra who first brought into vogue clothing, furniture, and wall stuffs in such peculiarly anæmic and almost chlorotic colours. With his dexterous draughtsmanship and charming harmony of cool, diluted blue, soft green, faint pale yellow and delicate rose, he might possibly have pleased connoisseurs, but could hardly have attained world-wide fame. He, therefore, hit upon painting women's portraits in amazing positions. He was the inventor of acrobatics in portraiture. His women lie about, in orgiastic contortions, on the ground or on sofas, with their legs up and heads hanging over the edge, or with forms twisted twice round, like a screw, or curled round like a sleeping dog, astonishing the inoffensive spectator, and suggesting to him of corrupt imagination certain lustful ideas. The means were effectual. Alexander became a first-class firm, and the _crétins_ of criticism did not fail to praise his special knowledge of, and feeling for, the "modern women of high-strung nerves and Satanic caprices." Now Alexander seems to find that he has acquired sufficient fame, and is abandoning his follies. Among his later pictures there very rarely occurs one of which the model betrays his earlier leaning to gymnastics. The ladies he now paints are quite decent in their attitudes, and only, perhaps, a serpentine movement in their long, flowing garments reminds us still of the old gutta-percha or snakelike contortions of his bodies. Alexander has slipped through the fingers of his modernistic critics. Whilst they still keep on raving about his "modern women with high-strung nerves and Satanic caprices," he is painting prosperously,

peacefully, and intelligently, and can now be recommended to the most respectable _bourgeois_ families to immortalise their matrons.

Aman-Jean is a melancholy painter, whose palette has been tuned in a minor key. He is the guitarist of the falling leaf, twilight, tapestry-hung ancestral halls, sombre Gobelins. His pictures result from the mood in which a man catches himself humming the _King of Thule_. I do not say that this tone of colour does not possess its charm. He who does not live his life like a thoughtless, devouring, and digesting animal has, I suppose, on every blessed day of his existence, an hour in which he finds his own soul in the subdued and faded palette of Aman-Jean. It is, however, morbid to see the phenomena of the universe merely as old Gobelins in the hue of twilight hours. And morbid, too, is the way in which Aman-Jean transforms his impressions of poems into a painter's view. I know, for instance, a "Beatrice" of his which affords the maximum of involuntary comicality. Before an artificial-looking orange-tree, which she overtowers in height, Dante's beloved, with the upper part of her body thrown back, and her stomach pushed forward, performs a sort of _danse du ventre_. To her girdle she has a golden laurel garland hanging, which, as a note of illumination in the dull night-hues, has an excellent effect as _valeur_ (as the French say), but as an object or requisite is very comic. Aman-Jean himself, with that misappreciation of subordination in his pictures, which is so common among artists, lays far greater value on such ridiculous whims than on his portraits. And yet it is only in these that he shows with what sureness and intensity he is able to seize and lay bare the most inaccessible and most mysteriously elusive thing that reality has to exhibit, viz., living man. His "Jules Caze" and his "Dampt the Sculptor" belong to the most delicate portrayals of men, just as his "Paul Verlaine" and "Madame Henri Martin" must also remain unforgettable by every one who has beheld them.

His portraits, to be sure, are not by any means of the same value. There is, for instance, a portrait by him of a "Cossack Colonel" that must fully mislead in regard to him. Materiality is entirely lacking in the full-length figure he has painted of the Russian officer; it is clapped flat on the canvas like a pancake. A laurel bush climbs from the bottom to the top of the picture—one cannot say in the background, as the picture has no depth, but, apparently, behind the man. The shrub seems painted on the wall to the height of the head. It suddenly grows plastic before our eyes, and shoots its leaves in front of the colonel's nose and forehead. By this symbolism which scoffs at all the laws of perspective, the painter evidently wants to suggest relations between the warrior and fame. One can only shrug one's shoulders at such puerility.

He is more and more breaking himself of the habit of regarding living models, and allows himself to be hypnotised by the Præ-Raphaelite magic lantern. We might wish for an Orpheus to take this noble artist by the hand and lead him back to the light from the shades in which he has lost himself. Perhaps the adventure would be more successful than in the case of Eurydice.

Albert Besnard.—Contemporary painting knows no more harsh contrasts than Puvis de Chavannes and Albert Besnard. The former saw nothing in the world except spectres; the latter sees only fireworks. Puvis's eyes perceived no living colour; Besnard's eye is in a state as if it had received a violent blow from a fist, in consequence of which it saw the proverbial ten thousand candles. There is nothing objectionable about his delight in colour; on the contrary, any one who is not suffering from Daltonism would be delighted to be invited to his debauch of colours. If only Besnard only satisfied his taste in a somewhat nobler way! It pleases him to introduce his dazzling rockets into women's faces, and there no man of healthy taste will care to follow him. Besnard has marvellously beautiful yellow, orange, green, blue, and red on his palette. He can attune them, too, to a beautifully sounding harmony; but why must he put yellow on the cheeks, green on the hair, and blue and orange on the shoulders in his portraits? Why must he so portray his model as if it were streaked with luminous paint or bathed in a stream of light that has flowed through a coloured glass window? His mastery of drawing and modelling certainly makes his colouring-run-mad somewhat more endurable, but it does not justify his not searching for the tumult of colour which he loves in actual life (where, after all, he might with some effort find them), but chasing them into actual life without any regard or thought.

In the _salons_ of late years, Albert Besnard pursues a curious policy. Near one or more aggressively stupid works, he exhibits a portrait or painting which is amazingly rational. In this there is method, unmistakably. It is a sort of self-defence. Besnard seems, from his canvasses, to address the visitors to the "Salon" in these words: "You see that I am in private life quite a sane individual and correct painter, who is as much the master of his art as anybody in the world. The other rubbish is for the fools of modernism. For those I am bound at times to play the Jack Pudding, but you need not, however, worry yourself about that." Once, for instance, this painted plea was the life-sized portrait of Denys Cochin, the nationalist deputy for Paris—an excellent work, laborious, powerfully drawn, and irreproachable in colour, which reminds one of Herkomer's best style. His clownery, on the other hand, was a huge picture which Besnard calls "The Isle of the Blessed." A bushy shore in the foreground, then a wide expanse of water which looks partly like sand, partly like wine-soup, and only in the remotest degree like natural water. Finally, in the background, a flat shore with the outlines of a white town that stick, as if cut out of paper, on the blue horizon. Across the level sea where it is reddest,

glides a skiff in which stands, in the attitude of the Saviour calming the tempest, an enigmatical figure in red, flowing garments, and with the countenance of an Indian chief, surrounded by a grass-green and wine-dreg-coloured woman and a monkey-like rower of sulphur-yellow hue. On the bank young maidens tarry for the new arrivals, their light raiment, blown bell-shaped by the breeze, reproducing a _motif_ of Botticelli. Between the trees groups of bright-coloured figures are camped, and on the steps of a hill sit or lounge flute-playing fauns, one of whom has the typical head of a retired French colonel. The women in the skiff are distinguished by distorted, acrobatic attitudes, which no model could sustain for ten minutes without supports and props. On principle, no two figures are placed side by side without being clad in the most opposite colours in the spectrum. This arrangement of colours suggests the thought that none of the figures must move away from the side of the others, and none could step into another group, as otherwise the harmonies intended by Besnard would be destroyed. That seems boldly and freely fanciful, but is soberly and painfully subtilised. It is a mechanical game with contrasts of colours, devoid of purpose and even of the charm of any sense of colour. Albert Besnard has, in his later days, evidently discovered Böcklin, or even has only heard him extolled and wants now to make his own Böcklin. The fauns—up to their heads—the maidens on the shore, the blue sea, the white town in the distance, are descended in the direct line from the pictures of the Bâle master. But Besnard has imitated the details as any one may copy a writing which he cannot read. "The link of the spirit is all that it lacks."

Jean Boldini is one of the most remarkable painters of female portraits in our time. In these he makes himself most solicitous to unite together the screw lines of Alexander's demoniacs twisting in hysterical convulsions, and Zorn's bold, sunbeam dances. The faculty of tumult hardly any one among contemporaries possesses like this uncommonly skilful Italian. His pictures seem to fly up as from a bursting bomb. Every fibre in his women palpitates and throbs. One of his women sits half naked, just as if she had torn, in a rage, the clothes off her body, on a lion's skin, and he has made the head and skin of this common floor-rug bristle with such an expression of cruel savageness, that you jump back in terror from the expected spring of the bloodthirsty monster. Another woman wears on her arm and shoulders a feather boa with wonderful convolutions, which seems to rustle from her in excitement like an eagle. A third lady stands in a door frame—she seems to be about to spring forward with the leap of a tiger. She wears one of those very modern, low-cut evening dresses, which are fastened over the shoulders only by a tiny chain; her bust looks as if it were laid bare because her dress was torn from her body in a brutal struggle with a satyr. There is an atmosphere about this woman of all hysterical convulsions, St Vitus's dance, or defence with teeth and claws against lawless attempts. There is a story about sorcerers and witches who through a touch give another shape to men. This changing of skin is not practised only in fairy tales. Certain portrait painters also have it in their power. Old Cabanel transformed the rich, fat wives of wholesale merchants and owners of house property, whom he painted for 30,000 francs, into goddesses of the old Greek mythology. Boldini by a spell transforms the ladies who trust themselves to him into mænads, mad women, evil witches that ride of a night on broomsticks to their Sabbath. I do not believe that people pay him 30,000 francs for that; but if a lady even disburses a centime to be represented by Boldini as a Bacchante or a Vampire, she must be as much a victim to neurosity as Boldini makes her out to be.

William Bouguereau.—The contempt of Bouguereau is the beginning of wisdom in art. That everybody knows who has occupied himself with contemporary painting otherwise than as a picture-dealer. Among the long-haired ones who dwell on the mountain land of Montmartre, no name conveys a worse insult. He who wants to make an impression on the Botticelli ladies when visiting the "Salon," must make a grimace of sudden, severe nausea when he comes across a painting by this "manufacturer of perfumery labels." On the other hand, Bouguereau has managed to collect in his head in a coronet of all sorts all the honours that blossom for an artist in France. He is Commander of the Legion of Honour and Member of the Institute; he gained the _Prix de Rome_, and has pocketed all the medals that the Salons and Universal Exhibitions had to bestow. His works fetch the highest prices in the market, and if no Parisian artist finds purchasers, the big pork butcher of Chicago, that painters' Providence, to whom in their prayers they turn their countenances, always has gold for Bouguereau. The deplorable Philistine, who would also very much like to have a little share in the æsthetic enjoyments of this world, tears his hair and groans: "Where is truth?" The _Chat Noir_ treats Bouguereau as a buffoon, but the Academy erects altars to him. Criticism scoffs, but America pays. And, however readily the Philistine yields to the appearance of daring modernity, if he listens to the voice of his own heart, he notices to his embarrassment that Bouguereau, as a matter of fact, pleases him. He gazes with secret delight at his "Cupid and Psyche," his "Pearl," and "Innocence," his "Oblation to Cupid," his "Wasps' Nest," his "Cupid _mouillé_," his "Holy Women at the Tomb." It is always the same: a sweet maiden, or even several, a well-built youth of rosy body and slender limbs, laughing little mouths with pearly teeth, blooming cheeks, snowy bosoms and rosy fingers—all lovely, all a delight to the eye. The Philistine wriggles under the decree of fashion, which forces him to find these charming things horrible, and his troubled look frames the question that his mouth dares not utter: "Why? Why?"

I think we are doing a good work when we answer him calmly and in a friendly manner, without exaggeration or cheap witticisms which neither explain nor prove anything, not even necessarily the sincerity of the witling. Bouguereau pleases the insufficiently

trained eye, because he paints prettily; but in art prettiness is the direct opposite of the beautiful, for it is untruth, since a conscience originally delicate or happily trained only feels truth to be beautiful.

Prettiness is necessarily untruth, for it is that which is conceived without trouble, which excites no opposition, which compels no strain on the attention and no adaptation on the part of the spectator to the peculiarity of the artist. Its effect is merely the effect of what meets the spectator's pre-existent thoughts or feelings completely. This pre-existing element is not, however, the result of collective observation and strong feeling, but the dissipated precipitate of the most fugitive, indifferent perception, which is totally unfitted to obtrude into the world of phenomena.

The artist whose goal is prettiness, does not glance at reality, but at the soul of the crowd which he wishes to please. He does not portray what he sees, and what makes an impression on him, but what suits the feeble, inexact concepts which the average man forms of things. He is a courtier of the crowd; he flatters their shallowness and incapacity. He wants them to say, with a self-satisfied smile: "This man is a great artist, for he has the same way of looking at things as ourselves." Prettiness is, in lyric poetry, rhyming "love" with "dove," "heart" and "part"; in drama, it is rewarding the good characters with advantageous marriages and lucrative posts, and making the wicked fall into the pit they have dug for others. For this is just what the public expects; such is the world-picture which the world has arranged for itself, and it is grateful to the poet that he does not force it to rectify its comfortable way of thinking.

In the plastic arts prettiness is the average or typical. Bouguereau paints a pattern, not a person. He has a canon to which he holds; and if he would only go so far as to look at real human beings, and had to admit that nature does not act according to his canon, he would certainly say: "So much the worse for nature."

Superficiality always confuses prettiness with the ideal. One cannot fail to see that prettiness lacks exactness. This inexactness is, however, praised as an improvement on reality: the master of prettiness understands nature better than she understands herself. He guesses what she would, but cannot always, do, and comes with his superior creative power to help the poor incapable. The truth is that prettiness is the exact reverse of the ideal; for the ideal is the presentiment of future developments: prettiness the pompous repetition of what is commonplace. The idealist is impelled by a restless longing after novelty to represent; he seeks in invisible germs which the average soul does not perceive to detect the later glory of blossom. The painter of prettiness shows scant satisfaction in attainment, and his creation is nothing but a sleepy reminiscence of impressions he is accustomed to.

The chief harm done by prettiness in art is that it confirms the multitude in their dulness instead of arousing them from it. What the "man in the street" feels in presence of a work of Bouguereau's is self-complacent pleasure at the artist agreeing with him. He will expect the same feeling also from real works of art, and be disappointed if he fails to find it. Pretty paintings deaden the mind of the average man for powerful works, which teach men to see, educate eyes, operate for cataract, and heal colour-blindness, are keys to the hidden sense of lines of movement, interpret the symbolism of form, and point the way to unknown beauty. The bloodthirsty backwoodsman of Montmartre is, therefore, right to think little or nothing of Bouguereau, and to scalp him; and the Philistine who expects to elevate and enrich his mind by art must make the sacrifice of renouncing the cheap pleasure which the engaging banality of prettiness procures him.

If Bouguereau has anything personal to say, he can say it no worse than many another. His "Portrait of Himself" in the velvet painting-jacket is sincere, and at any rate strives to be honest. It is true that here, too, he has not been quite able to overcome his habit of embellishing, and his cheeks are distressingly rosy. One could not expect from him the almost terrifying inexorableness with which a David has confessed the dreadful grimace of his face paralysed on one side, and a Rembrandt, in his old age, the puffiness of his features and the wateriness of his eyes. These men had such a pride in truthfulness that, in their anxiety not to be partial, they felt almost hostile to themselves, and tried, and judged themselves accordingly. Bouguereau does not understand why he should treat himself more ill-temperedly than his Cupids and nymphs, and smiles good-humouredly at himself.

Frank Brangwyn.—This young Englishman, born in Belgium, is a painter of the great class from which the kings of art spring. In his delight in colour, he reminds us of Delacroix in his _Sturm und Drang_ period; in the dauntlessness with which he wields the brush, of Franz Hals himself, the boldest fighter with this weapon that ever lived up to now. His two first works exhibited in the Paris Salon, "A Sailor's Funeral" and "All Hands Aloft," instantly called attention to him. His "Buccaneers" was a veritable revelation. In a boat, floating on the blue-black tide of the Carribean Sea, row some life-sized fellows clad in variegated material, their heads bound with bright red cloths. In the glowing, tropical sun that swelters down on them, everything is a blinding, bright flame: the foam, wet oars, the ship's planks, the clothing and headgear of the people. The brown cut-throats get in this noonday glory an almost superhuman

relief, and in their savage countenances a calm consciousness of their formidableness is revealed, which even in the picture has the effect of a challenge to mortal combat. A year later he exhibited "Goatherds," likewise life-sized, and likewise plunged in the noonday glow of a southern sky, and, in addition, a reposefully coloured and marvellously deep night-piece, "The Three Holy Kings offering the Infant Jesus Gold, Incense, and Myrrh." His ability was further enhanced by a "Market on the Shore" and a "Miraculous Draught of Fishes."

The "Market on the Shore" is held in a Barbary harbour. Little bright-coloured carpets are spread on the yellow loamy sand, where negroes in brown and green-lined _haiks_ and _burnooses_ lie squatting. They are surrounded by poorer people in fantastic rags, with red _tarboosh_ on long, clean-shaven Hamitic skulls. Beyond, three ships extend their prows over the flat beach, and in the background, on the further side of a strip of water, we get a glance, through a gateway with three pointed arches, at the dim throng of a mysterious Mohammedan town.

The "Miraculous Draught of Fishes" takes place in the evening. The fishing-boat rocks softly on the almost oil-smooth, dark blue mirror of the Lake of Genesareth, on the shallow valleys and crests of whose waves the setting sun's nearly horizontal beams strew leaves and strips of thin gold. Four fishermen are busy hauling in with powerful movements the net heavy with their catch. Behind their vessel, a green, flat-bottomed boat with sails, steered by a disciple, carries the Saviour, veiled in the gloaming, across the water.

Religious subjects have an especial attraction for Brangwyn. In his great picture, "The Scoffers," he shows a man with the bearded curly head of an enthusiast, fastened to a pillory. The scene, as is usual with Brangwyn, is an Eastern town. A crowd, which is amusing by its negro and Moorish types and their charming garments and rags, presses on the prisoner, who is wearing the strange garb of a Western artisan, and reviles him with the words from their mouths opened in sneering laughter; with the glances of their stupid, malicious eyes; with the gesture of their forked and pointed fingers. Pity is mingled with curiosity only in the case of a handsome, brown, young maiden in the foreground, who, with a noble water-pot on her head, evidently returning home from the spring, remains standing in order to gaze at the scene. You may understand the story as you please. Perhaps it is a foreign socialist or anarchist, who tried to preach his doctrines there, and to whom the authorities are giving short shrift, and whose only reward now is the mockery of the stupid crowd to whom he intended to bring a message of salvation. Perhaps the incident has a deeper and more solemn sense, and is the subjective, half-touched-up, half-modernised representation of the mocking of Christ when He was bound to the pillar in order to undergo flagellation. Whether the drama is conceived from a sociological or theological standpoint, it is of supreme power. The great pain of the altruist who sacrifices himself for mankind, and sees his sacrifice despised; the great sin of the populace that is thoughtlessly guilty of the most horrible ingratitude, are strikingly expressed. And in what form is this rich spiritual and moral purport clothed? Such repose and nobility in varied colour; such witchery in the flat triad of dark yellow, reddish purple, and deep blue; such amazing sureness in modelling by means of mere patches of colour without outlines, it has not been my lot to meet with twice in contemporary painting.

Neither must I leave his "St Simon Stylites" unnoticed. The saint is sitting, with his back resting against a pole, on the platform of his lofty pillar. On the other edge of the platform, ascending by a ladder, appears a priest in mass vestments, accompanied by a deacon, in order to administer Holy Communion to the Stylite, who is apparently dying. The story, however, is a matter of indifference. It is the wonderful harmony of colours that makes this picture so expressive. It is late in the day; twilight is approaching; the last ray of sunlight is finely sprinkled through the air around the figures above the roofs of the Syrian town, from which arises a transparent cloud, so thin that it is rather a breath, an exhalation, than a vapour, and is more surmised than seen. A flight of swallows glides past the saint, and the birds, with their arrow-swift and pleasing motions, observed in the precise Japanese way, greatly help to produce an impression of height and airiness, which Brangwyn attains chiefly by his art of distributing light, and his eerie perspective.

Brangwyn fixes in his pictures all the magic of noon and midnight. He shows his figures either flushed by the quivering heat of the full burning sun, or covered with a veil of half-transparent darkness. Both illuminations have the peculiarity of suppressing all subsidiary work and letting only what is essential remain. The face or body of a man steeped in sun rays becomes almost transparent. Behind the skin and the connecting tissues which we perceive only as a covering, the muscles and bones come forth. The intense brightness prepares a body almost as the dissecting knife of anatomy. Darkness has a similar effect; it blots out the connections and transitions, and only accentuates the strong lines of construction. Only diffused light gives an equal value to all the parts of a surface; it shows all and explains nothing. Direct light, on the other hand, just like darkness, graduates phenomena, makes us recognise at the first glance what is external ornamentation and what are the supports and timber.

Brangwyn is an impressionist in the best sense of the word, a perfect representative of what Impressionism contains that is justifiable. He does not stop over trivialities and accessories. He sees only the essential in phenomena, but this he sees with infallible certainty and intensity. A feature which marks exhaustively the direction, purpose, and force of a movement; a spot of colour that challenges and fixes the eye, as a sudden stroke of a bell does the ear—these are the optical elements which he grasps, and with delightful simplicity, weight, and carelessness, and, as it were, in student fashion, throws on the canvas "straight from the wrist." The spectator finds once more in the picture exactly the component parts of the phenomenon which in the actual thing would alone excite and fix his attention, and, corresponding to his psychological habit, he supplements the indications of the painting by pictures from his own memory, till it becomes a perfect copy of the real thing, which then includes also all the subsidiary matters either merely hinted at, or quite passed over by the painter.

Brangwyn is one of those rare gifted _virtuosi_ who does not need to draw. The line does not subsist for him, just as it does not subsist in nature. He models with light and colour. He puts spots irregularly near one another, little and big, long and short, angular and round, bright and dark, white and coloured; and from these spots, from this mosaic of correctly-felt effects of light, he builds up the phenomenon in space with incomparably genuine and intense corporeality. Our judgment adds the lines which the painter has never drawn, as it does when looking at the actual thing. We have here the optical elements themselves, which are perceived by the retina of the eye as mere gradations of light, but are apprehended and interpreted by the higher centres as coloured and plastic phenomena. Such a way of painting demands infallible certainty of sight and trustworthy obedience of the hand, else it leads to bankruptcy in art.

Paul Cézanne.—He was one of the protagonists and pioneers of Naturalism. He was with Claude Monet, Caillebotte, and the other Impressionists an interesting subverter; with Zola he was for a moment a victor, and is now vanquished, although, probably, he will not admit it. A barefooted Masaniello, whom a successful revolution of the rabble carries to the top and lodges in the king's palace, but who has very soon to exchange his purple mantle for his hereditary rags. Fortunately, the lot of overthrown art-revolutionaries is not so horrible as Masaniello's; they do not end under the executioner's hand.

Cézanne has one thing in his favour which prepossesses us for him, _i.e._, his uprightness. It is his nature that ugliness has for him an attraction. He sees only what is abnormal, unpleasant, and repulsive in actual life. If he paints a house, it must be warped, and threaten to tumble down soon. If he portrays a human being, the latter has a distorted face, apparently paralysed on one side, and a deeply depressed or stupid expression. Every model that submits himself to him is put in some sort of convict's dress. Here is a female portrait. A withered, dried-up face, mud-bedaubed clothes that look as if they had been trailed through the gutter. Doubtless a "professional" who at a raid was accommodated in "Black Maria," and, after a night in the cells of the police station, discharged? Nothing of the sort. She is a respectable lady of the upper middle-class. This man with the trouble-distorted countenance and the greasy felt hat and overcoat is perhaps a starveling from Bohemia, a broken-down creature, ruined artist or writer? Most certainly not. He is a well-to-do person of independent means. It is curious to me how any one can allow himself of his own accord to be painted by Cézanne, unless it were done in a contrite, penitential mood as a penance. To be sure, one cannot be angry with him, for he does not treat himself any better than his other victims. He has painted portraits of himself which would be grossly libellous if another had painted them. In truth he is not vain, for he sees himself as he represents himself in these pictures. And his morose eye disfigures not only faces, heads, and raiment, but also the rest. Heine assures us that "A woman's body is a poem." He would not dare to sustain this statement if he were to see Cézanne's "Three Naked Women before the Bath." Such nudities are really immoral, and shriek, not for a discreet fig-leaf, but for a nine-fold covering of cloth and fur.

Blaise Desgoffes.—This painter, who died in 1902, was an incomparable copier of still life; for indeed there exists a still and secret life in the productions of the artist's hand, as an eye lovingly steeped in form and beauty of colour sees them. Desgoffes was great in little pictures, which rendered splendid things of gold and enamel, of rock crystal, jasper and chalcedony, trinkets and precious stones, lace and embroidery on velvet and silk, carved and polished ebony in insurpassable perfection. There is a school which very contemptuously calls these pictures _bodegones_. That is the disdainful Spanish expression both for a cookshop and for daubed representations of vulgar eatables such as sausages, smoked herrings, and cheese made from whey. Copying the productions of human hands should be unworthy of an artist. Only what is living, nay, only human life, should be justifiable. But that is too narrow a conception. Certainly the highest mission of all human art is the portrayal of men and women; and what is not itself human becomes artistic in proportion as it gains relation to humanity by means of secret anthropomorphic animation and spiritualisation. But he who demands harshly and dogmatically that the human figure should be treated to the exclusion of everything else, relegates a Hondekoeter, a Landseer, a Rosa Bonheur to the second class, and denies a Desgoffes the title of artist, which is sheer nonsense. I do not know if there is a precedence in art, or any other precedence than that of the ability to

express and transmit the life of emotion. Anyhow, a man stands very high who understood how to translate into painting the optical peculiarities of choice woods, metals, stones, and textures better than any painter before him.

Léon Frédéric amazes like an anachronism; in him lives the soul of a primitive. Thus the Van Eycks, Roger van der Weydens, and Hans Memlings regarded the world and man. That is, however, not a sort of affected, antique skill, as in the English Præ-Raphaelites, and their Continental imitators, but genuine, unconscious atavism, the purity of which is evident from the fact that Frédéric paints no masquerades, but only nude, human limbs, or contemporary types of the people in the miserable working garb of our days. If they appear like figures out of mediæval ballads or folk-stories, it is because Frédéric feels them so. He is an out and out Fleming: mystical like his countrymen Ruysbroek, Suyskens, etc.; and, besides, delighting in form, like the builders of the Belgian cathedrals and guildhalls; in love with life, like the feasters and dancers of the Flemish kermesses; honest and conscientious in his work, like an old guild-master of the time of the Spanish Netherlands; brooding and earnest, like a Beguine or a Lollard.

Frédéric does not actually copy, but he is curiously vivid in his recollection of what he has seen. The old Low-German and Flemish masters, whose outlook on the world he shares, hover before him. From the Low-German artists he has his _naïve_, brick-red flesh tone and the painfully conscientious kind of workmanship, which neglects no wrinkle in the skin or curl in the hair; from Memling, his loving accuracy in treating all accessory work—flowers, ground, clothes, and utensils. Sprinkling the whole canvas with equally finished details, chiefly luxuriant plants, is common to Frédéric and all the Præ-Raphaelites. The pictures of this school, even if they take their subjects chiefly from the fourth dimension, are optically of two dimensions. They are only surfaces. They do not understand perspective, and, therefore, cannot shade off a middle distance or background. Everything lies in one and the same plane and is treated with the same clearness and precision. In the accuracy with which they render every little stone, every texture, and plant, the Præ-Raphaelites have no equals. If, in addition to this, they could paint human beings also, they would deserve unstinted praise, at any rate, as draughtsmen, if not as colourists.

Frédéric feels the sacredness of his art profoundly, as do few other painters of the present day. He seems to himself a priest. It is an external, but a characteristic one: he paints hardly anything but triptychs, which he regards, to a certain extent, as altar-pieces of a philosophical religion; and what he portrays is always a sort of pathetic symbol, from which there comes a sound like verses from the Bible or Vedic hymns. His symbols are not always clear, but it is not his fault that painting is not a fit expression of brief syntheses of long trains of thought, or ethical and philosophical abstractions. At most it is his fault that he does not feel this. His triptych, the "Golden Age," is, for instance, a view such as Ovid might have described if he had lived in a Belgian district among Flemish people. Frédéric relates the history of one day of his happy race: how human creatures of all gradations of age sleep peacefully in the gleaming night, clinging to one another; how they are awakened by rosy dawn and refresh themselves in a crystal brook; how, beneath a noonday sun, they play and dance and shout for joy, pluck blossoms and fruits, and sit before dainty dishes. It is a profusion of magnificently modelled nude women who are all very red of skin; a laughing exuberance of life such as an old-time worshipper of the obscene god of fruitfulness might have dreamt of amidst the reek of sacrifice. It is also a funnily cannibalistic debauch of delicious children's flesh and blooming, well-nourished bodies. In other pictures Frédéric has occasionally tortured us by quite as perfectly painted, but, on account of their inexorable truth, fearfully painful representations of radiant nudities torn by thorns, and whole heaps of children's corpses. Here, however, he is all joy and peace, and his picture is a delight to the eye.

In another of Frédéric's triptychs, "The Ages of the Workman," we can measure the whole emptiness of such concepts as "Realism" and "Idealism." Compare Frédéric with the Bastien Lepage of the Luxembourg. Bastien Lepage passes for the most perfect didactic type of realistic painting. His brutalised, ape-like, feeble-minded, staring Reaper is supposed to be genuine, unrouged nature. Possibly the painter has, on some occasion, seen a disgusting idiot of this sort. I do not know, but I will believe it, for I should like to assume that he had not discovered in his own imagination so perversely distorted an image of the human form. But as such repulsively bestial young women are, in any case, rare exceptions among the white races, Bastien Lepage has unmistakably taken the trouble to choose out of thousands the most hideous model he could hunt up, out of a base, corrupt delight in ugliness, with the malicious intention of defaming nature. Frédéric tells a story in his triptych, "The Ages of the Workman." Who can deny that he, too, has held with absolute accuracy to reality? On the right, early childhood: workmen's wives, young and fair mothers are suckling their babies, sweet, fat little creatures with firm little limbs and skins like rose leaves; little maidens, who can hardly stand on their feet, take in tow and act the mother to still smaller brothers and sisters; old grandmothers, who can no longer take part in the labours of the household, keep an eye on the children crawling and swarming about. In the middle, youth: neglected yet happy scapegraces are playing cards in the street, sitting or squatting on the curb-stone; undisciplined lads are venturing the experiment of their first cigarette; grown-up youths go out with young girls of their class on their arm; what they whisper in the ears of their

blushing sweethearts would scarcely delight severe guardians of morals; but, at that period of life, in that human environment, their feelings are so natural and healthy that, in spite of all crabbed affectation, they are felt to be pleasant and touching. Finally, on the left, men in their prime are at work: they are erecting toilsomely, with heavy pieces, a scaffold, and a little youngster looks at them; what he has before his eyes is his own future lot, but in his careless, boyish curiosity he notices only the amusing side of the growth of a skilful and intricate work of man, not the hard seriousness of the ill-paid, dangerous, and severe exertion. Thus the life of the poor artisan lies exposed to our gaze. Frédéric does not conceal from us either its hardships or the scantiness of its material condition. He shows us how poorly the people are clad, how ugly their streets and houses are, how narrow is the circle that includes their petty joys and sorrows, and how serious, now and then, is their pastime. But he makes us see also the sunshine resting golden over their years of childhood and youth, and feel the satisfactions with which their families also animate and delight their monotonous existence. He brings these poor, humble people humanly near us, and gives us a great lesson in brotherhood. Every feature in his picture is true; but from this truth a noble and consoling thought proceeds, revealing to us its full extent of beauty and moral motives. Frédéric is a Realist quite as much as Bastien Lepage, so far as he deals with the painfully exact reproduction of sights he has actually observed. But in Frédéric's presentment the commonplace appears ennobled, and that a superficial æstheticism dubs Idealism. The fact of the matter is that the words Realism and Idealism mean simply nothing. There is no art, there is no artistic tendency, which could be so designated. There are only artists' temperaments, which are themselves bilious, and, for that reason, dwell with malicious joy on the unpleasant sides of reality, and others which delight in all that is bright, and have a presentiment of a deeper redeeming meaning even behind the unpleasing external. The Realism of a Bastien Lepage is calumny; that of a Frédéric, a speech for the defence.

Jean Paul Laurens has reached all the heights of artistic success. He is a professor, an Academician, and he receives the most honourable commissions from the State and great cities. He has been graciously permitted to satisfy his ambition as a monumental painter with enormous wall- and ceiling-paintings, like those of the Capitol of Toulouse. He was often more happy, often less happy, always powerful, always pathetic, now and then, I will admit, declamatory. But he has also once forsaken his visions of history and turned a glance at the present; and what he saw there, he fixed in a great painting which he calls "Mining Folk," which stands above all his far-famed frescoes.

It is evening. Between a high, steep-sloping heap of coal and slack and a low line of distant hills closing the horizon, a big town is painted in a wide trough of country. Over the crowded roofs of this town numerous chimneys rise up. No church towers or palace gables, only chimneys which belch aggressively, one might say, white vapour or dense black smoke in the face of the twilight sky. From the middle distance a procession of weary, toil-worn men, whose legs drag and heads hang down, is moving forward along a causeway. From the depths on both sides of the causeway ascend clouds of sulphurous yellow and blue smoke.

Any one engrossed in the details may see how the workmen wandering homewards are clad in the garb of the modern proletariat, and how a manufacturing town of the present day with typical factory buildings lies stretched before us. But the first rapid, comprehensive glance conveys quite a different impression. The town looks like a Sodom and Gomorrha in rebellion against God, and is on the point of being chastised by fire from heaven. The procession of men appears to be a band of the damned which a hidden, mysterious abyss of hell, behind the bend in the road, has vomited. Near the causeway, uncanny depths seem to yawn, from which tongues of hell-flames leap up. It is a prophet's vision, and the atmosphere of a saga. You fancy you have an illustration of the Inferno before you, but also a note from the formula according to which the painters and sculptors of the Middle Ages were wont to depict the Last Judgment.

And the most remarkable thing is that this epic extension and enhancement of so banal an incident as the exodus of a shift of pitmen knocking off their work is by no means intended. The painter nowhere consciously works with a view to melodrama. He keeps, in all details, strictly to facts. It is only his perception that has made a canto of Dante out of a true copy of an everyday incident. At the sight of the flaming forges, smoking chimneys, and exhausted slaves working for hire, there came to him an inkling of the mighty forces of nature and society which are at work in the man- and horse-powers of a modern wholesale business, which fixed the choice and arrangement of elements in his picture, imprinted on it the demoniac feature, and rendered it a profound symbol of the history of a part of humanity.

Jef Leempoels is one of the most interesting of contemporary Flemings in whom the exquisite artistic qualities of their mediæval forefathers and masters live again. Leempoels has the sturdy, homely truthfulness of these ancestors, their profound feeling, and speculative mind, which easily goes astray into the fantastic. He has their masterly draughtsmanship, and he only lacks their delight in colour and their gift of free, clear composition to rise entirely to their greatness.

He does not rely on his capability or right to distinguish between the essential and the non-essential. He does not dominate his subject with sovereignly subjective perception, but makes himself the humble slave of the phenomena and all their most capricious and lowest details. He does not span the world with the eye of a creative artist, but glances at it as though he were a photographic apparatus for taking authentic negatives. To this intellectual dependence is joined an insufficient development of the sense of what is picturesque. Leempoels is dry in his accuracy and sober in his colouring. He does not seem to think it is his vocation to harmonise tones and to please the eye by a well-arranged palette. And in spite of all this I can never forget his chief pictures. He revealed his nature in _naïve_ little features. For instance, on the wall of the room where the father and mother, old and worn out by life, are sitting together, hang faded photographs representing them, as a young married couple, in a strikingly comic dress according to the latest fashion of five-and-twenty years ago, yet young and full of joyous hope. This discreet contrast, which must be sought for to be noticed, contains the whole melancholy poetry of their life from blooming youth to withered age. And the pictures of his sisters. The good girls are not particularly favoured by nature; they are true daughters of the homely Flemish race, in whom beauty is rare. When Leempoels painted them, there was a struggle in him between the conscientiousness of a sworn witness to reality and brotherly love; but the former gained the victory, and the latter was allowed to reveal itself only in the delicate, almost caressing, perfection of their hands, necks, hair, and clothes.

His picture "Friendship"—an old and somewhat younger man are sitting boldly before us, hand in hand, with their honest, ugly faces turned full towards us. They are figures from the people, the one wearing a green, the other a dark red knitted waistcoat. They are evidently neither rich nor educated, and no particularly developed intellectual life speaks from their clear, reposeful eyes, or their heavy, vulgar features. And yet they are noble creatures. It is their feeling which ennobles them. Only lofty souls are capable of such loyalty and attachment as these two workmen, who so affectionately clasp each other's hands and lean shoulder to shoulder—let come what come may!—and he who comprehends character without declamation says to himself involuntarily before this picture: "It is well for him who in his path through life meets with such friendship." Here Leempoels has performed the highest mission of the artist—he has recognised and indicated convincingly what is grand and beautiful in the insignificant and commonplace. That is healthy idealism, for which it is my pride to fight—a consoling and uplifting moral purport in an exact and true form.

I am less agreed in respect of another picture. Leempoels calls it "Fate and Humanity," and in this he has gone beyond his natural vocal register. From the lower rim of the picture there grows a marvellous flora of hands stretched forth on high, either folded in supplication or clenched in threatening fists, embracing many symbols of faith of various kinds, such as crosses, communion chalices, fetishes and offerings; over them appears, in violet light and filling two-thirds of the picture, a huge, bearded face that, indifferent and unmoved, gazes forward without noticing the hands of supplication and blasphemy raised towards it. It is plain enough what Leempoels wants to express; but it is not apparent what the effect will be of this violet face as inexorable destiny. Its feeble, vacant gaze and stiff nimbus infuse no particular horror, and nothing else which might be imposing is discernible in it. On the other hand, Leempoels imparts to the hands the full measure of his amazing capacity. These hundreds of hands, which are painted with a patience that is almost painful, have all their individual physiognomy. They are all individual hands of men and women, young and old, industrious and idle, Caucasian, Nubian, and Indian. The hands of all races, callings, ages and temperaments are so perfect in their characterisation that error is impossible. If among the hands were to be found those of a friend, I should certainly recognise them at the first glance. As a study of human hands, the piece is a museum-picture which has not its peer in all the collections with which I am acquainted. As a work of art it saddens through want of taste. Leempoels would sin against himself if he strayed into unlimited symbolism. His talent points him in the direction of the clearly circumscribed. He need not trouble himself about being implicated with Philistinism through his devotion to actuality. His sincerity of feeling, too, in the treatment of Philistine subjects, will always raise him above Philistinism.

Henri Martin has always aimed at lofty ends, but the paths he has followed to gain them were crooked and wrong. He was, when he began, and still is, in moments of relapse, a dabbing stumper, _i.e._, he laid on a thick dab of colour the size of a hazel-nut and extended it somewhat. With this method, his famous "Vibrations" was, indeed, successful, especially at a certain distance; but he broke up all form, and this allowed him to draw quite superficially. If any one reproached him with not rendering a single outline with exactness and certainty, he could use the excuse: "One cannot at the same time flood a picture with flickering light and model precisely." Stumping was with Martin as with his imitators the cloak to cover up artistically dishonest forms. His idealism—the main feature in his physiognomy as an artist—was revealed, in his first period chiefly, by his feeble figures being dressed in the garb peculiar to no time or country, the garb in which the Primitives were wont to make their angels appear, and by their moving in an artificial stage, which one can call neither earth, nor air, nor heaven; for, as a rule, it was painted a single iridescent, mixed colour, mostly a sort of pale lilac, into which some darker, smooth tree trunks, placed regularly like a lattice, were introduced.

Typical of his first period are his symbolical pictures "Towards the Abyss," and "Every One has his own Chimæra." We are almost ashamed to linger over describing this confused rubbish.

"Towards the Abyss."—A hussy unclad after the fashion in vogue at a Paris artists' pot-house—her cunning nudity is emphasised by ball-shoes, long black gloves, and by a black veil, thrown back at the right place, but transparent throughout—is hurrying down the gentle slope of a hill. Bats' wings wide outspread sprout from her shoulders. A crowd of people, in which men and women of all ages and ranks are mixed up, rush after her with the attitudes and gestures of epidemic madness. Some run, others drag themselves along on their knees, others, again, on all fours, after her, and scuffle for flowers which she strews in her wake. Every meaning can be imported into this picture, but nothing can be gleaned from it, or, at most, that the frenzied attitudes of the slaves and victims of this creature, wallowing in the dust, kissing and licking the hussy's footsteps, betray an unconscious masochistic trait in Henri Martin's soul.

"Every One has his own Chimæra" is even more futile than this perverse illustration of the pious admonition: "Keep from sin, for the lust of the flesh leads to destruction." A number of daubed, shadowy figures crawl painfully along in a clay-coloured mass; each is bent under a burden which represents in bodily form his ruling passion. Thus the sensualist carries a naked strumpet; the miser a sack full of gold; the ambitious man laurels and the spoils of war, etc.—a lamentable attempt to represent a literary commonplace in an artist's vision, in a living and concrete form.

Luckily, Henri Martin showed development. After his first period of crudely affected stippling and streaking, of bold neglect of drawing, amidst the shapeless daubing of coloured _confetti_, serpentines, and pomposities, with a would-be profound yet absolutely vacant symbolism, he returned to nature and life, treated warmly human subjects from an ideal standpoint, and toned down the crudeness of his execution without, I admit, giving it up altogether.

Commissioned by a rich banker, he painted for the Marseilles Savings Bank a monumental triptych which he called "Labour." He assigns views of Marseilles—certainly treated with great freedom—to the three backgrounds. The manifest meaning of the three panels is morning, noon, and evening. In the first panel, the children are on their way to school, reading their books; the women are going to market, the labourers to their place of work. In the second, dockers, under the glowing sun of Provence, are unloading a ship's cargo, which consists of baskets full of golden oranges. In the third, the waterside is almost deserted; an old couple, with a child carrying a doll in its arm walking in front of them, stroll in the cool of the day; some artisan families are also enjoying some fresh air after leaving off work, and

Jam majores cadunt altis a montibus umbrae.

But the times of day are, as I have said, only the plain meaning of the picture. Beside or behind it, it has also a deeper, veiled meaning. It would illustrate also an actual state of things in the future. Valiantly take full advantage of school in the morning of life, learn and prepare yourself by that means for working and daring later on. Labour in your prime until your ribs crack: you can do so, and it is lucrative. In return, in the evening of life you will be at ease, and, as a comfortable man of means, enjoy refreshing leisure.

We must be allowed to laugh at this optimistic aspect of industrial life. If Henri Martin has known a docker—of Marseilles or any other place—who was able to end his life as a man of independent means, I should like to ask him for that man's photograph. Nevertheless, a painter need not be a political economist, and the picture is, you know, intended for a Savings Bank, and the people who will see it there may actually find themselves on the way to the independency that makes blessed, though hardly after noonday unloading of orange boats. We might be able to pass lightly over the poverty of thought in the work, if its artistic qualities were satisfactory. But there's the rub. It was indeed a questionable thought to put in juxtaposition three pictures separated only by slender pillars, which had to exhibit three absolutely different lights; for either the lights of morning, noon, and evening were properly kept apart, and we had a discord in three notes, or the tones were pitched in one key in order not to shriek at each other, in which case they were untrue. Such is indeed the case. There is a somewhat more silvery breath about "Morning," a somewhat redder one about "Noon," a paler violet about "Evening"; but the lights and shadows are about equally powerful, whatever be the position of the sun. The forest of masts in the middle panel is of such exaggerated density that the eye is confused in the maze of shrouds and yards. And the entire picture is executed in the crudest stippling, with dabs of colour thickly plastered on, so that it looks almost scaly. If Henri Martin could give up his vagaries and lack of good taste, he would be a monumental artist of lofty vocation; for, though the fairies have refused him sundry things, they have given him one precious gift when he was in his cradle, viz., that of light. There is sun in his pictures, and they brighten up the space they occupy.

His best work up to now is a huge wall-painting for the Capitol of Toulouse.

A landscape of big, restful lines with a background of dark-shadowed mountain forests, against which all I have to object is that they wall in the whole horizon. From this range of darkening blue heights the country sinks in undulating tiers of hills to the plain of the foreground. Here the idyll of the seasons and men's lives is developed in three pictures. First, amidst the laughing spring, a strapping maiden, intoxicated with love, on the breast of the young lad who is embracing her. Next, a number of stalwart country folk in the summer work of haymaking, on whom, beyond the cut grass, their wives and children at play are gazing. Lastly, under melancholy autumn trees, a lonely old woman preoccupied with recollections. The people are homely, of course, without crude realism, poetic without the shepherd-insipidity of Gessner. The parallelism between the aging of the men and women and the progress of the year is unforced; the symbolism clear and free from morbid, perverse mysticism. Turf, trees, and bushes are decorative in form, delicate, and at the same time sufficient in colour, and the whole is flooded by a wonderfully joyous sunshine, which is more reminiscent of the glories of May in Provence than even Montenard's symphonies of light. Henri Martin has, I admit, here, too, indulged in stippling, but he has given his people and trees strong, free outlines, and scarred only the outer skin very lightly with pock-marks. He has not abandoned that ill habit, but he seems to practise it with remorse. Perhaps he thinks gradual transition is due to his conversion to better insight. In any case, this picture was conceived and executed in a happy moment.

Henri Martin's career teaches a moral. Let him who would honour an artist continually bear in mind an appropriately modified reading of Solon's warning to Crœsus: "Do not pronounce on any artist before his death."

Jean Raffaelli.—Like Henri Martin, Sisley, and the other stipplers who painted with little dots, Jean François Raffaelli at first painted with thin, slightly serpentine strokes. And we have had to get accustomed to this manner. Raffaelli has been able to succeed, because he long favoured subjects for which his ripple lines were the suitable style. He painted poor people in poor landscapes, emaciated bodies in slatternly clothes under trees as dry as brooms. Like a raindrop on a window-pane, and like a tear on a furrowed cheek, the slender traces of colour flowed down these pitiable figures, arousing twilight imaginations of weeping, plaintive trickling, and dissolving. Later on he caught cheerful, coloured views of Paris streets—The Invalides, Notre Dame, and the Place St Michel. In these his streaky way of painting was somewhat inadequate; but his amazing feeling for a crowd in the hurried, nervous movement which is peculiar to the Parisian lower orders, saved him. I know no painter who feels as Raffaelli the bustle of the world's metropolis. I think that any one who suffers from dread of the market-place, must get a feeling of fear at seeing his pictures.

In a third period of his production, Raffaelli gave a rare example of complete change in his maturity. He who had grown famous as a painter of the poor and miserable, of vices and sicknesses, turned, at the zenith of his success, from the aspects that he had hitherto cherished, and opened his heart to the joys of existence. In his mind a process occurred, such as the ninth symphony describes in eternal strains. In his despair a voice suddenly cries out: "Brothers, let us sing other strains," and roars out exultingly: "Joy, fair brightness of the gods." Formerly, he knew only abandoned tramps, tattered beggars and thieves, broken-down hospital brothers. His plant-world consisted of the leprous turf in front of the Paris forts, decayed flowers, the half-withered, suburban street trees, broomlike and leafless as in autumn. And he painted this misery in miserable colours and in his own peculiar, streaky manner, especially appropriate to the subject. Now he caresses with a broad, full brush bloomingly beautiful maidens in white raiment, sunny, ornamental gardens with rich _parterres_, fresh nosegays or living flowers. He has also changed his style with his subject. It is all renovated—palette, execution, and story. I have a feeling of a secret happiness having blossomed in this artist's soul, and I rejoice in the cheerful unconcern with which, by his altered work, he makes all men privy to his _Vita Nuova_.

Odilon Redon is a completed artist. His development is ended. It came from Gustave Moreau, and it never deviated from him. He is a delightful harmonist of colours, who handles the sharp and flat notes with equal mastery, and if he condescends to paint flowers, fruits, unpretentious still life, and landscapes every one can understand, he displays naturalness, taste, and winning homeliness. But when he strives for higher expression he gets beyond his master's range of vision, and becomes purely hallucinatory. Fabulous creatures, at once Pegasus and Centaur, stagger about amongst rare flowers, which gape like bleeding wounds or grin like vampires' mouths. Monsters without recognisable organic shape, bastard combinations of parts of dragons, beetles, birds and Ashes hover or swim in an uncertain medium, which may be water, air, or ether. Dreadful human heads, bound in clusters, grow bushlike out of the ground. All this is in colour pleasing; in form, enigmatical. Gustave Moreau is always intelligible; we know the myths he clothes in forms of extrahuman and superhuman splendour. No one can make head or tail of Odilon Redon. He himself does not think at all in his unearthly representations, and they awaken no definite thoughts either, but affect us like wild faces in a fever.

Pierre Auguste Renoir is also counted among the Impressionists and Naturalists. When we see that the same designation is applied to him as, for example, to Cézanne, we can, as it were, clutch with our hand the misuse of the words, and convince

ourselves how senseless classification in art is. Renoir is certainly no painter of prettiness. He does not paint nature white and rosy, or stick beauty-patches on her face. He does not go out of his way even for pronounced ugliness. You have only to look at his two Megæras on the garden bench to be convinced of this; but beside these witches he has so much refreshing, individualised beauty, that one fails to understand how he could have been classed with Cézanne and, what is more, the routine Naturalists. His naked young woman with the mother-of-pearl flesh; his lady in a cashmere dressing-gown on the tapestry sofa; his girl in blue with the red cap, and the little sister in white; his two ladies with the roses, are simply charming. And love speaks no less from his chrysanthemums and his sunny meadows than from his men and women. He who has the same feeling as Renoir for roses and children, is not only a great painter, but also a good and noble man.

Alfred Roll is one of the most amiable figures in the art world of to-day. No one has such feeling as he for the exquisitely delicate silvery vapour of a May morning atmosphere, quivering with sunlight and saturated with dew. No one knows how to model out with such creative genius as he a human body from the daylight that flows around it in gushing torrents. In his free-light painting one breathes free from all oppression. Besides qualities which, in all ages, make a great artist, he has the little trace of corruption which makes him a legitimate son of our age. One of his masterpieces—the naked young woman who clings caressingly to the bull—awakes Pasiphaistic ideas of old classic aberration. To procure pardon for this picture, he had to do no less than paint the splendidly healthy peasant girl with the brimming milk-pail and the cow—certainly a worthy penance.

Roll is, to be sure, not always the charming, luminous painter of the milk-maid and the girl with the bull. He very often strikes other notes. Thus, for instance, in his picture inspired by socialism, which he calls "The Martyr's Road," he shows an old tramp who, with his back leaning against a tree, has collapsed by the wayside, has let his wallet fall beside him, and appears to be about to give up the ghost. The misery of his worn countenance already overshadowed by death, of his emaciated figure and tattered clothes are convincing. On the other hand, it is open to question whether it was good taste to paint the dying man in front view, with bold foreshortening of the outstretched legs, and with boot-soles of a terrific size, that rear up before us, in the extreme foreground, like two præ-historic _menhirs_. Roll intended to pay his homage to Maxim Gorki also. Was it from sincere feeling, or to show that he is _dans le mouvement_, and is keeping step with the most advanced of his time?

He has insisted on trying his hand at monumental decoration also. The fruit of his effort is a gigantic picture which he entitles "Life's Joys." He has evidently thought of Watteau, probably of the latter's "Embarcation to Cythera." It is the same blissful landscape with roses, trees, and water that seems, in the haze of the distance, to continue interminably until it reaches Paradise. It is the same air which the rain of blossom renders coloured and almost opaque. It is the same spring sky which we might hail with shouts of joy. The men and women, however, who give life to this Eden, are different to Watteau's. In Roll, everything is marvellously austere and hard. His women in the foreground are naked, and partly lie in Michael Angelesque attitudes on the grass, partly sit there overpoweringly monumental. Loving couples, walking and dancing, behave as if they were possessed by wild, brutal lust. Something like a tragic current is traceable amidst this idyll. We exclaim in alarm: "Here, this very day, there will yet be murder or manslaughter?" And with the object of destroying still more the ideal note of May, Roll puts, in the midst of this fairy-tale splendour, three realistic musicians, whose clothes were bought at _la Belle Jardinière_, who will certainly, after every dance, go round with a plate and collect from their audience. Where will the nude ladies take money from to throw to them? How much more charmingly and wittily does Watteau begin his theme! Only a marble statue of a woman renounces the advantages of elegant toilettes. Winged Cupids flit about the young couples, and translate, as it were, into lyrical, rhymed verses the naturalistic prose of the gallantry exhibited. The men do not rage in brutal eagerness, but pay delicate and discreet court to their ladies. And above all things, Watteau's infallible taste warns him against telling his stories at excessive length. As brevity is the soul of wit, so moderate compass is a great advantage in an Anacreontic scene. This should be elegant and pleasant; but the monstrous excludes elegance and pleasantness. Roll's Titans and Cyclopses are not suitable for masquerading as Arcadian shepherds.

Lucien Simon, a painter who has been an imitator of Cottet, puts himself forward now, by an impetuous movement, into rank with him. "The Evening Gossip" unites the family round the table lamp, which lights up a number of richly animated faces with curious lights that play and flicker. "Nuns Collecting"—one old and one young nun try by gentle yet tenacious and irrefusable pressure to overcome the resistance of a well-to-do and apparently somewhat niggardly country lady, and to determine her to open her well-guarded purse. In a "Ball-room in Brittany" peasant couples, in the dress of the Celtic province, under smoking lamps emitting a yellow light, spin round, with heavy stampings, to a bagpipe tune which drives the blood into the simple dancers' browned cheeks, and kindles sparks in their eyes. All this is stumped in broadly and luxuriously without petty dwelling on the less essential, yet with a sure feeling for what is characteristic in appearance and movement, and in a harmony of dark colours, which is as far remote from the bright tone of the style of painting in vogue the day before yesterday as a Guido Reni is from a Franz Hals, but affirms its own

justification as self-consciously as the particular note struck by a Hennar and Gustave Moreau among the moderns, of a Velasquez and Rembrandt among the greatest ancients.

Up to now, his most important creation is his "Mass in Brittany," a work of an exquisite nature. The young and old peasants and seamen who hear High Mass standing in the bare village church, are truly and lovingly individualised head by head. Proudly renouncing pleasing externals, L. Simon has made up his mind to produce his effects only by the noblest means, viz., by characterising with accuracy these manifold types, and by the depth and fulness of the spiritual life of these pious folk here gathered together. Offence has been taken at the broadness of his execution, which already bordered on superficiality, and on the coarseness of his colour, which put one now and then in mind of the bill-poster's newer art. He has laboured conscientiously on himself, and diminished the defects of his qualities without weakening the latter. He still continues to paint with large strokes in fresco style, but he pays attention to the solid building of his figures. He is still pronounced and unaffected in his colouring, but he avoids letting power degenerate into coarseness, and expressiveness into shrillness. Thus Lucien Simon rises slowly and steadily, though unerringly, to the lofty peaks of pre-eminence.

Jean Veber is quite a peculiar phenomenon which has not yet been deservedly appreciated. On one characteristic ground: because he never understood how to be solemn; because he seems not to take himself or his art seriously. He began as a caricature draughtsman for Boulevard papers, and only when his vocation for this peculiar province was well established, did he exhibit oil-paintings. But he was already labelled, and people continue to regard him merely as a comic draughtsman. The public refuses to allow a double renown to a single talent. Its admiration, you know, costs nothing, but it is, nevertheless, scanty with it, as if it were bringing a sacrifice obtainable only with difficulty. That is a royal trait in the sovereign mob. It is niggardly with its distinctions in order to enhance their value. The splendid Daumier also had to suffer from this coyness on the part of the public. For a long time nothing was thought of his easel pictures, and it was really the Universal Exhibition of 1900 that first revealed to posterity the fact that Daumier of the "Charivari" was one of the most important French painters of the nineteenth century. The caricaturist of our days is, as it were, the journalist among plastic artists, and we know that it is very hard for journalists to succeed with poetical creations, however brilliant. The older humorists among the painters fared better. The Dutch painters could make rough fun of the life of the populace without injuring their reputation as artists by so doing. Hogarth attained high recognition, although his clumsy, Philistine, moralising painting ranks below the works of many caricaturists of to-day. Cruikshank, however, whom I rank, without hesitation, above Hogarth, occupies, in popular estimation, a lower rank, because he put his pencil at the service of the Press.

Jean Veber is the descendant in the direct line of the younger David Teniers, the Adriaen Brouwers, and the Höllen-Breughels. From them he derives his full style of painting, his deep, rich colours, his great sureness and luxuriance of execution, his clear composition and florid imagination. He differs, however, from them in the quality of his fancy which delights in symbols replete with philosophical references; frequently in Saadic spectacles of cruelty and lust, and very often in lubricities of the Félicien Rops kind. This is the effect of the hundred and fifty to three hundred years which separate him from his more innocent spiritual ancestors.

Of the pictures he has exhibited, some are unforgettable, when one has seen them. The "Triumphal Procession" of a gigantic crowned goose through the streets of a mighty city, amid the loud applause of a populace raving mad with loyalty. The "Struggle for Gold" of a number of awful cripples tearing each other to pieces in their mad struggles for a few gold pieces that have fallen in the street; the "Sight of Terror" of a man reeling home at night, apparently after a long drinking-bout, in whose eyes the houses and monuments take weird, living physiognomies, are most impressive utterances of the misanthropic pessimism, the satiric bitterness, and the humour of Veber, also, to be sure, of his predilection for the weird, the ghostly, and the horrible.

These qualities are repeated in almost all his works up to now. The greatest and most pretentious, "The Machine," offends through the daring symbolism by which he illustrates the murderous power of woman over the sensual man. On the other hand, "Sunday Morning" is a bit of life observed with exquisite humour: a barber's shop in the village, with a soaped victim under the nimble but not too considerate hands of the beard-shaver's wife, whilst some other customers, of unspeakable comicality in looks, bearing, and dress, smoking, dreaming, staring, or chattering, wait their turn on the bench by the wall. "The Hermit and the Female Faun" is a scarcely orthodox, but keenly witty modernisation of the old theme, the temptation of a saint, which these square-toes of painters for the past five hundred years have cherished with predilection, since it permits them to present quite heathen sights with a hypocritically contrite air. "The Three Good Friends" are of refreshing cheeriness. The ugliness of these contented louts is touching. The painter, by way of exception, exhibits them without malice, rather sympathetically, with a plea for extenuating circumstances. But generally, his wit belongs, in the main, to the species of evil-speaking. We laugh over the malice with which a sharp-tongued observer characterises our fellow-creatures, but we feel quite well that it is not the better man in us that laughs. Jean Veber loves to

mock at mankind in goblin fashion. He sees men perpendicularly pushed together like a telescope, horizontally drawn out as short, square gnomes with pumpkin faces, who, pleased with themselves and unconscious of their grotesque ugliness, strut about as if they were so many Apollos and Dianas. Thus Jaurès appears with mouth agape and flourishing gestures on the rostrum of the Chamber, at the foot of which breaks a flood of blustering deputies in stormy session. So in a parody of Rubens' "Kermes"—itself of the nature of a parody—villagers resembling sacks amuse themselves with feasting and drinking and amorous tendernesses which are calculated to disgust us with love itself. A grandly rigged-out, inexpressibly laughing lady in a low-cut dress between two greybeards paying their dreadful court at an exquisitely appointed supper-table; a physician at the foot of the bed gazing with devotion at the tongue, put out quite a yard, of a rich, fat lady-patient; a short, stout woman in a fashionable tailor's _salon_, whom the slenderest of the show-room girls is trying, with "cake-walk" movements, to fit with a dress like an umbrella-cover, are amusing in their stupidity and ugliness. On the other hand, I cannot follow Jean Veber further when, in "Family Joys," he tries to make the newborn child ridiculous—a shapeless bit of sprawling flesh, red as a crab, which the midwife has brought from the bed of the exhausted mother at the back of the room, and is exhibiting in triumph to the gaping family. He should keep his sacrilegious hand off the sanctity of this event.

The happy combination of a faultless dexterity with an arrogant, creative humour, in which I would only like to see a trifle less admixture of gall, renders Jean Veber's an artistic physiognomy that is far more interesting than many an idol to whom altars are raised.

Emile Wéry, a young and fortunate man of talent, began his career with a great success. His view of an Amsterdam canal made a sensation, and gained the great prize at the "Salon." Perhaps a little stupefied by this triumph, he kept for a while to the style of his prize picture, so that there was reason to fear he would early stiffen into a manner. He painted, for instance, an attractive triptych, which presents Venice to us in her three characteristic decorations: the narrow _Calle_, the slender _Rio_, and the splendid _Canal_. But what we cannot anyhow fancy absent from a view of Venice—the southern sky, the gleaming sun, and the warm tints of her old stones and tiles: these are here altogether lacking. It is all grey, northern grey. It is the same tone as in the prize picture of Amsterdam. As Faust found Helen in every woman, so Wéry then found apparently Dutch water-towns in every town, and Amsterdam herself in Venice. People think they are flattering the city on the Amstel, when they call it the Venice of the North. Wéry reversed the compliment: to him Venice was the Amsterdam of the South. How true it is that we see not with the eyes but with the soul!

The South, combined with his youthful impulses to development, was to save him from the danger of mannerism. Though he had seen Venice with his Amsterdam eyes, and found in the azure and gold of the city of lagunes the leaden waters and mist of the north, further south, in the light, he bathed his eyes clean from the muddiness of higher latitudes. In "Sicily" a girl's brown head, with red cloth in the midst of a cluster of dark green-leaved branches with ripe oranges, flashes and glows the whole noon of the magic island, which this vigorous woman—a golden fruit among golden fruits—is to personify. But even after his return home he still remained drunk with the light of Italy. In a new picture, "The Little Ones," we are once more in a harbour on the North Sea, at a place where Wéry's talent takes its root. Flaxen-haired youngsters are playing round a boat; one of these, a little chap in wide, flapping trousers, is droll enough to eat. Water, sky, and river-bank are wedded in silver sheen, and over the whole reposes a happy sense of comfort, in which the artist's cheerful heart is disclosed. He has happily got over his first crisis. Now his artistic career lies smooth and sunny before him.

Anders Zorn.—This Swede is a virtuoso of amazing skill. He delights in marvellous effects of light, in surprises, in fixing fugitive views. His pictures are snap-shots pitched on the canvas with an almost mechanically smart brush. He is a concert painter possessing talent. He is one of the great corruptors of young artists nowadays. It is so fascinating, by a few wild, staggering, nimble strokes of the brush, to conjure up a human figure or a scene. But this method leads to the worst superficiality, and attracts most the lazy fellows who wish to save themselves the trouble of learning properly the principles of drawing and painting. Zorn did not make the thing easy for himself. He honestly and industriously acquired a thorough mastery of technique before turning to execute his dazzling little pieces. He may allow himself to storm and rage over the canvas, for accuracy has become automatic in him. In spite of this haste, every line is on the right spot, and though people often regret that he only hints instead of stopping and deepening, nevertheless it is continually said: "The man knows how to build up a figure or a group." His imitators, however, have caught only his daubing, and with them superficiality is but a bold excuse for ignorance of drawing.

Ignacio Zuloaga.—Spain can at the present time boast of a number of painters who might call out to their greatest predecessors among their countrymen the proud _anch'io_. What characterises them is a peculiar, almost mad energy in drawing, which appears in all details, in the living and the dead, not only in the mien and attitudes of men, but in the sharp profile of every leaf and blade of

grass, in the bold relief of every stone, in the aggressive self-consciousness of every being as of every thing. This energy is not to be learnt. One has it or one has it not. There are foreign painters in plenty, whom Spain has bewitched, and who their whole life long recount nothing but bull-fights and processions, shepherds and gipsies, _cigarreras_ and _manolas_; but no one who knows the genuine Spaniards will confuse these with the foreign imitators. There is, for instance, the excellent Jules Worms. He has been exhibiting Spanish scenes uninterruptedly for forty years. They are always nicely painted, prettily conceived, and pleasantly executed. As contributions to knowledge of the nation they are not without value. They have gained him all official honours, and he passes for an undisputed master of his particular province. And yet how un-Spanish is this life-long Spanishness of Worms and all his rivals and imitators! It is as smooth, licked, tricked up, entertaining, and banal as the railway novel of an inquisitive but superficial globe-trotter. It is a conventional comic-opera Spanishness, a theatre decoration for scenery, with groups of costumes for living figures. It lacks the power, the stern virility which distinguishes the Spanish painters, even those of the second rank, and gives them a family likeness to their great ancestors, Valdes, Velasquez, and Ribera.

The most typical of these modern Spaniards is Ignacio Zuloaga, and the most typical, perhaps, of his pictures are the three sketches from Spanish folk-life, which were exhibited a few years ago in the "Salon." An Andalusian, young, thin, and delicate, with a little crumpled face of apish ugliness, with a supple body that seems to whirl, stands in front of a poor mirror, and powders her face with coarse rice-powder, as though she were sticking on a comic Pierrot-mask, whilst her sparkling eyes testify that she wants to make herself thoroughly beautiful for the bull-fight. Then we see her in loud, bright ribbons, with the inimitably draped mantilla over her head and shoulders, passing quickly through the street, greeted by two old connoisseurs with highly-spiced endearment. On the third occasion she or her sister goes with a diabolically piquant young gipsy girl, whose insolent laugh discovers gleaming wolf's teeth and turns up the sharply-curved nose, rapidly over the ground, probably to keep a Sabbath, from the expression of both grimaces. This is warm life such as not often glows on painted canvas. Zuloaga has felt his Andalusian wild creatures to his finger-tips, and renders them with all their _garbo_ and _salero_—the German _Schneid_ and _Mumm_, and the French _montant_ and _mousseux_ are weak translations of this expression. The pictures seem to be painted, not with mineral colours and oil, but with sulphuric acid and lunar-caustic. These ladies are young witches, of whom you would imagine that by touch they must give an electric shock like a torpedo-fish, that, if they open their mouths, red mice will jump out, and that it must be more natural for them to ride through the air on a broomstick than to make use of their legs in the usual way. In the piquant ugliness of their faces, made up with a thick layer of rice-powder, in the gorgeous Sunday array, in their attitudes and movements, in the gipsy-girl's bestially insolent grinning and winking, in the lustful glances and laughter of the men, there is a fulness of hot life, an insolent sensuality such as is only met with in Brangwyn's youthful works. One often heard the name of Goya pronounced before these pictures. It is indeed the same temperament, but another outlook on life, another art. Zuloaga has much of the cutting virtuosity of his great countryman; but he is no embittered critic of the world, rather a laughing Sunday's child who enjoys life with all his senses.

And, above all, his pictures are patterns of a domestic art which, through its unreserved sincerity, is at the same time an universal art. For it reaches so deeply that it penetrates beyond the special type to humanity in general.

XIII

AUGUSTE RODIN

Rodin's place in present-day art is a peculiar one. Auguste Rodin has been raised to the dignity of a test for decadent ways of feeling. We admittedly call "tests" or proof-objects the objects (for the most part, the shell-armour of diatoms or the scales of butterflies' wings) on which the magnifying power and exactness of analysis of microscopes is tested. By Rodin the fanatics and snobs of insane tendencies test the genuineness and power of symbolico-mystic sentiment. What do you think of Rodin? Do you admire him? Good: then you need further only adore Besnard and rave about Félicien Rops, and you can claim to be numbered with the newest, without respect to the colour of your hair or opportunist baldness. You do not admire Rodin? Then sneak whimpering from our league. You are no decadent. No beauty with her hair combed in the Botticelli style will love you; Mallarmé will not write poems, nor will Nietzsche philosophise for you. Nobody will invite you even to a Black Mass. Go to the Philistines; you belong to the narrow-minded community, which is a herd of ruminants.

It would be intelligible if the provocations of the shriekers, who, after the manner of howling dervishes, dance and rave round Rodin, were to induce men to take a violent part against this very man. Justice, however, demands that people should suppress their natural tendency to make him responsible for the ear-piercing din of his drummers and trumpeters. After all, he cannot help a horde

of swindlers and silly people making a vulgar disturbance about him and his works. If we are to judge him, we must try to forget that critical offenders, by invoking his name, continually outrage the sense of æsthetic decorum and artistic conscience. Rodin is, in fact, not the originator of this shameless proceeding, but the victim of the æsthetic Catiline conspirators who have got possession of him, and are pushing him on before them, so that it looks from a distance as if he was their leader. Rodin is not the least _cabotin_. He is of a modest, homely nature, but no strong character; and he has not been able to stand against the suggestions of those whose interest it is to eulogise him, who have for so long chattered his poor head full of their most brain-firing, æsthetic doctrines, and most profound interpretations of his alleged purposes, until he has lost his own personality, and makes the most desperate efforts to become like the picture which his critical Corybantes present of him to the open-mouthed gapers.

What has raised Rodin to an article of faith among the degenerates is three peculiarities. First, the choice of his materials, which appeal to the mysticism and sensual psychopathy of his body-guard of degenerates; secondly, his technique, which deviates from tradition in childish, would-be-original whims; and thirdly, his mistaking the natural limitations of his art, which he wants to make say things for which sculpture possesses no means of expression. These traits are proved by a short review of his principal works.

The production which first brought him the custom of the decadents is a composition which was devised for the gate of Dante's _Inferno_. He had worked at it for decades. After a few fragments, which were to be seen in 1889 in the Universal Exhibition at Paris, he showed the whole in a plaster model at his private exhibition of 1900. It is inspired unmistakably by Ghiberti's door of the Baptistery at Florence, but stands in intentional contrast to it. The great Quattrocentist depicts life in Paradise; Rodin's intention is to show existence in Hell. The framing and articulation of the work, and nearly all its details, were rendered with organic necessity from this starting-point. The door is cut up into panels, which are not divided by stiff, geometrical lines, but, just as in the case of Ghiberti, are at the same time immediately separated, and again indirectly connected into a higher unity, by a feature of the picture itself, _e.g._, a cliff, a man's figure, a piece of building. In every panel an act from the _Inferno_ is played. The parts, in the majority of cases indicated only in a sketchy way, betray strong, indeed mainly perversely directed, erotic imagination, and the gift of exhibiting human bodies in the movements of passion. Of course, Rodin, too, has not dropped down from heaven, but is the descendant of easily demonstrable spiritual forefathers. This sculpture of violent action, a particular development of French art, and in no way connected with the Laocoon, as one might easily make the mistake of assuming, has its first master in Rude, whose power is revealed most grandly in the "Marseillaise" on the Triumphal Arch at Paris. Rude's successor and continuer is the incomparable Carpeaux, who, as is most clear from his group "The Dance" at the Grand Opera, in place of the wild heroes of his model and master, substituted wild Bacchantes; who celebrated, instead of self-oblivious joy in sacrifice in the service of rugged duty, self-oblivious intoxication in a debauch of sensuality, but represented a life of excitement no less sublimely and no less ravishingly than the former. Rodin is closely connected with Rude and Carpeaux. With him passion descends a step lower still to the uncivilised and dissolute. Heroic with Rude, voluptuous with Carpeaux, it is Satanic with Rodin. The "Gate of Hell" exhibits rows of naked women in all the situations and occupations of the witches' Sabbath, when it is most devilish. Fits of hysteria shake and twist these bodies, every motion of which betrays shocking aberration and eager Sadism. The patients of the Salpetrière or the Atlas of Pictures edited in this _clinique_ (_Iconographie de la Salpetrière_) evidently served him for models. And from him, be it incidentally observed, Alexander appears to have drawn his inspirations with the aggravating circumstance that he clothes Rodin's naked women in rich, modern toilettes, and by this artful means makes them even more obscene. The feminine genius of tragedy in Rude is inspired by Tyrtæan war-songs. Carpeaux's two female dancers have drunk sparkling wine; Rodin's demoniac women have swallowed pills of Spanish-fly. Thus it is clear that Rodin must be dear to all wanton schoolboys, impotent debauchees, and incipient spinal sufferers.

If the "Gate of Hell" is an illustration of hystero-epilepsy and feminine Sadism, so, too, is a marble group which he exhibited in 1898 of Masochism. A naked woman with horribly glacial, unmoved features sits leaning against a wall of rock. A man, apparently growing out of the earth, kneels before the merciless image, embraces its knees with despairingly imploring gesture, and presses his head against its body. This is supposed to show man in an ecstasy of desire, subjugated by the sexual power of woman. I can only say that a copy of this group would excellently suit as a frontispiece for an edition of the collected works of Sacher-Masoch. Other smaller groups of Rodin, which he exhibited in the Champs de Mars Salon, hint at other forms of morbid sensuality on which I am reluctant to dwell. They all disclose a sub-soil of corrupted sensuality in the artist's soul. That secures him influence on natures in harmony with his own. The degenerates who revel with Baudelaire in love of corpses, and with Félicien Rops in highly-spiced lewdness, find the same excitation in Rodin, and they intoxicate themselves with his ecstatic lasciviousness just as with the unnatural or madly exaggerated eroticism of their other fleshly poets and painters.

So much for Rodin's choice of themes. Now for his technique. One of his singularities is that he loves to astonish people by a crude, external contrast between a block of unworked marble and the most exquisitely finished and sweetly polished sculpture of bodies. He takes a great cube out of all proportion, which he leaves as the labourer hewed it as it came out of the quarry; and he works a little corner of it into a head and body polished with the utmost nicety. In this way, the figure grows out of, or into, the natural stone. Looked at from three sides, a lump of rock or stone is presented to the eye, only on the fourth side the work of art is revealed, blooming, as it were, in the wilderness. We may describe this manner as the sculptural form of mysticism. The association of ideas which Rodin wishes to awaken by this device should make the idea dawn on the consciousness that here, before our eyes, a miracle of creation is being accomplished; that we surprise the very incarnation of the stone; that we are witnesses of the birth of organic form from the stiff, lifeless original matter, and may observe how the figure, still half imprisoned in chaos, struggles painfully forth to a form instinct with life. There are subjects for the representation of which Rodin's style would have been a happy invention: perhaps the creation of Adam from a clod of earth, or the story of Deucalion and Pyrrha, or a Promethean motive. But its uniform employment for all possible subjects—on banal busts or groups which have no reference to creation or genesis—causes the manner to be recognised for what it is, a snatching at effect by means of eccentricity. Of course, this striking and easily imitatable freak has founded a school. No American or Scandinavian who wants to frighten the Philistines with "modernism" neglects to exhibit a piece of, for the most part, wretched sculpture as tiny as possible on a clump of unworked rock as Cyclopean as possible. It cannot be said that the joke is cheap. The unhewn block of marble often represents a pretty stiff value in hard cash, in any case a higher one than the corner that has been chiselled. One can only say that any idiot can succeed in using a ton weight of stone as a support to a figure the size of a man's hand.

Yet, in conclusion, it is a comparatively harmless folly which a practitioner can remedy with a few strokes of the saw. It is sufficient to cut the sculpture off, and give the rough block to a needy sculptor. Far worse, because it is incurable, is the æsthetic principle to which Rodin pays homage in the technique of his more important works especially. He is, to wit, an Impressionist. A line of motion in an individuality or group interests him. He seizes it, shapes it with convincing truth, with an emphasis exaggerated—certainly purposely—to the point of caricature, and neglects everything that does not serve to illustrate this line of motion. Sculpture, however, is an art which does not allow any Impressionism. It demands, according to its nature, a perfectly accurate formation of the whole figure, and simple honesty in reproducing the phenomenon. This can be proved by a theory of perception. Sculpture fills space and is of three dimensions; it addresses itself, in the first place, certainly to the eye, but also to the sense of touch. It calls for stereoscopic vision, and is, at least in theory, capable of further proof by a second sense. Now just this theoretic possibility of further proof, by means of the sense of touch, has the prohibitive effect, that fancy feels no inclination to supplement the image provided by the sense of sight. In works of painting we add in our mind much which is not optically given in the picture. In plastic works we have not this psychical habit, because a testing with the hands is opposed to the free, inventive power of the imagination, and makes us at once recognise what has been given in space, and what has been added by our imagination. On this ground, there is no place in sculpture for intentions or hints. That is enough for a rough plan, but not for the finished work. Rodin, however, stops at a stage of completion, which may, at best, pass for a promise, but never, in any case, for an achievement. He deliberately breaks up the frame of artistic form. He would fain work with the habits of the painter's eye and the painter's hand, and he applies this treatment to the statute, standing free and exposed to examination from all sides.

The confused lines which represent the draughtsman's first sketch (_ébauche_) have their special charm and meaning on the surface to be painted. If, however, you translate them into three dimensions, if every careless movement of the artist's hand, either still feeling its way or hurrying on, is finally fixed in clay or bronze, something inadmissible results, which has no right to proclaim itself a work of art.

Such a seeking after the right expression, such a stammering in metal is Rodin's monument at Calais, which represents the burgesses of Calais with the rope round their necks, standing before Edward III., who had successfully besieged that city, and asking for mercy. The crushed spirit which Rodin tried to express is actually visible in the group; but the figures which express this emotion are formless from head to foot. The limbs are rugged boughs; the bodies violate the laws of anatomy; the whole group is on the stage of technical perfection reached by the idols hewn from wood by the South Sea Islanders, and is far inferior to many a pre-historic picture on mammoth's teeth and stag's horn, which may be seen, for instance, in the Museum of St Germain. Rodin's domestic trumpeters promptly proclaimed this for a work of lofty genius. The Corporation of the town of Calais, who had ordered it, dared not reject it. The decadents' reign of terror—it was in the year 1895—was then in all its fury. The whole Paris Press was in the power of the dictators of the Chat Noir, and the poor Calais burgesses, clever men of business, but very uncertain in questions of art, feared to be jeered at as wise men of Gotham, if they rebelled against the æsthetic edicts of the tyrants of Paris criticism. But they blush for shame and anger whenever they pass by the memorial, and now, when the reign of terror of decadent criticism is

over, it will probably not be long before the Calais people pluck up courage enough to have Rodin's bronze abomination carted off from the public square, and withdrawn, in a store-room in the Town Hall, from the scornful eyes of strangers.

A counterpart of the Calais group is the design for the Victor Hugo Memorial, which was for the first time exhibited in 1897, and again five years later, when it was somewhat further advanced. This design also showed nothing but intentions. The poet is sitting naked by the seashore. The last shallow wave washes gently up to his feet. Two female tutelary figures—perhaps History and Legend, or Poetry and Philosophy—are flying to him horizontally at the level of his head and whispering secrets in his ear. As a mere intention, the composition might be allowed to pass; but nothing of execution, practically, was yet to be seen. Victor Hugo's body was not modelled; the flying female figures could not be distinguished, either from a distance or on close inspection, from cloud packs, or the fantastic animal figures of Gothic gargoyles. Nevertheless, Rodin disarmed intelligent criticism by declaring that the work was a mere sketch. Of course, he could no longer be fairly reproached with its shapelessness, and people had to content themselves with waiting for its completion, which has not come to pass up to now.

Rodin has overstepped, in his Balzac Memorial, which he first exhibited in 1898, the very extensive limits within which his silly aberrations might have been borne. Master Shallow, who tolerates much, could not tolerate this work, and broke down under its crushing exaction. When the public saw this provocative monstrosity, it broke out into that uncontrollable laughter, whereby the outraged intelligence of mankind revenges itself with primitive force for restraints that it has long suffered in silence. In the face of this result, the Committee of the French Union of Authors, which had commissioned the Balzac Memorial, resolved unanimously to decline it. In vain the Condottieri, who had usurped supremacy in art criticism by the most unscrupulous methods of conspiracy, violence, and oppression, made desperate efforts to maintain themselves. They were powerless against the armed rising of sensible people who had at last come to themselves. Their tyranny was vanquished, and they were swept away. They might still talk all sorts of twaddle about the stupidity of the masses, and, in impotent rage, hiss at the victors the well-known shibboleths, "Philistine," "provincial," etc., but this final, faint-hearted nagging sank unheard in the unanimous cry of scorn from public opinion.

Rodin has represented Balzac as, jumping out of bed in the morning, he wraps himself unclad in his monk-like dressing-gown, without even putting his arms in the sleeves, irresistibly impelled to hurry to his writing-table in order to fix the thoughts of which his creative brain is full to bursting. Agreed: that, again, is the intention which Rodin might, perhaps, have secretly put into the figure. What the eye really sees is a sort of tree-trunk, hewn in the roughest manner by a woodman with an axe, which is surmounted by a hideously swollen tadpole head on a goitred neck. Malicious Parisian wit has exhausted all the droll comparisons that this monstrosity can suggest to flouting humour. People have called Rodin's work a meal-sack, a carved potato, a snowman made by a cheeky schoolboy, an unpacked statue, a stalactite, etc. The work is all that, for it is nothing at all; but it is pre-eminently the conclusive refutation of Rodin's æsthetics. For it is the highest expression, and, on that account, the unintentional parody, of his impressionist technique and of his third mistake, viz., ignorance of the limitations of his art.

Rodin worked at this wretched piece of work for ten whole years. First he read all Balzac's works; then he made a journey to Touraine and spent months there, so as to absorb the human environment from which Balzac took so many of his models, and to become permeated with the feelings and impressions with which Balzac may have satiated himself when composing—all this to make a human figure which was to be the likeness of a man whom many people now living have known in the flesh. After these preliminary studies, Rodin finally proceeded to form his Balzac. His head was to be "a synthesis of his works," his physiognomy was to be summed up "in an eye that looks on the _Comédie humaine_ and in an upper lip that is curled in contempt for humanity." So said Rodin himself in several interviews which were published at the time when his statue was exhibited. He was then merely repeating what the twaddlers of Montmartre had chattered to him. It would be easy to make jests about this inflammation of the brain, but it is not worth even cheap raillery. It is quite enough to establish, soberly and drily, that Rodin, like a child or an idiot, aimed at something impossible. Sculpture cannot furnish any "synthesis of Balzac's works." Nature herself cannot, in the sense that Balzac himself, when he was alive, did not synthetise his works, in his externals, in his physiognomy. He had perhaps the head of a man of mark, but there was assuredly nothing in his face to show that he had written the "Physiology of Marriage," and not written "La Chartreuse de Parme" (Stendhal). Rodin imagined that a portrait-statue could quite alone, merely by its own means, supply the place of a biography and a psychological and literary characterisation of the person represented. This patent lunacy was necessarily bound to end, as it has ended, in a mad caricature.

"The Thinker," a colossal statue which was exhibited in 1904, is almost as bad an aberration as Balzac. It is a gigantic enlargement of a little sketch that one saw many years ago over Rodin's "Gate of Dante's Hell," in the confused and scarcely indicated unborn _foetus_ lines of which confident devotion might imagine all possible promises of future splendour.

The promises are realised in “The Thinker.” He who still wishes to shudder with foreboding in the presence of the finished work will be at liberty to do so. It will be the same sort of man who grew enthusiastic over the “Balzac,” before which every criticism of intelligent—not “intellectual”—men dissolved into unextinguishable laughter. “The Thinker” is brother of the “Balzac,” only it is not so comic, for it is not dressed in a meal-sack, but is naked, and the bared human body, when misshapen, excites in a spectator of unvitiated taste, not cheerfulness, but discomfort, which may even rise to loathing.

“The Thinker” is not only naked, but also flayed. Its anatomy is executed with obtrusive importance, without the covering epidermis with its vital warmth. The enormous exaggeration of the muscles, the impossible assertion of strength which is expressed by the extreme contraction of all the muscles, therefore also of the counteracting muscles, are well-known features of sculpture in its worst period of decline. There is still, however, a distinction between Rodin and the _rococo_ sculptors, who confused fleshy tumours over the whole surface of the bodies of their statues with the power of portraying artistically. At any rate, the latter had a correct knowledge of myology, or the subject of the muscles, whereas Rodin’s anatomy is shockingly inaccurate. I really do not think much of Lorenzo Matthielly’s groups at the Vienna Hofburg-gates; but in the face of Rodin’s monstrosity I apologise in my heart for all the objections I have ever made against them. At any rate, with Matthielly every muscle occupies its proper place. Rodin, however, invents muscles which do not exist, and never did exist. Two mighty ridges, ending below in sausage-tips, run down the “Thinker’s” back, which are perhaps intended for the two _longissimi dorsi_; in this case, however, they are howling blunders as regards their attachment, their whole course, and their form. The muscles of the forehead and temples are treated quite as arbitrarily as those of the back. Where nature only recognises thin cutaneous muscles and ligatures, there Rodin puts bumps which remind one of blood tumours after blows from a club, and impart to the face the appearance of evil _Verschlagenheit_; not, as Fritz Reuter says, in the sense of craftiness, but in that of receiving a sound cudgeling. As a record “The Thinker” stands on the same level as the anatomical plates in Japanese manuals of the healing art of the time of the Shoguns.

This, however, is not yet the worst; the intellectual element fares even worse than the bodily one with this oaf who calls himself so pretentiously “The Thinker.” The flayed man sits crouching, with a distinctly crooked hump, on a sharp-edged block of stone. His toes claw convulsively into the ground. He holds a clenched fist before his mouth, and seems to bite it fiercely. His bestial countenance, with its bloated, contracted forehead, gazes as threateningly dark as midnight. He who has to interpret the figure without the help of a title will, from a back view, conclude it is some one writhing in agony on the rack; and from a front view, a criminal meditating over some foul deed. Its mien and bearing would suggest a designation such as “The Fallen Titan,” “Lucifer’s Rebellion,” or “Cain before he murdered his Brother.” The last thing which one would think of would be to look for a mind working behind this bulgy forehead, or to imagine that thought was supreme in this body seized by a spasm of rigidity in all its muscles. The name given by Rodin to this wretched performance sounds like a scoff or a calumny, and it might be thought the misled artist, robbed by his fanatics of all self-criticism, had intended to make a malicious parody of Michael Angelo’s _Pensieroso_.

Rodin himself, by his portrait busts, makes it possible to gauge the whole insincerity of his pose as a profound thinker, and his genius-playing arrogance; for instance, by that of Octave Mirbeau, and, still more easily, by a female bust which was exhibited at the same time as “The Thinker” monstrosity. With the exception of the folly, which is, moreover, not too obtrusive, that a piece of the rough block was allowed to remain on both shoulders, there was not the faintest feature in the bust that could differentiate it from a severely classical, coldly correct work. Here he had to satisfy a lady client, and he was irreproachably smooth, executed all the details lovingly, and produced a soft, delicate flesh, to which the elegant Injalbert might sign his name. If one were desirous of making an objection to this pleasant bust, it would, at worst, be that it is too sweet. He becomes the destroyer of all form, the bungling sham-Titan, the inscrutable philosopher, dramatist, and lyric poet, whose eye rolls in a fine frenzy, and who, in the throes of his fever to create, confines himself to hurried indications—he becomes all this only when he works for his bodyguard of sympathetic sensitivism.

How future generations will laugh over all this buffoonery of “nerve art”! Only, indeed, when it comes to know the comments of contemporary “intellectuals” in addition to the artists’ silly bungling. For the former will show them in a way to excite sympathy and amusement what devastation the deafening babble of a band of gossips, dreadfully ignorant of art and innocent of any feeling for beauty, could produce in the taste and thought of a large majority, which honestly yearns after æsthetic education, but, on account of a lack of trustworthy traditions and adequate instruction in art, has not sufficient self-confidence to set up the promptings, however obscure, of their own feeling against the impudent dictates of presumptuous arbiters of taste.

Mysticism and sexual psychopathy in the choice of themes; Impressionism and incidental eccentricities in technique; overstepping the limitations of his art, have made Rodin the great man of the fellows who for some two decades have set the fashion in art and literature. By these three peculiarities, to which he owes his spurious celebrity, he will be ruined as an artist, whatever the success

he owes to puffing may be. And that is lamentable, for Rodin is a genuinely gifted sculptor, who created beauty when he did not yet think himself bound to work out of gratitude to the "young" journals. Unfortunately, it is extremely improbable that he will now find his way back to that simplicity and naturalness in which salvation is alone attainable. There is no return from Montmartre, not, at any rate, for an old man who has climbed this height and accepted with passionate earnestness all what he saw and heard there in advanced years. Young people who are still capable of change, in many cases awake from the idle dream of Montmartre æstheticism. Nature does not vouchsafe to the old to begin a new life.

XIV

RESURRECTION

BARTHOLOMÉ

I do not want to speak of Tolstoi's novel, but of a work of art—great, at any rate, materially, as a statue—which every pilgrim to Paris will, I suppose, wish to see, viz., the monument which Bartholomé dedicated "To the Dead," and which is to be seen in the cemetery of Père Lachaise.

It is interesting in so many aspects that one might devote to it a monograph as thick as a book, which would send out suckers over the whole domain of æsthetics and the history of art. Never do I feel so painfully the inadequacy of a short essay as when I proceed to handle a subject so rich in connections. It is impossible to exhaust it in this form, and it is painful to leave it as a fragment. One appears limited, whereas one is only restricted. We must satisfy ourselves with indications which will easily be looked upon as superficial, though they are merely terse. What is thought out as a proof takes the form of mere assertion, and in cases where we should like to convince, we must think ourselves successful, when we have incited the reader to kindly co-operation—which, however, goes for the most part its own way.

This pious ejaculation will make it easier for me to accommodate myself to the conditions which have been imposed on the short essay.

Works of sculpture in public places, which are neither monuments nor ornamental buildings, viz., such as are not intended to call to mind special events or particular individuals, are something novel in the development of high art. Antiquity knew only monumental creations which had their origin in patriotic sentiments. We have to bear in mind that religion in ancient communities constituted a part of patriotism, for there were no gods for mankind in general, but only gods for a particular people or a particular state. When Socrates had to drain the cup of hemlock, it was not because he had sinned against Olympus, but because he had given offence to Athens in the person of her tutelary divinities. The Battle of the Giants and the Frieze of the Parthenon, the Pallas Athene of the Acropolis and the Olympian Zeus, were felt, by those who gazed on them and for whom they had been wrought, as images from the past and present of their race. Even the "Laocoon" and the "Farnese Bull" were so regarded: a distinction between the legends of their race and accredited history, nay, between theology and politics, did not exist in the consciousness of the multitude at large, or even in that of the select few. The god made of ivory and gold was the public worship of a living being who was invested with high rank in the commonwealth, and the Olympian victor to whom a statue was erected entered into mythology as a comrade of Hercules, Theseus, and Perseus.

Religious art was the only public art known in the Middle Ages. If material political interests swayed the minds of communities in Pagan times, when the nations became Christian the supersensual, _i.e._, the salvation of the soul, became the great concern of the individual as of the community. Patriotism disappeared from the domain of emotion; what took its place—the pride of town, or class, or guild—was merely delight in material possession, or, if you like, a sort of vulgar dignity without any ideal background. Faith was their only sentiment, piety the artist's sole impulse from which genuine creations could spring. It followed, therefore, that religious art—the only monumental art then in existence—attached itself to sacred places, and subordinated itself to them as really mere accessory decoration. Without resting on architecture, sculpture stood on its own feet only in the Stations of the Cross on Calvaries, but, even in this case, it had no object of its own, but served a definite purpose of worship. The beginnings of a public art which grew out of an abstract thought of the community—one not of a religious but of a temporal, of civic nature—are scanty and dim. As forerunners of such an art we can claim the Roland Pillars of the Free Towns—the symbol of their civil and criminal jurisdiction—with their indistinct, historical background of dim memories of Charlemagne as the legal source of municipal liberties, and perhaps also the Byzantine Lion of Brunswick.

The Renaissance was the first to create a monumental art that was to serve no practical, religious, or dynastic purpose, but one purely æsthetic, from which people looked for no strengthening of ecclesiastical views, no increase of authority and, through that, of power in a prince or government, but looked, in fact, only for delight in beauty. Renaissance art, I admit, rich and free as its development was, also remained thoroughly under the influence of mediæval traditions, and knew no other range of themes than those derived from the Bible and Classic mythology. Even worldlings among the artists, who had outgrown religious ideas, drew at least their stories from the New and, even more commonly, from the Old Testament, or from pagan mythology, which was familiar only to the educated, and to the multitude at large was meaningless, and devoid of life. A scholastic pedantry hung about such works as Benvenuto Cellini's "Perseus," for instance, which prevented the masses from appreciating them fully. It was not, however, done from haughty disdain, for monumental art—the art of the streets and squares—appeals indeed to the masses. The modelling, on the one hand, of what is purely human, which appeals to feelings in every human heart, and is, therefore, understood by every man; on the other hand, of a subject, well-defined in time and place, which must be familiar, at any rate, to contemporaries and residents: this degree sculpture attained only gradually and late. The Goose-man of Nuremberg and the Brussels Mannikin are instances of local Realism; Tadda's "Justice" at Florence and Michael Angelo's "Pietà"—these in spite of their religious relations are examples of universal human Idealism. It is characteristic of the timidity of sculpture, even in its proud epoch of the Renaissance, that it dared not cast itself adrift from presenting what was of immediate utility. It thought it needed an excuse for stepping out into the market-place before all the people. It found it fairly in supplying towns with water. It created fountains. These are the first and, for a long time, the only monumental works which were suggested neither by religion nor by loyalty to some dynasty; which aim neither at immortalising the memory of a particular event, nor at refreshing the schoolboy knowledge of the more liberally educated, but embody, without any pre-possession, a purely artistic conception of form fulfilled and animated with subjective emotion. The stages of development of the monumental fountains, which pretend to be mere sports of untrammelled fancy on the artist's past, extend to the present day, in the latest phase, in which the fountain is not really intended to distribute water, like Sluter's "Fount of Moses" at Dijon, or Jean Goujon's "Fontaine des Innocents" in Paris, but uses the water only as a decorative element, as Donner's fountain in the market-place of Vienna, or Reinhold Begas's Neptune fountain in the Berlin Schlossplatz.

We must come down to the last century to find at last a monumental art of universal feelings or thoughts, still, for the most part, modestly cringing under the protection of architecture, as groups on pediments of palaces, theatres, and exhibition-buildings, and taking possession of the public square in full independence only in the last decades. Historical works, even of an universal, impersonal sort, such as the numerous war-memorials in Germany and France, the _risorgimento_-monuments of Italy, the patriotic battle-memories in Switzerland—do not come under consideration here, but only abstract works such as Bartholdi's "Freedom enlightening the World," at New York, or Dalou's "Republic as the Protector of Labour and Culture," in the Place de la Nation, at Paris.

Even these works still continue to show a birthmark, which betrays their origin from the sculpture of purpose, for Bartholdi's gigantic statue is a lighthouse, and Dalou's "Triumph of the Republic" belongs to the fountain series.

On the other hand, Bartholomé's "Memorial to the Dead" is as free from every idea of commonplace utility as any mouldings for the rooms of a house. It originated in the artist's emotion, and had, at its birth, no other purpose than that of relieving its creator by the gratification of an impulse. What was to become of the work after it was finished is a question Bartholomé probably never asked himself at all. Perhaps he resigned himself to the thought that it would pass a pensioner's existence in some museum or other. In any case, carelessness as to what use would be made of it left him entire freedom as to the form it should take. And now he had the unexpected happiness of the work being purchased by the city of Paris, and placed in Père Lachaise. This has been the first instance, as far as I know, of a purely subjective, monumental work capturing a public position without this being justified by a practical service to the community, without embellishing a building, without satisfying any religious need or patriotic feeling, without immortalising any historical reminiscence, without glorifying any event or individual, but basing its claim to the grateful attention of the people at large only on the grounds that it attempts to embody in beauty an elemental emotion alive in the masses, that is to say, a real, common interest of moral order. The work may become the starting-point of a new monumental art, which will set itself the hitherto unknown task of presenting, with the authority of great sculpture, moods and views of the world, viz., the spiritual conditions common to a people, of interpreting them to that people, and of fixing them for history.

With all its novelty, Bartholomé's work is, notwithstanding, not without organic connection with the historical development of art. There is no virgin-birth in art. Every work has a pedigree. Bartholomé's art is allied to the Campo Santo art of the Middle Ages, from which it borrows thoughts of consolation and promise. It nevertheless exhibits a daring progress when it has emancipated itself from the architecture of gateways, outer walls, chapels, etc., and forced its way in independent form, complete in itself.

The street of tombs opens at the main entrance of Père Lachaise, and leads to a gently rising hill, the declivity of which Bartholomé's masterpiece occupies. It displays the irregular, decorated side of a two-storied stone building of ancient Egyptian architecture of the simplest lines. A high door opens in the middle of the upper story, into the shadowy depth of which a naked man has entered. Him follows hesitatingly, with her outstretched right hand grasping his shoulder and seeking support, a young woman, the lines of whose profile, from her mouth distorted with fear down to the soles of her feet that detach themselves reluctantly from the ground, express a horror in presence of the unknown.

Towards this Gate of Death move, on the right and left, groups, each of seven persons, whom the artist has striven honestly, yet without real success, to fashion in various shapes. At the first hurried glance, the two processions appear to be variously moved; but on looking more closely into them, we recognise an uniformity which proves a striking poverty of imagination. On the left, hard by the Gate of Fate, a young woman is sitting on a stone-bench without support, with her countenance concealed by her hands. She cannot make up her mind to rise from where she is resting, in order to take the last step. A second woman is visible in a similar irresolute attitude, in weak relief on the wall. Cowering behind the two, kneeling quite low, so that the thighs lie in parallel lines over the legs, a naked man seems to be whispering words of encouragement into the ear of the seated woman. Then follows a woman sunk on her knees as if crushed, who hides her face like the first with a somewhat different movement, and behind her a man standing, but bending down to her, and addressing words of consolation. Last of all, another woman sitting down, whose dishevelled hair is streaming over her countenance, and, behind her, a man standing upright, likewise as a consoler. Thus is repeated on this side the theme of the despairing woman and the calm, comforting man. On the right side the invention is somewhat richer. Close to the door stands an old man—decidedly the most expressive figure in the whole composition—clinging tightly to the door-posts; and with his head and the upper portion of his body bent forward, he tries to get a terrified glance at the awful mystery, ere he pulls himself together for entering. To his group belongs a woman stretched on the ground with her face pressed in her hands before her; another folding her hands in prayer, and a half-grown girl shrugging her lean shoulders in terror. There follows a second group of three figures—a woman with dishevelled hair, bowed low to the ground; a crouching man supporting her and preventing the feeble figure from sinking down completely; and a young woman who kneels on one leg, turns her back to Death's portal, and glances back on life as though she still hoped for deliverance.

The lower story shows, through the front-wall, which is removed to its full extent, the interior of the vault into which the upper Gate of Death seems to lead down. On a mattress-like couch rest, side by side, the naked bodies of a man and his young spouse; across their bodies is laid their little one year old child; in the background is visible in low relief on the wall a winged angel with outstretched arms, who looks down lovingly on the three quiet sleepers. With a _naïvité_ which does not rise above the puerile method of the _quattrocentisti_, of making their figures express themselves by means of legends issuing from their mouths, Bartholomé writes on this wall beneath the angel the sense of his allegory: "They that dwell in the land of the shadow of death, upon them hath the light shined."

Above all, the artist deserves the respect that is due to long and earnest effort. We have here before us a work of ten years' labour, executed with composure, inspiration, and conscientiousness. He who can do that, of him one may say, without the slightest suggestion of irony: "With his talent, however applied, the man is certainly a character." Many details of the monument, nevertheless, prove that Bartholomé is not only a character, but also a man of talent. The husband and wife turn their quiet faces to each other in the rest that is in the grave, and lay their hands one upon the other; and this movement is so tender and sincere that it makes a deep impression. It really expresses in sculpture the love that endures beyond the grave. It is the solitary true emotion in the whole work; for he whose eyes grow moist at the sight of the dead child with the sweet little baby limbs, will say to himself that his emotion is not of an æsthetic nature, is not evoked by the means of art, but is the purely physical reaction of a human heart from a cruelly painful impression, in which no artistic element or inspiration is mingled. The woman who enters Death's portal a prey to horror exhibits graceful lines, and the old greybeard who timidly peers into it is cleverly conceived and accurately represented.

Beside these excellent details, many middling and absolute weak ones disturb us. The dead husband in the grave has an Aztec face of repulsive ugliness, which is not called for by any artistic considerations. The attitudes of many figures, especially those squatting or cowering, are in bad taste. A primary personage—the man who has stepped into the Gate of Death—stalks bending forward with head bowed down and the muscles of his back contracted, like one who is hauling with all his might. It is a matter of surprise that the tow-rope with which the vessel is dragged is not to be seen. I cannot prove it, but I am convinced that Bartholomé has formed this man, not after a model, but from what he recollected of a hauler by Constantin Meunier. I have already called attention to the monotony of the group _motifs_. The whole conception of the composition, at any rate of the upper story, is an echo of Canova's monument to Maria Christina at Vienna, with the further development that Bartholomé shows the subterrestrial and

supernatural continuation of the theme which Canova carries only as far as the entrance to the realm of shades, leaving what follows to the pious belief of the spectator. The weightiest objection which must be made to the work as a whole is its offensive lack of repose. All the individual details are, with few happy exceptions, realistic, whilst the effect of the whole composition moves in extreme unreality. How has Bartholomé's most original artistic instinct not preserved him from trying to present a wholly ideal dogma with the most vulgar, petty realism? Simple mediæval sculptors might work thus. In our contemporaries we do not believe in simplicity, and therefore the discord between idea and form has a jarring effect.

The most ideal dogma that Bartholomé preaches is, however, that of the immortality of the soul and the resurrection of the body; for his monument can mean only that, if it means anything at all. It is conceived as a consolation to the sorrow-laden who form the last escort to a dear one that is dead, or are making a pilgrimage to the grave of one they loved. And what consolation has he to offer them? See, he says, in the figures on the upper story, the sorrow with which men approach the gates of shadow-land. Why this faint-heartedness? Why this timorous shrinking from the terrors of death? Death has no terrors. It is entering into peace and the fulfilment of a high promise. And he shows, in the lower story, the gentle, blessed rest the dead enjoy who there slumber until their resurrection, watched by their guardian angel, who awakes them at the appointed hour, and convey their immortal souls to their divine destination.

That is the cosmic view held by an artist on the threshold of the twentieth century. Holbein and his predecessors in painting the Dance of Death were men who believed in Christianity, but the only consolation that they offered mortals was this: Don't bewail your mortal lot, you share it with Pope and Emperor. The path from the Rationalism of this exhortation to the mysticism of Bartholomé's dogma is called by the decadents Progress.

The decadents are consistent when they call Bartholomé a modern, one of the most modern, and hail his work as the art of the future. It is logically on a line with the "progress" and "modernism" of a Huysmans, Maeterlinck, Bourget, and other New Catholics. But what is to be said about the city of Paris having this unctuous work erected in Père Lachaise? Had the Moscow Duma done it, everybody would have found it natural. But the Paris Municipal Council! This society of boasting freethinkers which has banished the Cross from the schools and churchyards, hounded the Sisters of Mercy from the hospitals, has the dogma of the Resurrection preached officially!

That is the highly interesting ethical side of this work. It reveals monumentally the confusion in the donkey-heads of the self-styled freethinkers. That they should decree the honour of a public site to a composition of a dogmatically religious character is proof of crass ignorance of their own standpoint, or else of their hypocrisy. I prefer to assume it to be their ignorance.

XV

JEAN CARRIÈS

The little palace, the charming edifice which was already attractive as the abode of the Dutuit collection, has received a new value and consecration. A room has been opened in it, in which a great artist reveals himself, whose acquaintance, though not indeed quite exhaustively, but nevertheless very profoundly and familiarly, can be made only here in the wide world. This artist is Jean Carriès, who died in 1894, at the early age of thirty-nine, after a marvellously planned life. To this pattern life, as expressive as any whose story Vasari has told, belonged a patron who kept what is vulgar away from him, who saved him from care and anxiety, who made his mind easy as to his influence on contemporaries and posterity, and, to a certain extent, symbolically personified his fame for him. This useful part was played by a certain Herr Hoentschel, who acquired most of Carriès's works. He has now presented them to the City of Paris, and, by so doing, rendered the opening of the Carriès Museum possible. In return his name has been engraved in letters of gold on the marble slab which declares the purpose to which the room has been assigned, beside that of his trusted artist—no mean satisfaction to a high-aiming ambition.

Carriès was the son of a poor artisan of Lyons. He seemed destined, as he thought, to follow his father's avocation; but the fairies had conferred gifts on the proletarian's child in his cradle: sense of beauty and power of design. He was for a short time apprenticed to an artisan; then he taught himself to be an artist. He pursued no beaten tracks, and could follow no guides. He was left to his own sense of locality for finding out a path, and he made wide _détours_, but, nevertheless, raised himself safely to the highest peaks. Phenomena delighted him as form and colour. His pleasurable sensations sufficed to impel him to utterance in sculpture and painting; he satisfied his delight in form by modelling in clay, his delight in colour by enamelling.

For nearly two decades he sought, strove, and created in solemn loneliness. Only the patron whom he luckily found at the right time glanced over his shoulders when at work with bated breath. His reverential admiration expressed itself in a convincing manner by the helpful gesture of the open hand. Some intimate comrades were allowed to witness the lofty drama of an exquisite development. His studio, however, was far removed from the noise of the market. The heat of praise and the icy breath of blame brought no disturbance into the even climate in which his talent was powerfully developing. Quiet and collected, he worked on until he saw his inner vision realised before him. Then he said: "It is good"; and allowed a great Sabbath to follow the hard days of creation. Absolutely unknown to wider circles, in 1892 he stepped before the public for the first time in the Champs de Mars with a rich exhibition. An hour after the doors of the "Salon" were open, he was famous. In the history of modern art, never before had such an impressive revelation been observed. There was no hesitation, no vacillation. Artists, critics, connoisseurs made pilgrimage, as if guided by the shepherds' star in the bodeful procession of the three kings of the East to Carriès' glass cases and pedestals, bent their knees, and brought incense and myrrh. His countrymen shouted for joy: "France has one great painter more." Thoughtful persons looked at one another and said softly: "The world is by one beauty richer."

All asked: "Who is the man?" for they insisted, in their amazement, that nobody knew him. And then they found out that Jean Carriès was a finished artist, a man of thirty-seven, who lived in the provinces, and had, up to that time, sought nothing but the satisfaction of himself. He had not wasted the tiniest little spark of his Promethean strength in the vulgar melodrama of fighting for success. His tragedies were the great struggle with the resistance of material, and doubt of himself, and they had been played in secret in his soul. And now was pressed upon him that for which candidates strive convulsively, and how often fruitlessly! The Champs de Mars Society elected him with acclamation to full membership, and dispensed him from the probationary period is associate. The State asked for specimens to serve as models for its museums, and tied the red ribbon to the buttonhole of his blouse. What was purchasable was bought up by the ladies of Arc de Triomphe quarter during the first days of the "Salon." A rich American lady, Mrs Winnareta Singer, commissioned him to carry out the model of his fantastic "door." The artists fêted him by a banquet in his honour—a homage which at that time was not lavished as was the case afterwards. Mdlle. Luise Breslau painted his portrait, which is now exhibited in his room in the midst of his works, and showed his admirers a still youngish man of noble beauty, with a Lucius Verus head, the Cæsarean nobility of which was not in the least injured by a careless slouched hat. I do not know whether Mdlle. Breslau has flattered her model or has been honest, for I never saw Carriès himself; but in the picture he appears, as one would like to fancy him, every inch a gentleman, on whom his careless working-dress has the effect of a disguise which does not for a second deceive as to the rank of the wearer. A delicate, slender figure; wonderfully active, inspired hands; deep, searching eyes that seem to sight and fix a dream-picture hovering away; soft, narrow cheeks, on which uneasy shadows play, under the short beard; a thoughtful, white forehead over which an abundance of light brown curls falls. How many women may have indulged in dreams before this likeness, for it fascinates even men!

The homage received had no intoxicating effect on him; the activity of the Press concerning him did not infect him with the smallest beginnings of conceit. He withdrew from the curiosity of the world by quietly returning to his provincial nest, where, day and night, he stoked his flaming furnace, and mixed his acids and metallic salts; suffered under frequent disappointments, and enjoyed rare delights in the success of a firing or a coloured enamel. In the ensuing year one looked in vain for him in the "Salon," and not quite two years after his unparalleled triumph that came like a bomb, men learnt that he had died.

His life had ended artistically. Carriès disappeared ere his locks grew scanty or grey. Beautifully and noiselessly, like another Euphorion, he soared away from the admiration of his contemporaries in the full lustre of his fame; and his works, through his early death, experienced the enhanced value of the Sibylline books. We may call him happy, for in this room we feel that he had given his best when he died. With a longer life he might have gone astray, for there is no lack of short openings to false paths. Very likely he would have repeated himself many times, and that would have detracted from the dainty charm of rarity which, besides their noble beauty, is peculiar to his works.

He unites in himself two different and equally perfect artists: the sculptor and the art-potter. Each tilled a tiny field; but with what intensity! And what harvests they conjured out of it! As sculptor, curiously enough, the whole human figure in its Olympian nudity failed to interest him. He has not on a single occasion sought to represent the body's Paradisaic beauty. He confines himself, apparently on principle, to head and hands; but these are surpassed by nothing, and equalled only by little, that all the centuries since the Renaissance have produced. I pass respectfully, yet without deeper feeling, by his busts of Velasquez and Franz Hals. They are merely exercises of his hand, perhaps only pastimes. They seem theatrical by reason of the accentuation of the costume. In their countenances the absence of the model is too evident. But beside them the busts of Gustave Courbet, of Jules Breton, especially of Carriès himself, operate with unequalled authority. They live before us; they think, and they reveal themselves. In

looking at them we involuntarily call to mind the old stories of the earthen statues which a magician filled with the breath of life in order that they might serve him.

The same impression, only intensified and deepened, is felt before the busts of the "Young Girl with the Drooping Head," the "Dutch Wife," and the "Dutch Maiden." This young Dutch girl is particularly adorable. I do not consider I am exaggerating when I say she ranks as a sister, though in a different technique, with the "Mona Lisa." The maiden's innocent eyes, which have no presentiment of the passionate secrets of Gioconda; the graceful, reposeful countenance, that seems wondering blissfully over her own blooming youth and the loveliness of the world, charm us like the miracle of a spring day. Similar joy streams from his sleeping and waking little children. The softness of this baby flesh, the delicate texture of this plump, warm, satin skin, are unattainable. Carriès discovered a new technique for the life of the outer skin, the results of which, in his hands, are amazing. He gives a delicate, perpendicular creasing to the membrane of the lips, and marks it off from the skin of the face in a discreet but firm line, so that it imparts the illusion of seeing swelling lip-red framed in mother-of-pearl. The mouths of his women are weirdly seductive. It would really not surprise me if semi-fools and lunatics were to pounce upon these ravishing lips with eager kisses.

Even when Carriès is not idealising, but is reproducing portraits true to nature, he imparts to them an inwardness which seems unfathomable, like that of a deep soul. For this let any one only look at the "Bust of an Unknown Lady" and "Mother Callamand"—the former a cold, proud patrician, perhaps the Clara Vere de Vere, in whom Tennyson admires "that repose which stamps the caste of Vere de Vere"; the latter a splendid old nun, probably an abbess, a sturdy, peasant woman who is conscious of her high rank in the convent, and in whose broad face goodness and severity, healthy power and enthusiastic spirituality, are mingled. This gift of filling the subject with inward life is the strongest element in Carriès' genius. In a series of works which were exhibited in the Champs de Mars Salon, and are, unfortunately, not to be found in the room of the Little Palace, this cropped up overpoweringly. There were fabulous animals, monsters, which a luxuriant imagination had invented—toads, frogs, lizards of gigantic size, in positions humanly conceived, the female reposing on the breast of the male, whose eyes are closing in rapture, and delicately embraced by his paws. One might think they would have a grotesque effect; by no means. Their anthropomorphism brought them in danger of derision; but the genius of Carriès was here directly revealed. The quasi-human, emotional life manifested in their attitudes made them pathetic. The toads' legs were not seen; their mouths and goggle eyes were not seen. People saw only the unmistakable trait of love, and were moved by this exhibition of the primitive feeling—the same in man and beast—which holds the world together.

Perhaps it is in accordance with this gift of spiritualisation that Carriès never worked with marble, rarely with bronze, but, as a rule, and preferably, with potter's clay. Stone and metal, however painfully correctly they render, with every stroke of the thumb and impression of the finger, the clay model, seem to him too hard for the inexpressible tenderness which he wants to express. Only one material satisfies him—the one which possesses the softness of flesh and of nerve-plasm. He can knead only clay so that it retains his lightest vibrations. There is something about his busts of burnt clay that reminds me of phonographic cylinders. There is soul-melody inscribed in them in invisible lines, and, set in our mood, they again begin to give forth sounds, and to repeat the mood of him who composed them.

The ability with trembling fingers to coax emotions into soft clay and to render them plastic seems to be something divine. It did not satisfy Carriès. Anybody else would have found the limits of his genius enviably wide; to him they appeared narrow, and he tried to pass beyond them. He wanted to create monumental pieces of sculpture, and he constructed his "Martyrdom of St Fidelis" and his astounding "Gate." The "Martyrdom" is a group, composed of the kneeling martyr in monastic habit and the executioner behind him, raising his armed fist to deal the murderous blow. In the details the artist is here, too, distinctly Carriès, _i.e._, the executioner is of superb cruelty—a fine specimen of the family of brutalised legionaries or torturers who, in mediæval _relievi_ of the Way of the Cross, scourge Christ at the pillar and nail Him to the Cross. Taken as a whole, the master's art is a failure; the group has no line. The drama cannot be seen from any side, that is, the gesture of the executioner, with its menace of death, and the countenance of the martyr who is awaiting his last trial, cannot be comprehended at once in a single glance.

If this group is weak, the "Gate" is a complete failure. He imagined a gateway with a depressed keel-arch top, divided by an intervening pillar into two gates. The pillars are covered with grotesque masks and mythical animals from top to bottom. The arch of the gate is formed by a dragon, in the gaping jaws of which stands a noble lady. The separate masks and monsters scintillate with spirit, fancy, and humour. In richness and variety of invention, and in depth of humour, I unhesitatingly place these heads far above Germain Pilon's Pont Neuf masks. The contrast, too, between the fearless maiden standing in the animal's jaws, full of quiet self-confidence, and the hideous beast, is of pregnant symbolism. The work is, nevertheless, an aberration, as a whole. The masks and monsters have no organic connection with the gate, either constructively, or in accordance with the meaning. They are simply

stuck on. And the gateway itself is an insoluble riddle. Where should it lead to? To a lunatic asylum, a museum of caricatures, or a carnival ballroom? Or should it mean "the abstract door," the door pure and simple, without the purpose of an entrance into a building? The poor, great artist consecrated years of his life to this prodigy, and never saw that he had wasted them.

The decorator amused himself in devising unheard-of enamels. He modelled vessels of smooth, supple plant-forms—calabashes, melons, cucumbers, mamillaria-cactuses, bulging or fallen in, smoothly swelling, or warty and shrivelled, whimsically dinted like a thin copper-plate, wantonly hammered, or lumpy and swollen. And over these whimsicalities, which show an incredible mastery of the material, he poured glazes which look so fat and moist that they seem to flow still, viscous and languid. Many are purple, like half-curdled blood; others white and rich, like fresh cream; and others like coloured fruit juices; but many a time we think we see thick matter and brains in frightful discharges; and on some vases the enamel imitates the lichens which overrun the bark of trees in spots, grooves, and bands. And when Carriès has done enough with these glazes, which remind us of opalescent life-saps, he tries diversity in glazes of gold, silver, coral, and precious stones, which change his stoneware phials into splendid vessels from a treasury of the Thousand and One Nights.

As a sculptor in clay Jean Carriès stands as high as Della Robbia; in details—in forming lips and cheeks—far higher than the latter; and, as a decorator, no one can be compared with him, not even Bernhard de Palissy—to mention a name by which his rank may be estimated. Carriès is not a man of to-day, and fashion lies far below the height on which he works. The wretched æsthetic-babbling coteries of the period cannot get hold of him, or make use of him for the senseless but furiously bellowed catchwords peculiar to the polemics of the day. He is not a modernist, not a classic, not an impressionist; he is not this, he is not that, but, he is, quite simply, himself. He works up what he has learnt in his own person; he invents his own, and always gives himself. He creates from his own soul, without looking to right or left. In him there is no school, no tendency, and no straining, but only feeling, personality, and the service of beauty. Yet it is through these great artistic natures, which belong to no time, that the line of development in art proceeds, and not through the pitiful _homunculi_, whom Faust caricatures artificially engender in advertisement-retorts.

XVI

WORKS OF ART AND ART CRITICISMS

During the last years the relation of public opinion to works of art has been repeatedly discussed, and on each occasion with great warmth.

The discussion, in the main, is concerned with two questions which are independent even if they are connected with each other, viz.: Has the public a right to judge a work of art, or must it renounce its own opinion and simply bow before the verdict of specialists? Have not all, or, at any rate, many, works of art that have subsequently gained undisputed recognition by the world, been strongly opposed and rashly rejected on their first appearance in public?

In 1899 intellectual Berlin was excited about a pertinent question. Professor Franz Stuck, the Munich painter, had obtained a commission for a wall-painting for the German House of Parliament. When the artist sent in his sketch, there came a shriek of most unpleasant astonishment from the judging committee of the Reichstag, and a member, Dr Lieber, expressed in public session, in very strong language, his absolutely unmixed feelings in respect of the work.

The Munich friends of the insulted artist, to their credit, made common cause for him. They published an armour-clad protest, in which they characterised the members as "laymen unable to judge," and reproached them with impertinence because they "thought they understood everything better than learned specialists did."

I expressed my views then in the _Deutsche Revue_ of this opposition between specialists and laymen in plastic art, and I ask permission to repeat here in brief the essential part of my arguments.

Who are the experts? From the general drift of the objection on the part of the Munich artists it was to be concluded that they must be the practising artists, the critics, perhaps also the professors of art-history. Let him who does not belong to these three sacrosanct categories steal weeping away from the confederation of experts. And even among the critics there is probably a selection to be made. The critic who praises the artist is to him undoubtedly an expert; the critic who blames him shows himself incontestably as a _bourgeois_, and in intelligence stands almost as low as a common University professor who does not teach art-history.

All this is foolish talk. In matters of art, if, indeed, any one can, only an individual—never a category—can lay claim to the rank of expert. Is, perhaps, the practising artist the expert? He is not so necessarily. There are people whose vocation in life, or, speaking more correctly, whose usual occupation, is painting, but whose painting is a continuous insult to art. One may be a professional painter, and yet a pitiful dauber, and commit such impudent sins against good taste that every non-expert must recognise this at the first glance, and be provoked at it. Or is the critic the expert? It would be a good joke to assert that.

Nearly every verdict on a work or an artist committed to paper by a professional critic is opposed by another verdict, also by a professional critic which says the exact contrary. Which of the two critics is an expert? Which of the two has a right to demand that people should bow before his verdict, because he habitually makes phrases about works of art in public? What proof of capacity do the papers as a rule demand of the _beaux esprits_ to whom they entrust art criticism? He who has observed dozens of times how ambitious young newspaper-writers, on their first report of an opening of an Exhibition, or after forming a coffee-house acquaintance with an artist thirsting for advertisement, suddenly discover in their minds a gift for art criticism, and have subsequently cultivated this with brazen self-consciousness; he will feel highly amused when people try to crack up art-critics as experts, simply because they exercise this function. Even professors of the history of art, even directors of museums, are not, by reason of their office, experts in the sense of possessing very profound understanding of art. The academic study of art-history lays the chief stress on the facts belonging to the history of life and morals, which need have nothing in common with the understanding of art. One may make in archives the most beautiful discoveries for the biography of Leonardo, and not feel a single one of his pictures. And as regards superintendents of museums, it is possible to relate the funniest anecdotes about their fallibility, and oppose to them simple connoisseurs, also “non-experts,” who have formed splendid private collections.

The truth is there are no experts in questions of art, as there are, perhaps, in questions of technique. Expert knowledge presupposes the existence of fixed rules, of a canon. There can be no talk of this in the fine arts. The only element of painting that, at least to a certain point—to the point where the individual conception and, with it, really artistic interest first begins—is under objective rules, is drawing, both from its figure as well as its perspective side. This element can be taught, learnt, and faithfully measured, for nature furnishes the scales. On the other hand, the colour element in painting is subject to absolutely no canon, but at best to subjective feeling, at worst to a fashion of the period. Every artificial colour is a convention; for, as I have argued more particularly in my studies of Sisley and Pissarro, none can truly reproduce the real colours of natural phenomena, and it is wholly a consequence of education and habit, when the polychrome of oil-painting or water-colour more easily excites in us the illusion of colouristic truth than the monochrome of the two-colour or of black and white art. One decade paints in dark, another in bright colours. One school likes powerful, another subdued harmonies of colour. Præ-Raphaelites imitate the tone of old frescoes and faded Gobelins. Puvis de Chavannes took the colour out of his pictures by a transparent white-wash, pale as the moon. Besnard, on the contrary, discharges fireworks, without caring in the least if the mad tumults of colour that he loved are possible or not in nature. Carrière envelops his figures in a dense mist. Cottet has, very recently, brought into fashion the black and dark shadings which go right back from Ribot and Prudhon to Velasquez and Ribera. Who is right? Who is wrong? Here everything is feeling, and consequently subjectivity. Of drawing, one can in all cases say (and by photography irrefutably prove), it is correct, or it is wrong. Colour does not admit of a similar verdict. All that can be said of it is: “I like it,” or “I don’t like it.”

For beauty in art, in the present condition of the perception theory, the physiology and psychology of pleasurable feelings, there is no other standard than subjective feeling. This is dependent on the greater or the less sensitiveness of the nervous system, on its perceptivity of slight qualitative and quantitative differences in the excitation of the senses, and, therefore, on an essentially congenital constitution of the organism. The gift of receiving strong impressions from works of art can be developed by practice, by the frequent and attentive study of works of art of different kinds; but it cannot be attained artificially by any effort or any amount of study.

What, then, mean the expressions expert and layman, when applied to æsthetic verdicts? The classes of society, in which preponderating occupation with intellectual problems, continued through several generations, has refined the nervous system and rendered it more sensitive, produce, as a rule, individuals with a feeling for art. These live in large towns, in the centres of art life, they travel, and visit numerous collections, and thus their feeling for art is developed into a wide understanding of it, that studies works of art from the historical standpoint. These are the real experts, so far as there can be any talk of such in æsthetic questions. But these classes of society, these individuals are only to the very smallest extent painters or professional critics, _i.e._, critics writing for the public. To wish to exclude them, on that account, from the expert class is ludicrous presumption of certain persons who, by their own authority, confer this title on themselves. The educated public—the intellectual _élite_—has not the least reason for allowing their opinion on works of art to be dictated to them by painters who may well be daubers or crack-brained fools, or by

critics who may be ignorant phrase-mongers.

So much for the first question as to the fitness of the so-called layman for criticising works of art.

The second question, as to the changes in public opinion about certain works and their authors, is considerably more complex.

It is not to be gainsaid that such changes have occurred, but they are much rarer than those would like to make us believe who, from instances of pretended later conversions of originally rebellious taste on the part of contemporaries, hope to succeed in proving that the ugly is beautiful and the beautiful is ugly.

The names which were most often cited to prove the incompetency of contemporary judgment on works of art of modern tendency are most unfortunately chosen. Millet, Rousseau, and Corot were looked upon by their contemporaries as smearers and daubers; Manet was laughed to scorn, Böcklin pronounced a fool, his friends advised Hans Thoma to change his name, etc., etc. In order not to go to too great length I will now leave Thoma and Böcklin out of the discussion. But the others! That Rousseau and, especially, Corot passed for smearers and daubers among their contemporaries is simply not true; on the contrary, justice was at once done to them for their technique. Even their most unscrupulous opponents admitted that they were draughtsmen and colourists. What they were reproached with was only the alleged intellectual insignificance of their work. People remained under the influence of classical landscape with ancient buildings or ruins, and a decoration of ideal figures such as Poussin brought into fashion, and Claude Lorrain cultivated. A landscape without nymphs or shepherds in Arcadian dress, without temples or figures of Hermes, seemed empty, insignificant, ignoble. The majority had as yet no taste for the witchery of mood in wood and field. Why, Corot himself was not clear about what was new and determinative in his own art, for in some of his grandest pictures Dryads dance, beneath young-leaved trees immersed in the mists of springtide, the most correct sham-classic square dance. It was only in his last period that he renounced this ancient magic. Rousseau had broken away from tradition more resolutely, and was on that account less esteemed than Corot by contemporaries whose education had been perverted by precedent. But the worst that was said against the two did not go beyond the assertion that they were "vulgar."

The case of Manet is, of course, different. People have roughly disowned this painter; but it is absolutely false to talk about a change in popular opinion about him. Those who "laughed at" him thirty-five years ago, laugh at him in precisely the same way now. In my study of the Caillebotte room in the Luxembourg Museum I have alluded to the angry protest of Gérôme and Gustave Moreau against admitting the works of Manet and his friends into a State collection. If the laughers are not so numerous, and if their laughter is not so ringing as in the "Olympia" year, it is simply because the man is absolutely done with. Only a few stragglers still talk nonsense about Manet, men who have missed the connection of "the last train," and some greybeards in their dotage—the barricade warriors of the "Salon"—who fancy they are still breathing the gunpowder smoke of 1863, and will keep up to the day of their death, which cannot be far off, the happy, exultant mood of the beer-evenings at the Café de Madrid. None among the pillars of young and living art recognises Manet as his ancestor. People know now that he was a discovery of Zola's. The sharp turn in the development of art in the last thirty years of the last century was inaugurated, not by him, but by others. Courbet introduced realism which has nowadays shrunk to nothing. Monet kindled "Free Light," and that was a very great service which, unfortunately, is also no longer fully acknowledged, for the latest race of Parisian painters again abandons joyful brightness and goes back to the gloomy, oppressive tones of "the 'fifties." Manet, however, found nothing and invented nothing, and he owes the noise that was, for a period, heard about him only to his relations with a devoted friend, who vindicated his own tendency by that of the painter, and said of him all the good which he thought of himself.

The change in taste from one generation to another is a general law which I proved in the _Neue Freie Presse_ of 9th August 1896, and afterwards developed and established in the Florence _Rivista Moderna_ (No. 3, of 1898, "_Le alternanze del gusto_"). I strongly believe in the prevalence of this law; but if particular cases are followed in detail, it is recognised that many an apparent change in the appreciation of a work or an artist rests on an illusion of the senses.

To return to the subject of Manet. An awful din arose at the first appearance of "Olympia." Friends and foes waged wild battle with each other. Each panted for the blood of the other. Twenty years later the picture that had been so hotly contested was hung in the State Museum, which roused fresh, but considerably weaker, opposition. Finally, however, no one any longer protested against its presence in the picture-gallery, and now a sophist might assert: "There, you see! The picture which was once laughed at is, thirty years afterwards, acknowledged as a classical work of art."

Gently! That is by no means proved. The fight has ceased only because it has become objectless. Who nowadays waxes warm against Manet? The man, you know, is dead, not only as a human being, but also as an artist. He no longer troubles any one. He

no longer exercises any bad influence. He no longer even poisons popular taste, for it is sufficient to observe the visitors to the Luxembourg, to see that they pass by the "Olympia" with laughter, and shrugging of the shoulders, or else with astonishment and shakes of the head. If a belated corybant raises a shout of "Hail, Manet!" he is merrily allowed to shout. It is superfluous to shout him down, for nobody listens to him. The truth is that the taste for Manet is not in the least changed. People find the "Olympia" every whit as repulsive nowadays as it was thirty years ago; but they no longer say so with a loud voice and with the veins about their temples swollen, because, generally, people no longer stop before its mouldy ugliness.

If you examine very carefully, you will generally find that the various appraisements of particular works in a new generation do not originate from later generations regarding it differently than did contemporaries, but from their generally no longer viewing it with the same eyes. Let us only bear in mind always that the vast majority of mankind have no feeling of their own for artistic beauty. They act as if they had some feeling only because they know that a feeling for art is pronounced to be a mark of higher culture. We cannot rate too highly the part played in art idiocy by sham culture, pose, and self-deception—or, shall we say, more indulgently, by auto-suggestion? Honest confession of obtuseness to art is hardly found in any but the two poles of humanity—on the extreme summit and at the lowest antipode. A man must be either a rustic lout or an overtopping genius like Prince Bismarck, to confess that he can make nothing of the fine arts. The culture-Philistine never has this courage. He always pretends that he finds luxurious enjoyment in the contemplation of art. This culture-Philistine always repeats what has been said to him; he admires where the Baedeker-star prescribes admiration. And he is, in many cases, not even dishonest. He persuades himself that he feels what he regards it as his duty as an educated man to feel; and he really comes to feel it in the end, thanks to this self-persuasion. All the effects of art depend on suggestion, so far as they are not concerned with the most absolutely primitive and undifferentiated sensual excitations. On one who has a genuine feeling for art the work of art itself conveys the suggestion, which is followed by feelings of pleasure. On the average men, whose blunt nerves take no impression from the work of art itself, the Baedeker-star—the label—exercises this suggestion. If a work of art has once got the reputation of excellence, either because it deserves it, or because it acquired it from a dishonest, busy, bold, and swaggering clique, the next generation of Philistines in art does not test it further, but takes it as something accepted. The clique can then state triumphantly that the work they have puffed is a success. But has it on that account acquired real success?

The number of free, strong men is extremely small, who have the courage, desire, and ability to examine the veracity of traditional labels; but there is a frightful devastation every time that such an idol-destroyer and overthrower of altars breaks into the Temple of Renown, which is guarded by that dragon, the Good Old Way. People are then convinced about the quantity of plaster rubbish which has been smuggled into proximity with real marble and gold-and-ivory work in the semi-darkness of the sanctuary, and has enjoyed for hundreds, perhaps for thousands of years, the same veneration as the wonder-working revelations of genius.

But suppose we conceive in our mind's eye the extremely rare case in which a real masterpiece was misjudged at first, and, later on, was greeted with acclamations. In this case the question, as a rule, is not of lack of understanding, but of lack of sense of proportion. The contemporary age which blames, and the succeeding age which praises, are both right, _i.e._, they do not praise and blame the same thing, and the divergent appraisement of the work is simply due to the fact that contemporaries like to dwell on the faults and overlook the excellencies, whilst latter generations neglect the faults and regard only the excellencies. The contemporaries were biassed in severity, their successors are biassed in indulgence. Ideal justice is not of this world. But faults remain faults even in the ages that come after, and excellencies, too, were excellencies even in the period of their origin; and it is jugglery and forgery when people interpret the change in appraisement as if a later generation had admired as a merit that which an earlier generation had stigmatised as a fault. Just one example to illustrate these propositions: Millet is said to have passed for "a dauber and smearer." Now, his contemporaries who blamed him used no such harsh expression. They said only that Millet drew incorrectly and painted carelessly, and those with a real feeling for art notice exactly the same thing to-day, only they say it no longer, unless the question is expressly put to them. On the other hand, his contemporaries, too, noticed his deep moral earnestness, his warm human feeling, the touching simplicity of his style, which we prize so highly in Millet to-day. But they were not inclined to forgive him his defects in execution on account of these intellectual merits, whilst we take his weakness in form into the bargain on account of the feeling it contains. These weaknesses, however, are there to-day precisely as they were thirty years ago, and he who fails to see them is guilty of presumption if he passes a verdict on pictures.

Taking them altogether, the works and artists that were overvalued by contemporaries are far more numerous than those that were underestimated at the beginning. And even in the extremely few cases of the latter category, the injustice of contemporaries did not, as a rule, take the form of violent opposition, but that of indifference. Contemporaries did not gainsay their beauty; but it escaped their attention, because this was claimed by other fashions and styles. No work of plastic art that is nowadays accepted

without dispute was rejected, when it appeared, with such anger as certain products of the "Secession" are at the present day.

That is natural. The conditions of art production were half a century ago absolutely different to what they are now. The artist gave his personality full scope, and sought to please only a few customers of rank, without troubling himself about the people at large. To-day he wants to excite a sensation at any price, and he looks, for this end, not into himself, but about himself. By creating he is not satisfying his impulse to give form and shape, but his hunger for success.

Vain _amour propre_, swaggering, conceited vanity and cunning "pushfulness" are the motives that far too often guide the artist's brush or chisel. The coarse vulgarity of the means corresponds with the coarse vulgarity of the motives and aims. One must make a sensation, and that is attained most easily by a rowdy rebellion against taste, truth, and healthy human intelligence. If he annoys his contemporaries, the ruthless advertiser finds his account more surely than if he praised them. Only he who startles dares hope to be noticed in our present huge exhibitions with their three thousand numbers. That is why the unscrupulous competitor works with the object of startling, and only with that object. His natural allies are writers who seek by aggressive criticism to satisfy the same hysterical impulse towards sensation as he, and the snobs who hope to justify their claim to be un-Philistine by pretending to discover and appreciate hidden beauties, where the thick-headed majority of their fellow-men observe and condemn only unblushing outrages on the sense of beauty.

The necessity for creating a sensation has arisen only in our times of over-production in all fields of intellectual creation, and of frightfully murderous competition for success. In the earlier days of art it played hardly any part at all. On this account it is fallacious to try to deduce from the, after all, extremely rare romances of works, originally misjudged but afterwards recognised, in the past, an argument in favour of certain creations of the present day, which a large proportion of educated men rejects, not because they do not understand, them, but because they understand them only too well.

Let men only have the quiet courage not to allow themselves to be put out of countenance; they will carry their point even before posterity.

XVII

MY OWN OPINION

There is hardly anything which I hate so cordially as opportunistic criticism, which, in respect of phenomena in art-production presented in a noisy and pretentious way, affecting to signify modernity and progress, does not honestly take a side, but with the cunning foresight of the bat in the fable attempts to come to an understanding with both the opposing armies, of the birds and of the mice. Criticism that openly wears the uniform of a pronounced movement in art can be put up with. The enemy of the movement fights the criticism and the movement at the same time. It shares all the fates of its banner; it is in the danger, and it may be in the victory. If the movement for which it carries weapons succumbs, it gets the worst of it too, and experiences the treatment accorded to the vanquished. It has to lay down its weapons of criticism, falls into contempt, and has no longer the possibility of devastating art life, of perplexing artists, and oppressing those who enjoy art. Insufferable, on the other hand, are the clever, the unprejudiced, the eclectics, the smooth civil sneerers who praise, yet with faintness, who blame, yet with a saving clause, who carry in their lips such well-known and rather good phrases as: "Certainly, there is some exaggeration here, but the peculiar style is not to be misjudged": "It is certainly no finished creation, but the work, nevertheless, contains some promise": "This is not exactly a work, you know, which one could recommend for imitation, yet there is much to be learnt from it": "It is the new wine in Goethe's _Faust_ that is acting so absurdly, but still perhaps it will yield a good vintage." These people who talk so sweetly are those who really poison the springs of public taste. Thanks to them, movements which ought to stand without the pale of the law enjoy a sort of equal justification, as it were, of the æsthetic, historico-artistic copyright. Their mask of benevolence, justice, and toleration gains them the confidence of the irresolute, who, left to their own feeling, would recognise, at once, in certain works, either a gross impropriety of the shameless sort, or an indubitable manifestation of insanity, yet through the cheap phrases of opportunistic critics, become doubtful of themselves and say: "If such sober-minded scholars as this and that critic constantly find something to recognise in this stuff, I am perhaps wrong to condemn it at once."

Moderate feelings are much more widespread than extreme feelings. They are the normal product of the nervous system in civilised men; to the great majority of half-coloured, faded grey men subdued colours only are sympathetic; violent and shrill colours may amuse it; but, in its innermost being, it feels instinctively drawn only to the lukewarm ones. It believes them; and on their information, on their irresponsible recommendation, gives to the most openly rascally art-firms the credit through which alone they

can hold out for a while.

And these critical warpers of justice are not assailable. They always play an imposing part, and are always right. If an objectionable movement lasts—and there are aberrations which have held their ground for at least a generation—then they triumph modestly, for they have been among its first heralds and have "recognised at once the sound kernel in the first strange shell." If the imbecility is as such patent to all, and disappears amidst the derisive laughter of the intelligent, they triumph again, only somewhat more self-consciously, for they have "not let themselves be dazzled by novelty, and have pointed out its weaknesses, and worked strenuously at its defeat." Thus every adventure in art life, every campaign in criticism, be its issue what it may, increases their esteem; and the longer they continue their course, which is so mischievous to the community, the more blindly the multitude yields to their leadership, and the greater devastation they are guilty of through their dishonourable exercise of their office of guardians in matters of art.

I well know how this opportunism in criticism arises. It is the result of the co-operation of the basest and most despicable intellectual qualities. I find its causes in the dull feeling for the beautiful which renders weak and indistinct all reactions from artistic influences, and suffers neither delight nor irritation to arise: in the cowardly fear of man and pitiful adulation, which aims at injuring no one and only thinks of keeping a retreat open for itself; finally in common vanity, which prefers to please a crowd of gaping boobies rather than the select few, and the flattering, though so cheap, reputation of being "very intellectual," to the responsibility of crude performance of duty. The favourite word by which the opportunistic critics compound with every artistic confidence trick is "development." If the clairvoyant monitor utters the cry of "decay and degeneracy," the opportunists reply, "buds of a new and splendid bloom." They love to appeal to the history of art. That is right. When the Masolinos and Masaccios sprang up, the last pupils of Gaddi and Orcagna whimpered, "Now there is an end of painting." But what was at an end was Byzantine art filled by Cimabue and Giotto with some fresh life, and what began was the ever glorious _Cinquecento_. And much nearer to us: when Delacroix emancipated himself from the colour rules of David's pupils, and broke out into a downright exultation of red and blue and purple; when Corot, Rousseau, and Dupré set homely nature viewed with lyric eyes in the place of Poussin's classic landscape degenerated into dial painting; then earnest voices likewise accused the innovators of digging the grave of art, and yet we know nowadays that Delacroix and Corot were by no means the wild anarchists which the Academicians held them to be, and that an uninterrupted line of development extends from David and Prudhon through Géricault to Delacroix, and from Nicholas Poussin and Claude Lorrain through Joseph Vernet, and even through Watteau to Corot—a line which was unnoticed by contemporaries, yet one which we now see clearly. It is the dodge of an unscrupulous attorney to quote these examples when treating of the art of a Puvis de Chavannes, an Aman-Jean, the Præ-Raphaelites, _pointillistes_, _vermicellistes_, and _pipists_. There are sure marks of recognition by which the authorised can be distinguished from the unauthorised, the true from the false, development from retrogression, and buds from gall-nuts. A movement which, indeed, resolutely diverges from the taste dominant at a given time, though striving to approach nature, need not, but may, have a future; and he who does not suffer from stiffness in the joints will not, as a matter of course and on principle, refuse to follow it with benevolent curiosity. If, however, the new movement departs from nature, one may confidently say "it leads to nothing." If an independent method which strives after personal expression reveals itself in a revolutionary effort—however peculiarly, nay, perversely, it might impress—the intelligent man will not condemn, but wait to see if something living comes from the attempt. If the practised eye, however, recognises, in the peculiarity, either a cunning imitation or a cold-blooded, intentional oddity, then one may confidently pronounce the death sentence, for it contains in itself no germs whatever of development. The only two eternal sources of art are, and will be, feeling for nature and personality. Fidelity to nature and honesty produce living creations. Unnaturalness and affectation are marks of decay. He who ever holds fast to these simple dicta will hardly ever run the risk of mistaking a Will-o'-the-Wisp for a lighthouse, or what is morally, if not practically, a more serious error, of treading under foot an insignificant chrysalis with the living and beautiful butterfly it enshrines.

Even of the manifestations of insanity of crack-brained painters, of the hoaxes of tricky strugglers for success, and the whims of childishly immature and childishly careless people living from hand to mouth, who have sprung up in the last two or three decades, the good man's insinuating word of the "sound kernel," of the "tendencies, capable of development, to a new blossoming of art," has been spoken by the opportunistic of critics. Well, time has now given the answer to these verdicts, at any rate in regard to some of the movements for which those prophets so benevolently predicted a glorious future. Fifteen or twenty years ago we saw in the Paris Salon, beside the expressionless fabrications of the usual daubing artisans—the "Mother's Joys," the "Young Lady at her Toilet," the "Oyster with Lemons," which constitute the stock in trade of all exhibitions of pictures—only two formulæ appear in hundreds of repetitions: the vulgarly realistic, after the style, let us say—to mention a particular name—of Bastien Lepage, that pupil of Cabanel who had degenerated into an apostle of Courbet; and the pseudo-idealistic, after the model of Puvis de Chavannes. Workmen with brutalised countenances and greasy blouses, and unearthly figures in antiquated landscapes of chalky

paleness, disputed the visitor's attention. A concreteness which did not spare us a single finger-nail in mourning, struggled for supremacy with a careless vagueness which styled itself "Abstraction" or "Synthesis" and produced only questionably schematic types. Whole walls exhibited unbroken rows of pictures which reminded us of the spectral ballet of the dead nuns in "Robert the Devil." Then we came to rooms where an unmixed company of rag-pickers, and night-men exercising their calling, of huzzies on the night-prowl, dung-carting stable-helps, and rapscallions at loggerheads, were quite at home. One of these movements, _i.e._, painting in faint colours, has hardly a representative left; the other—the art of vulgarity, meanness, and ugliness—only a dwindling few.

Here, then, we have two movements, to which "the intellectuals" have promised a future. One of them is as dead as a door-nail and buried, the other dying. He who did not let himself be cheated, or want to cheat others, could predict this outcome with certainty. Debased realism was a misunderstanding of the impulse towards truth displayed by the Manet School. This School held itself bound in conscience to record minutely even the unessential and the ugly accessories. Their limited imitators sought only that which was ugly and unessential in the world of phenomena. They thereby wandered far from the eternal aim of art—to excite an emotion by a work of art; for the mere imitation of a sight either actually indifferent or frankly repulsive can never excite an emotion. It was, therefore, easy to recognise that this tendency could not be lasting. The pseudo-idealism of Puvis de Chavannes showed the other infallible mark of morbidity, viz., impersonality and dishonesty. He tried, by an artificial bleaching of colours and a semi-transparent white-wash, to produce the effect of old and faded frescoes, in which their age of several hundred years is an element of æsthetic effect, by reason of the dim depictment of what is remote, dead and gone, and unknown; by reason of the longing they awake for what has for ever passed away and will never appear again. It was imitation; it was an attempt to deceive. It was not the honest revelation of personality, but its disguise in a strange, historical costume. That had no future, and it could not last.

What justified the primitive naturalism of the pioneers, the convinced fervent service of truth, this survives victoriously every change in fashion, and, in fact, is developing strongly further. True naturalism, which grows enthusiastic for the poetry of unpretentious sights, and was the logical development of Rousseau's return to nature, and of Greuze's village stories inspired by that return (the "Village Bride," the "Father's Curse," the "Son's Punishment," etc.), has held its ground. On the other hand, loathsome painting, which is naturalism run mad, has been finally conquered, and the spectral painting of Puvis is about to follow it into oblivion.

These much-extolled tendencies have, then, no future in them. They were not buds which were to develop into blossom and fruit. They were wild suckers in which a generation of artists fruitlessly squandered its best strength, and which are now withered and blown away by the wind.

And that, too, will be the lot of other aberrations which have not yet quite run their riotous course. That may be predicted with quiet confidence, without any being taught by the future of another.

A great philosophical doctrine is deducible from these facts. All development—including that of art, which is a part of nature and a part of human nature, and obeys the common laws of nature—all development is constant, and will be diverted from its logical course by no power. Its great procession always goes through a main street, and sudden turnings aside branch off only into blind alleys. Extreme forms have no stability; they remain individual monstrosities without issue. The strenuous life is always making efforts back towards the typical constitution of the species. In art this law may be found deplorable up to a certain point; for it is inimical to strong individualities, even to honest and justifiable ones, and favourable to the indifferent average, whilst in art the absolutely untypical individualities are full of charm. But, as things are, it is the iron law of development which no living thing can escape.

It is not easy to oppose successfully the opportunistic criticism which always professes to see, even in the maddest and silliest things, at any rate, "germs of artistic development"; but it is, nevertheless, a duty of subjective morality to do so. My verdict on many notabilities of fashion stands in sharp contrast to that which one generally hears and reads about them nowadays. He who does not suffer from the delusion of greatness, or a morbid distemper of contradiction, feels a position of this kind painfully. I have earnestly and conscientiously tried whether my adversaries were justified in demanding that I, as an individual, should submit to their huge majority. Well, I cannot concede this right to them. In dozens of instances, I have too closely observed how the unanimity of contemporary opinion about an artist arises. It is enough for an artist to invent a whim and obstinately cling to it, without letting himself be put out by indifference, vexation, or scorn. Very soon some ass of a critic will come and explain this whim as an inspiration of genius. This he will do out of vanity, affectation of originality, or an itch for sensation. He will do it to give the impression that he is of more brilliant intellect than the common herd, and that he alone can appreciate a beauty which the

Philistines stupidly pass by. If the humbug of a critic has some skill in coining phrases, a little perseverance, and a fairly sonorous pulpit, he will infallibly, in course of time, collect a congregation around him; for it is easy to gain adherents to a chapel which one designates as a place of worship for the intellectual _élite_, men of fine feelings, and those gifted with understanding. Provided that this sham lasts only a few years, it must needs triumph over all opposition. A young generation grows up which takes it for granted. No one puts to the test what has come into his possession, but takes it as a matter of course. It attains iron permanence. What was a paradox yesterday has attained the rights of dogma to-day by mere lapse of time. Busy pens now vie in outbidding each other in the elegance and wittiness of the phrases with which they express the prescribed admiration for the great man. If an independent person steps forward, and shows the worthlessness of the puffed up celebrity, the devotees of the little chapel, which has grown into a great church, feel an honest indignation against the heretic. "How does this man dare to doubt, when we, who are certainly better and cleverer than he, piously believe." That is the history of every religion: when it is organised it becomes intolerant and endeavours to assert itself by means of violence. But, to the honour of mankind, there are, nevertheless, always independent spirits who will not let themselves be intimidated, and on whom authority does not impose. They test the dogma, and kick it away if it is not firmly based. The stake has not protected religion from these independent critics; still less can the Corybants of art-reporting guard a fashionable idol from them.

The right of criticising the views even of the most overwhelming majority must be maintained. A final proof in disputed questions regarding æsthetics is, I admit, not to be supplied. All artistic influence rests on suggestion. The work of art, itself and, originally, exercises the suggestion on a minority endowed with delicate sensibilities. On the great majority an opinion of others, delivered with firmness does so. The great majority of people admire one who is praised because it is suggested to them by his trumpeters that it is their duty to admire him. As a matter of fact, they feel the admiration, without being conscious that not the work of art has inspired them with it, but the enthusiastic gossip which they have read and heard about it. These people refuse to believe me when I tell them that they are admiring something which is an aberration. The prior suggestion prevents them from tolerating a fresh suggestion from me. No one, however, can contest this so far as he is quite certain only of his own feelings. In art, effect is an infallible criterion, even if of only subjective value. If a man feels definitely as regards certain pictures that they are valueless and unmeaning, he has a right to express it as strongly and honestly as he feels it, even if millions declare that they discover all kinds of loveliness and depth of meaning in them. One will perhaps fail to convince a single creature, and will, as likely as not, long remain a preacher in the wilderness. But perhaps not for ever. The inventors of a fashionable _culte_, whom their selfishness obliges to stand up for their own work, will not remain in arms for ever and live. Those who worship after them have not the same strong, effective grounds, the originator's vanity, for defending that _culte_ desperately. The snobs who thronged to it because it was the singularity and they were the exceptions, necessarily abandon it as it becomes commonplace and they find themselves in a vulgar majority. Then the uninfluenced art-conscience again faces the work; it becomes susceptible to the warning of him who was, up to then, "the one voice crying in the wilderness," and in a short time all lips murmur: "That was indeed a swindle."

FOOTNOTES

[Footnote 1: In the department of Doubs.]

[Footnote 2: Ps. xc. 10 in Luther's version.]

[Footnote 3: _Tchin_ is Russian official _noblesse_.]

[Footnote 4: _I.e._, of joy or suffering.]

[Footnote 5: Faust: II. Theil; _sub fin._]

INDEX

Æsthetes, School of, 32

Alexander, John W., 217-8

Aman-Jean, 218-20

Angelo, Michael, 23

Art, emancipation of, 16-22

"—— for art's sake," criticism of, 1-5, 12-5

——, future of, 27-9

——, prettiness in, 227-9

——, religious, 296-7

——, utilitarianism in, 11-2

Artist, psychology of the, 5-9

Artists, influence of the Byzantine, 59

Balzac Memorial, 285-8

Barbizon, School of, 97-8

Bartholdi, 299

Bartholomé, 294-307

Baudelaire, 162

Besnard, Albert, 220-3

Böcklin, 326

Boilly, 81

Boldini, Jean, 154, 223-5

Bonheur, Rosa, 92-3

Botticelli, 220, 275

Bouchot, Henri, 57

Bouguereau, William, 225-30

Bourdichon, 58

Brangwyn, Frank, 230-6, 274

Bruniquel, 4

Caillebotte Room, 93

Carpeaux, 278

Carrière, Eugène, 166-84

Carriès, Jean, 308-19

Castiglione's "Cortegiano," 24

Catholics, New, 307

Cellini, Benvenuto, 23, 33

Century Exhibition, 70-81, 93-4

Cézanne, Paul, 236-9, 259

Charonton, Enguerrand, 67

Chassériau, 83-4

Chauchard, 91

Chauvinism, 11

Chavannes, Puvis de, 185-200, 343

Cimabue, 60, 121, 339

Clouet, 67-8

Cone, Jacques, 67

Conti, 145

Corneille of Lyons, 67

Corot, 100-3, 131

Cottet, Charles, 201-16

Courbet, 91-2

Couture, 122

Criticism, opportunism in, 336-9

Dante, 18

Daubigny, 104

Daumier, 88-9, 265

Degas, 119

Delacroix, 84-6, 104-5

Delisle, Leopold, 57

Della Robbia, 319

Donner, 299

Drolling, 79

Dupré, 340

Dürer, Albrecht, 188

Enamels, Carriès', 318

Exhibition, the Century, 70-95

Fountains, 298-9

Fouquet, Jehan, 67-8

Fragonard, 74-5

Frédéric, Léon, 239-244

Froment, Nicolas, 64

Genre painting, 16-7

Gérard, 79

Géricault, 98

Giotto, 60, 121, 339

Girard of Orleans, 60

Gleyre, 148

Gorki, Maxim, 261

Gretchen, 193

Greuze, 74-6

Gross, Baron, 98

Hals, Franz, 209

Hebbel, Friedrich, 144

Höllen-Breughel, 265-6

Huddleston, Judge, 150

Hundred Years' War, Effects of, 56

Icons, Russian, 59

Inferno, Dante's, 277

John of Orleans, 63-4

Kipling, Rudyard, 93

Lafenestre, George, 57

La Tours, 168

Landscape, literary, 136-7

——, lyrical, 137-9

——, optical, 139-40

Laurens, Jean Paul, 244-6

Leempoels, Jef, 246-50

Leonardo, 188

Lessing, a remark of, 145

Lieberman, Max, 120

Lorrain, Claude, 327

Maeterlinck, 109

Mallarmé, 275

Malouel, Jean, 67

Manet, Eduard, 105, 108, 112, 121, 123, 327-8

Mantegna, 15

Martin, Henri, 250-6

Meissonier, 105

Meunier, Constantin, 33, 34-40

Mignot, Jean, 67

Millet, 89-91, 103-4, 333

Monet, Claude, 105-8, 112, 115-9, 121, 123

Montenard, 256

Moreau, Gustave, 93-4, 155-65

Mouthe, caves of, 3

Museum, the Luxembourg, 110-1

Nietzsche, 275

"Open Air" movement, 93, 100, 102

Palissy, Bernard de, 319

Pavilion de Marsan, 56

Père Lachaise, "Resurrection" at, 300-7

Perréal, Jean, 66-7

Pissarro, Camille, 132-144

Plane, mediæval, 49-51

Poussin, 132

Præ-Raphaelites, 324

Prudhon, 77

Raffaelli, Jean, 114, 119, 256-8

Redon, Odilon, 258

Renaissance, 15, 23-4, 297-9

Renoir, Pierre Auguste, 120-1, 259

Renouard, 123

Reuter, Fritz, 290

Ribera, 209

Ribot, 209

Riesener, 79

Rodin, Auguste, 275-93

Roll, Alfred, 260-2

Rops, Félicien, 154, 266

Rubens, 268

Rude, 278

Ruskin, 149-50

Scheffer, Ary, 86

Sculpture in early Middle Ages, 65

"Secession," 334

Simon, Lucien, 262-4

Sisley, Alfred, 123-30

Sluter, 299

Solutré, 4

Stuck, Prof. Franz, 320-1

Sweden, rock pictures in, 4

Thiéry, 96-7

—— Salon, 101

Thoma, Hans, 326

Trutat, 81-3

Van Eyck, the brothers, 60-2

Veber, Jean, 264-8

Velasquez, 209

Vernet, Horace, 87

Vigée-Lebrun, 74, 76-7

Watteau, 74-5, 261

Wéry, Emil, 269

Whistler, James, 144-54

Wierz, 155

Wilczek, Count, 68

Worms, Jules, 272

Zorn, Anders, 120, 154, 270-1

Zuloaga, Ignacio, 270-4

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Arts and crafts of old Japan

Max Simon Nordau

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The World of Art Series

ARTS AND CRAFTS OF OLD JAPAN

BY

STEWART DICK

[Illustration]

T. N. FOULIS, 3 FREDERICK STREET, EDINBURGH; & 35 LEICESTER SQUARE, LONDON . . . . . MDCCCCVI.

[Illustration: A RAINY LANDSCAPE From a Kakemono by SANSETSU (_British Museum_)]

PREFACE

This little book is intended not for the collector or the connoisseur, but merely for those who require an introduction to a field of art hitherto little explored but which will well repay further study.

For fuller information on the subject many sources are available, but a word of caution is necessary. A bibliography of works on Japanese art would be misleading rather than useful, for much of what has been written regarding it is, as criticism, quite valueless.

On Japanese painting the most important, indeed the only sound work, is contained in a series of articles contributed by Mr Arthur Morrison to _The Monthly Review_, 1902-3. The writings of Mr E. F. Strange deal fully and adequately with Colour Printing; Captain Brinkley is a good authority on Keramics, and Mr Josiah Conder on Landscape Gardening and Flower Arrangement.

The Transactions of the Japan Society contain many interesting and well-illustrated articles on Japanese minor arts, and the charm of Japanese life is nowhere reflected more pleasantly than in the writings of Sir Edwin Arnold and Mr Lafcadio Hearn.

To the custodians of public and the owners of private collections I am indebted for many courtesies, and especially to Mr M. Tomkinson, Franche Hall, Kidderminster, for permission to reproduce several of the illustrations in the sumptuous catalogue of his collection.

S. D. _October 1904._

CONTENTS

CHAPTER PAGE

I. INTRODUCTORY 1

II. PAINTING 16

III. COLOUR PRINTING 46

IV. SCULPTURE AND CARVING 63

V. METAL WORK 77

VI. KERAMICS 96

VII. LACQUER 121

VIII. LANDSCAPE GARDENING AND THE ARRANGEMENT OF FLOWERS 138

[Illustration: Stylized Chrysanthemum]

LIST OF ILLUSTRATIONS

PAINTING --

A Rainy Landscape, by Sansetsu _Frontispiece_ Flying Ducks, by Korin _To face page_ 4 Fukurokujiu and Crane, by Korin 12 Arhat and Lion, by Cho Densu 18 An Impressionist Landscape, by Sesson 22 A Landscape in the Chinese Style, by Sesshiu 30 Shoriken crossing the Sea on his Sword, by Motonobu 34 Kwannon, the Goddess of Mercy, by Tanyu 36 Bird and Pine Branch, by Naonobu 38 Flower Panel, by Korin 40 Monkeys and Plum Blossom, by Sosen 42 A Peacock, by Ippo 44

COLOUR PRINTS --

A Figure Group, by Utamaro 52 A Figure Study, by Toyokuni 56 One of the Thirty-six Views of Fuji, by Hokusai 60 A Landscape, by Hiroshigé 62

SCULPTURE AND CARVING --

Colossal Bronze Image of a Bodhisatwa 66 Portrait of Senno Rikiu, carved in Wood and Lacquered 70 A Group of Netsukés 74

METAL WORK --

Two Bowls Cast in Bronze 78 Eagle in Cast and Hammered Iron 82 A Group of Tsubas 90

KERAMICS --

A Group of Porcelain 104 Vase, Satsuma Faience 108 A Group of Various Wares 114

LACQUER --

Lid of Suzuri-bako or Writing-case 124 A Group of Inro 130 A Group of Inro, by Korin 134

FLOWER ARRANGEMENT --

A Flower Composition 148

TAILPIECES --

Equestrian Figures from the Mangwa of Hokusai; Fans from Korin Hiakuzu; and Crests.

CHAPTER I

INTRODUCTORY

In coming to the study of Japanese art we must remember that we are entering a strange world, where life and language, and even modes of thought, run on other lines than ours.

When Japan, only fifty years ago, was thrown open to the Western nations, in our ignorance and folly we were at first inclined to treat the Japanese as a barbaric people. But never was there a greater mistake. For the truth is that their civilisation is not only older than ours but in some respects has advanced much further than we have ever attained. In an æsthetic sense the people of Japan are cultured to a degree far beyond our Western standards; their arts are full of beauties which are too subtle, too refined, for our comprehension.

Here, in the most civilised of all Western nations, one is dubbed a visionary and a dreamer if he hopes to see the day when the pleasures of art shall be the solace of the poor as well as the luxury of the rich. But this happy state has existed in Japan for ages. One of the chief characteristics of the people is their love for beauty both in nature and in art. On the public highways are notices indicating to the wayfarer the points from which the most beautiful prospects may be obtained. The artisan mother in the city carries

her babe out into the public parks at the festival of the cherry blossom, that its infant mind may be permeated by the beauty and fragrance of the flowers.

And, loving beauty, they can also express it, for to learn to write in Japan is in itself a course of training in drawing. In art the European requires that everything should be stated with the utmost fulness of a tedious realism before he can grasp its meaning, but to the more cultured Japanese a mere hint or slight suggestion is sufficient. The leading characteristic of Japanese art is, perhaps, that it leaves so much unsaid. For the Philistine, who bulks so largely in the West, and has to be considered and propitiated at every turn, seems to be quite unknown in Japan. What wonder, then, that, with such a public, their art should be somewhat above our heads.

Doubtless the canons of European art differ widely from those of the Far East, but these things are not essentials. All art is based on convention, in the terms of which its meaning is expressed. If we would understand Japanese art we must accept its conventions; we must learn the language of their art and see things with their eyes.

It is the fault of too many critics of Japanese art that they fail to approach it in this sympathetic attitude, and by such it is quite misunderstood. The mystic and beautiful Buddhist figures are tried by rules of anatomy, and the dreamlike Chinese landscapes by the laws of perspective. The materialist weighs the spiritual in the balance and finds it wanting.

But we seem to be improving in these matters; perhaps we are becoming more humble. Of late years some of our leading artists are beginning to acquire the qualities which Japanese art has shown so long. Who shall say that the work of such an one as Whistler, in its sensitive feeling for balance, in its grace of line, in the unerring instinct which marks its spacing, and in the delicate harmony of its colour, is not essentially Japanese in style? Whether these qualities were knowingly borrowed from the Japanese, or whether the artist evolved them from his own inner consciousness, matters little. The important fact is that the qualities which mark the work of one of the greatest of our modern painters, and distinguish it from that of the vast body of his contemporaries, are just the qualities which for centuries have marked the art of Japan. But we know that Whistler was an enthusiastic admirer of Japanese art, and, doubtless, he would have been the first to acknowledge his debt.

With the younger school Japanese influence has been all-powerful. One might safely say that, but for the Japanese colour print, there would have been no modern poster school, working so daringly in bold outline and broad, flat tints; and recent black and white work is equally indebted to the Japanese woodcuts, with their beautiful, flowing line and dexterous use of solid masses of black.

[Illustration: WILD DUCKS By KORIN (_From a Woodcut in the Korin Hiakuzu_)]

The difference of mental attitude is not the only reason for the wide divergence in methods and ideals of Japanese art from that to which we are accustomed. There are other physical and material causes of great importance which have helped to decide its course. The basis of all pictorial and applied art is architectural, and here we find one starting-point of difference between the styles of the East and the West. The frequency of earthquakes in Japan has rendered impossible the erection of buildings of the stately proportions and massive grandeur of other climes. The old Buddhist temples, which are the chief buildings, cannot vie in importance with those of India or China.

In the Japanese house the walls are but paper screens, the whole weight of the roof being supported by the four corner posts, which, in their turn, are not sunk in the ground but stand on four large stones. This lightness of construction has to a great extent dictated the course taken by the arts of Japan. The Japanese picture, instead of being enclosed in a massive frame, is placed on a light mount of silk brocade, and when not in use is rolled up as we roll a map. And the field of applied art is similarly restricted. The temples contain most of the larger and more important works; there is no place for such in the house. The household furniture is reduced to a minimum. A few mats to sit on, for the Japanese use no chairs; one or two paper screens dividing the house into separate chambers at will; a charcoal brazier; a few cooking utensils and articles of pottery; some lacquered vessels, fans, mirrors, and other ornaments; articles of dress, weapons, and a few personal belongings, form the whole field which is open to the craftsman.

So in Japan we have no rooms crowded with a profusion of heavy ornament. Reticence is the keynote; but what ornament there is must be of exquisite quality.

Before dealing in detail with the different branches of Japanese art it will be well to glance for a little at the history of the nation, in the light of which knowledge we shall better understand the social system under which these arts arose and the mental qualities

which they embody.

The civilisation of Japan was the slow growth of many centuries. For more than two thousand years, if we may believe the ancient records, the Mikado and his forefathers have been absolute rulers of Japan, the present dynasty stretching back in unbroken line to the Emperor Jimmu, who flourished about 600 B.C. But, as written history did not exist till some centuries after the beginning of the Christian era, the records of those early days are of a more or less legendary character, as one might surmise from the fact that the Emperor Jimmu was reported to be the grandson of the Sun Goddess herself.

The origin of the Japanese race is shrouded in mystery. Little is known of them except that, somewhere between two and three thousand years ago, they invaded Japan, and drove out the Ainos, who still survive in the island of Yezo. A Mongolian race, no one can say positively whether the invaders came from China or Korea, from the Malay peninsula or Siam, or whether, indeed, they were an offshoot from the wild Huns against whom China raised the Great Wall. One thing tending to show that they were not a branch of the Chinese race is that, even at that early date, China was the abode of an advanced civilisation; while the Japanese were certainly little removed from barbarism, and, indeed, hardly more civilised than the Ainos whom they displaced.

But the Japanese character has always been receptive, and just as their new civilisation is borrowed from Europe, so for the foundations of the old they are indebted to China. When they first came into contact with influences from the mainland it is hard to tell. It is said that the use of Chinese characters was introduced as early as 157 B.C., and the early records give a full account of an invasion of Korea by the Empress Jingo about 200 A.D. After this victorious expedition many captives are said to have been brought back, who laid the foundations of Chinese learning and culture.

The real civilising of Japan, however, began with the coming of the Buddhist priests from Korea in the middle of the sixth century. Buddhism became the chief religion of the country, largely absorbing, though it never quite superseded, the collection of myths and superstitions known as Shintoism. For Shintoism was hardly a religion in the usual sense of the term. As a Japanese writer admits, it had no moral code; but, he adds naively: “Morals were invented by the Chinese because they were immoral people; whereas in Japan there was no necessity for a system of morals, as everyone acted rightly if he only consulted his own heart.”

The chief centres of the new culture which spread over the land were the great Buddhist monasteries. Just as our own mediæval cathedrals and monasteries were the nurseries of the arts, so in Japan arose a race of artist priests. Their work at first applied solely to religious purposes, but afterwards widened out till, along with the sacred, there existed also a secular school. For three or four hundred years under these benign and mellowing influences the country grew and prospered. The quiet and peaceful times from the eighth to the tenth century especially marked a period of great literary activity, several of the most famous poets of Japan, whose writings still live in old tradition, flourishing during this period.

As time went on, however, the horizon became overcast, and from the twelfth to the end of the sixteenth centuries Japanese history is one long record of strife and civil war. The Mikado became more and more only the nominal ruler; the real power lay in the hands of the warrior nobles.

In the twelfth century arose the terrible struggle between the two rivals, the Taira and Minamoto families, each supporting its own candidate for the throne--a war which gave to legend and story one of its chief heroes--Yoshitsuné, the Bayard of Japan.

A hundred years later Japan, for the only time in her history, had to repel a foreign invader, a huge Tartar armada threatening her shores; but, as in the case of England, the elements fought for the islanders. A terrific storm played havoc with the Tartar fleet, and of all the invading forces it is said that only three men escaped alive, and were sent home to tell the tale.

Then in the fourteenth century the bitter wars of the Ashikaga period once more bathed the country in blood.

Those long years of war set their stamp on the nation, hardened its fibre, and brought out its sterner virtues. A military class--the Samurai--arose, and these trained warriors were maintained by the local Daimios, or princes, to whom they owed feudal obedience. Bushido, the way of the warrior, a stern but lofty creed of valour and devotion to duty, became the real moral code of the nation. For the annals of Japanese knighthood are full of tales of dauntless heroism--tales still told in every cottage in Japan, and retold a hundred times in Japanese art.

In those warlike days there was little place for the gentler arts of peace. But the Buddhist temples still stood--quiet sanctuaries where, undisturbed by the turmoil and strife around them, the gentle, priestly philosophers pursued the even tenor of their way, and kept the lamp of art burning bright and clear. In the outer world the military arts alone flourished, and the swordmaker was the king

of craftsmen.

In the fifteenth century, however, during a period of peace, a second wave of Chinese influence gave a new impetus to art. The Court of the retired Shogun Yoshimasa was a circle of artists and learned men, culture once more reached a high level, and one of the most brilliant periods of Japanese art began.

The sixteenth century saw a gradual consolidation of the empire. The Mikado for long had been little more than the nominal ruler, the chief power lying in the hands of the Shogun, who controlled the whole executive of the state; but the local Daimios gave little more than a mere formal submission to the central authority--each was practically absolute king in his own province. In 1603 Iyeyasu, the first of the Tokugawa Shoguns, for in his family the office became hereditary, came into power. A man of great ability, he set himself to complete the work of subjugation which his predecessors Nobunaga and Hideyoshi had begun, and finally reduced the turbulent nobles to the state of vassals, owing feudal obedience to the Mikado. Under his wise rule the country settled down to a prolonged period of peace, unbroken for two hundred and fifty years, in which art and industry developed greatly.

The Tokugawa period, 1603-1867, especially in its earlier stages, is pre-eminently the period of the minor arts, which then reached a perfection which has not been attained before or since. The force of the nation formerly expended on war was turned into these more peaceful channels. The Daimios of the various provinces carefully fostered the local arts, specimens of which were sent yearly to the Shogun and the Mikado, and a keen rivalry existed between the different districts.

[Illustration: FUKUROKUJIU AND CRANE By KORIN (_From a Woodcut in the Korin Hiakuzu_)]

Often the local lord would establish a kiln on his private estate, where articles of pottery and porcelain were manufactured solely for his own use. In the shelter of his castle, too, the artist in metal or in lacquer worked peacefully, freed from all sordid cares. Time was no object to him, the final result everything. He had to consult no demands of popular taste, his work was always the best he could produce, and often years of labour went to the making of one perfect piece.

As time went on, however, gradually the work lost its first freshness and originality. It became richer and more elaborate but tamer and less vigorous, and by the beginning of the nineteenth century only echoed faintly its former glories. For the burden of feudalism was pressing on the country with more and more weight. The military classes, their employment gone, gradually sank into luxury and indolence; the only sign of life was the gradual rise of a more democratic feeling among the people. The later schools of painting were more or less of the nature of a revolt from the traditions of the older styles, and the art of colour printing saw the rise of a school of democratic artists.

The soil was already prepared, some change was inevitable, and the change came when the country was thrown open to the nations of the West, feudalism finally abolished, and a democratic government established in its place.

But contact with Western ideas and Western methods seemed to give the deathblow to Japanese art. In painting, the European standards have played havoc with the charming and beautiful conventions of old Japan. Aniline dyes have spoilt the soft harmonies of the colour prints. In metal, in carving, and in lacquer the new work is vastly inferior to the old. What the European market clamoured for was not quality but cheapness, and so, adaptive as ever, the Japanese turn out by the hundred superficial and mechanical imitations of the beautiful old work. Modern commercial methods have little to do with art, and in this case seemed at once to turn the artist into a trader.

Japan is now a modern nation, Western in its civilisation, in its methods, and seemingly in its ideals--destined to become a great industrial state. Perhaps, as she has done so often before, she may absorb the new influences, and without loss of individuality follow out her own course. Perhaps, phœnix-like, from the ashes of the old, new arts as brilliant may arise. But, again, some say that art belongs only to the more youthful stages of the world, and that in these days of science never again can the artist be more than a mere survival of an earlier age--one who still keeps green within him the youth which in others has long since withered and died.

[Illustration: Rider on Horseback]

CHAPTER II

PAINTING

In a general survey of the arts of Japan it will be best to begin with the art of painting. In a land of paradoxes there is this paradox regarding Japanese art, that while their pictorial art is the most decorative of all pictorial arts, yet their decorative art is the most pictorial of all decorative arts. For the Japanese decorative artist rarely or never uses ornament merely as ornament; it almost invariably represents something more than mere beauty of line, mass, or colour; there is usually some pictorial motive attached. The lacquerer, for instance, rarely uses purely conventional forms, but flowers, birds, figures, even landscapes, make up his schemes of decoration. It follows, then, that the decorative arts of Japan are dominated by, and indeed are based upon, its pictorial art, and, therefore, the necessary preliminary to their consideration is a study of the art of painting.

The European's introduction to the study of Japanese art is apt to be rather misleading, for in all probability the first specimens which come under his notice are the colour prints and paintings of the naturalistic and decorative schools of the last century. His first shock of surprise overcome, for both the medium and the style of presentment are new and strange, he speedily discovers in them real beauties. Harmonies of line and colour, finer and more subtle than any we have to show, arouse his enthusiasm, and he thinks that he has penetrated the mysteries of Japanese art, and that all its treasures lie before him. Even were it so the boon would be no small one; but, as a matter of fact, he merely stands upon the threshold. The real glories of Japanese painting are the works of hundreds of years ago. As well could one judge of the glories of English literature from the ephemeral periodicals of the day as of the painting of old Japan from the products of the more materialistic schools of recent years. To know English literature one must read the classics; to realise its full glory we must go back to Spenser, Shakespeare, and Milton. And so with Japanese art, we must go back to the works of the old masters--to Cho Densu with his amazing power, to Sesshiu with his wonderful dream landscapes--ere we realise its grandeur. Then we feel that, beautiful pieces of decoration though the modern works are, here we breathe a purer and a finer air; we are in another world, a nobler and a greater one. The finest landscapes in the world are those painted by the old Chinese and Japanese artists; monochromes, slight and shadowy as morning mist, but breathing the very poetry of nature.

[Illustration: ARHAT AND LION From a Kakemono by CHO DENSU (_British Museum_)]

The art of painting was borrowed by Japan from China, the first teachers being the Buddhist priests who crossed over from Korea in the sixth century. This origin, and also the nature of the materials used in the art, stamped it at the outset with qualities which have ever since distinguished it. The ordinary instrument for writing in China and Japan was the brush, dipped in Indian ink, and to form the native characters was in itself an exercise in drawing. Caligraphy, indeed, as penmanship in the old days of mediæval Europe, was reckoned as one of the fine arts; or rather, from the Chinese point of view, painting was reckoned one of the branches of caligraphy. This caligraphic basis is the root of most of the conventions of Chinese and Japanese painting, and in the quality of the brush work are to be discovered many of its beauties. For by means of line alone, not a pen line, thin and hard, but the supple, swelling line of the brush, the artist not only renders the outlines and shapes of things but suggests modelling, chiaroscuro, even the different planes of distance, in a manner indefinable in its subtlety. Colour, except in the later and more naturalistic schools, is used in flat tints only. This absence of chiaroscuro is often quoted as a defect of Japanese art; but if all that can be said has been expressed by line why add light and shade? One has only to study the work of one of their masters in the use of the brush, such an one as Motonobu, of the Kano school, to understand not only how unnecessary it would be but how impossible. We would as soon wish to see filled in one of the exquisite outlines of Flaxman. It is like setting a beautiful poem to music: you may exchange one melody for another, but both cannot exist together. And we must remember that all use of line is a convention, for line does not exist in nature, and Japanese art, after all, only differs in this respect from European art in having used this convention with greater freedom and more consummate mastery.

The simplicity of the means at the artist's disposal--a brush or two, Indian ink, a few liquid colours, and a sheet of paper or silk--tended to produce directness and simplicity of effect, and this tendency was increased by another influence. The Buddhist priests, then as now, were of a type of mind essentially idealistic. Their religion taught them to regard the spiritual essence of things as the great fact and the outward and visible world as merely a temporary and changing phase, and so in their art, for they were the first painters, they aimed not at a literal transcription of nature but at an expression of its inner significance. And this training has always affected the attitude of Japanese art. Directness, reticence, and restraint are its main characteristics. To present the essential quality of a scene, not its mere outward appearance, and that with the least possible obtrusion of the material, was its object.

Even in later days, in their more naturalistic studies, the Japanese artist never dreamt of drawing direct from nature as we do. His system, the system by which children still learn to draw in Japan, was to look steadily at the object to be depicted until it was learned by heart and could be reproduced at will.

In painting the artist seats himself on the floor, the sheet of silk or paper before him. For a while he gazes abstractedly, till the whole picture is clear to his mental vision. Then with the first touch the central point of interest--the eye of a bird, say--is indicated. Swiftly and surely, with a full brush, the rest of the subject is filled in. There is no niggling, no retouching, for the delicate, absorbent surface of the silk will not stand repeated workings. Each stroke is placed on the picture direct as it is to remain, and, though the result may be a masterpiece, the work, in many cases, is that of a few minutes. The technique of the brush has, indeed, been carried to a degree of perfection by the Japanese artist otherwise unheard of. He fills it, or it may be in the case of a large brush each part of it, with just as little or as much ink or colour as he desires, carefully arranges the hairs in a certain way, for the preparation and loading of the brush is often as important as the actual brush stroke, and then with one single sweep obtains the whole effect he requires. Many are the wonderful tales of the feats which the old masters could perform with one stroke of the brush.

A word may here be said as to the forms which pictorial art assumes in Japan.

The first and most common form is the kakemono, or hanging picture, formed of a sheet of silk or paper, richly mounted on brocade of various colours. It is furnished with rollers like a map, and is rolled up tightly when not in use. This is bad for the surface of the painting, cracks being inevitable if much body colour has been used, but it is a great protection against the fires which are so frequent in the light wooden houses of Japan; for, as there is a considerable space between the picture and the top of the mount, several layers of brocade and tough mounting paper are thus tightly wound round the painting.

[Illustration: AN IMPRESSIONIST LANDSCAPE From a Makimono by SESSON (_British Museum_)]

The two ribbons, which so pleasantly break the monotony of the upper part of the mount, are not merely ornamental. When the moving screens forming the side of the house have been moved back for coolness, and the kakemono hangs in the open air, the _futai_, as these ribbons are called, flap in the breeze, and prevent birds from alighting on the upper roller.

The makimono, or horizontal roll, is largely used for historical scenes or for landscape sketches, the series, many feet long, often forming one continuous composition. It is not hung up but laid on the floor, and unrolled and examined bit by bit, as we would look at the pictures in a book. Originally the kakemono was exclusively used for sacred, and the makimono for secular, subjects, but this distinction has long since ceased to exist.

A third form, gaku, is stretched on a frame, after the manner of our pictures, but is little used.

Screens, both folding and sliding, were greatly used for the longer and more important pictures. Sometimes a screen of five or six panels will be so treated that while the whole forms one composition yet each panel taken separately also forms a complete picture. Books, each page stiff and opening on a hinge like a miniature screen, are also used. Lastly, mural decorations on wood or plaster, and the dainty little paintings on fans, complete the forms of pictorial art most in vogue in Japan.

Some time about the end of the fifth or the beginning of the sixth century the Buddhist priests crossed over from Korea, and formed the first Japanese school of painting, devoted almost entirely to the sacred subjects which were used to decorate the Buddhist shrines. Very beautiful and dignified are many of these old Butsugwa paintings, recalling in their rich, full colour and their lavish use of gold the illuminations and early paintings of our European monasteries. In most cases they are unsigned, the holy man deeming it unfitting that objects intended for such sacred uses should be contaminated by earthly associations. The British Museum collection contains several fine specimens, which, though faded and sadly blackened with incense fumes, show these early works worthy to compare, for elevation of tone and religious fervour, with the finest works of Christian art.

For many years this Buddhist school of painting continued, its traditions lasting without a break until the fifteenth century. And here at the outset it will be well to call attention to a difficulty which arises in any attempt to give a brief and clear account of the history of painting in Japan. The matter is complicated by the fact that, though the different schools of painting are evolved one from the other, the later did not supersede the earlier form, but usually both continued to exist contemporaneously. Many artists painted in the styles of more than one school, the manner often being decided by the choice of subject, and latterly it was part of the training of Japanese artists to go through all the schools.

Then, again, some of the greatest masters, especially those of the last two centuries, formed their styles by adopting and combining what appeared to them best in each school. To follow out logically the growth of the various schools, and at the same time to treat of the different artists in a chronological order, is, therefore, a matter of some difficulty.

The oldest picture in Japan of which there is any authentic record was painted, probably by a Korean priest in the beginning of the seventh century, on the plaster wall of the Buddhist temple Horiuji at Nara, a storehouse filled with treasures of ancient art. For three hundred years little more is known--the names of a few priests and one or two priceless paintings are all that remain; but by the ninth century civilisation had reached an advanced stage, the country was rich and prosperous, and entered into a great literary and artistic epoch. The poets Narihira and Komachi, still ranked among the immortals, were contemporaries of Kosé no Kanaoka, the first great secular painter of Japan, and, if the double evidence of popular legend and the verdict of critics and artists of his own and later days is to be believed, the greatest of all Japanese artists. About a dozen examples, said to be by Kanaoka, exist, but, one by one, the genuineness of each has been questioned by experts. Perhaps the most authentic is the portrait of Shotoku Daishi at the Ninnaji temple in Kioto, which has been reproduced in colours in the _Kokkwa_, the Japanese Government publication. Although nearly all the existing pictures attributed to him are Buddhistic figure pieces, Kanaoka's popular reputation was based on his paintings of secular subjects, portraits, landscapes, and animals. He was especially famous as a painter of horses.

The story goes that in a certain temple hung a painting by Kanaoka of a magnificent black steed. The peasants in the neighbourhood were much annoyed by the ravages of some wild animal, which nightly raided their gardens, eating the herbs and trampling the flowers. At last they lay in wait, and found to their surprise that the intruder was a huge black horse. On their pursuing it disappeared into the temple, but when they followed the building was empty. As they stood below the picture great drops of sweat fell down, and there was Kanaoka's horse all hot and steaming. Then one of them had a happy idea. Seizing a brush he rapidly painted in a rope tethering it to a post, and the gardens were no more invaded by the nocturnal visitor.

The work of the immediate followers of Kanaoka seemed to be chiefly Buddhistic in style, but this may only mean that the only specimens which have survived the ravages of time are those sacred pieces which were safely stored in the temples, and that, like Kanaoka, they were equally at home in secular subjects.

In the tenth century Kasuga no Motomitsu founded the first purely native school, called the Yamato school, which afterwards, under the name of the Tosa school, became the recognised style for the treating of historical subjects.

The eleventh, twelfth, and thirteenth centuries formed a period of great literary and artistic activity. Buddhism was then in the height of its power, and there is no greater period than this in the history of Japanese art, but of these old masters we know little more than the names. In the twelfth century we have Takuma Shoga, Sumiyoshi Keion, and Toba Sojo, the last a marvellous animal painter, but examples of their work are practically unknown out of Japan. In the thirteenth century we have Fujiwara no Nobuzané, of whose Buddhistic work the British Museum has a fine specimen; and a hundred years later Kosé no Korehisa, renowned as the greatest military painter of Japan.

In 1351 was born a truly great artist, Meicho, or Cho Densu, whom some rank as the equal of Kanaoka himself. A Buddhist priest, he was famed for his sanctity, and the bulk of his works are of a religious nature, to which field he did much to bring new life and vigour, for the school had relapsed into the dull repetition of cut-and-dry formulas. But in secular subjects he was equally great. The British Museum is fortunate enough to possess a masterpiece by Cho Densu--a figure of an Arhat seated with a lion at his feet. The whole picture is presented with extraordinary force. The attention is seized and held by the eyes of the figure as they stare fixedly at the lion, which, with head thrown back and gums bared, glares savagely in return. The drawing is superb in its easy power, the colour rich and sombre, its highest note in the bright red of the lion's jaws.

A new influence arose with the Chinese renaissance of the fifteenth century, and we come to the times of the great landscape painters. Nothing could be further removed from the attitude of the modern European landscapist than that of these old Chinese and Japanese masters. Their object was not to depict a scene in a naturalistic manner but to convey its inmost spirit. In speaking of a painter of a later day a Japanese critic writes: "But in his landscape there is less success, as he was so particular about ensuring correctness of forms that they were lacking in high ideas and deep spirit. For a landscape painting is not loved because it is a facsimile of the natural scene but because there is something in it greater than mere accurate representation of natural forms, which appeals to our feelings, but which we cannot express in words." It is this deeper and inner art which the old landscapists give us. In monochrome, or with a few sombre tints added, they suggest the beauty, the repose, and the dignity of nature in a way that, to my mind, no landscape painters have done before or since. One little Chinese landscape especially lingers in my memory, though it was not the original I saw, only one of the delicate collotypes which can only be produced in Japan. It was called "The Evening Bell." On the strip of soft, brown-tinted silk is faintly touched a range of peaks against the sky; nearer is a grove of trees. Mist lies in the hollows and softens the forms, and in the distance, amid the tree-tops, peeps out a temple roof. Nothing could be slighter or yet more complete.

The old Chinese style, so strongly marked in the work of the old painter priests, had gradually fallen into disuse before the more popular Tosa style, when Josetsu, a Chinese painter, settled in Japan early in the fifteenth century. Little is known of Josetsu's own work; but his influence soon began to make itself felt, and he gathered round him a band of pupils. Of these the most famous is Shiubun, a Buddhist priest, still regarded as one of the greatest of Japanese landscape painters. The British Museum contains a very fine painting attributed to him, though expert criticism rather inclines to assign it to a somewhat later period.

[Illustration: A LANDSCAPE IN THE CHINESE STYLE By SESSHIU (_British Museum_)]

Shiubun had two brilliant pupils, Oguri Sotan and No-ami, the first a priest, a fine landscapist, and a wonderful painter of birds and flowers; the second a brilliant and versatile man of the world, courtier, poet, caligraphist, critic, and painter. In the last capacity he was especially renowned for his paintings of tigers. No-ami had a son Gei-ami and a grandson So-ami, both of whom, especially the latter, became famous landscapists of the Chinese school.

But the most famous of all the masters of the Chinese renaissance is Sesshiu, born 1420, died 1506, one of the greatest of all Japanese painters. As a youth he entered a Buddhist temple, but his thoughts were often far away from his religious duties. The story goes that once, as a punishment for some fault, he was tied to a pillar of the temple. With tears for ink, and using his toe as a brush, he sketched some rats on the floor, and as each was completed it sprang up, and began to gnaw through the rope that bound him. On the approach of the chief priest they scampered away; but the good monk was so impressed by the miracle that the youthful artist was henceforth allowed to follow his own bent.

At the age of forty Sesshiu, satisfied that he had learned all he could from the artists of his native country, went to China to study under the masters there, but to his surprise and discouragement he found none there who could teach him more than he already knew. Then said he: "Nature shall be my teacher; I shall go to the woods, the mountains, and the streams and learn from them." So for some time he travelled in China painting and studying nature. His fame soon spread through the land, and the Chinese artists, frankly acknowledging him as their master, came to him for instruction. By the Emperor himself he was commissioned to paint a series of panels on the walls of the palace at Pekin, and on one of these, to mark his Japanese origin, the artist has placed a view of Fujisan.

It is by his landscapes that Sesshiu is best known, and never was the grandeur and the dignity of nature more fully expressed; but his figure subjects, notably the magnificent painting of Jurojin, the god of longevity, reproduced in the _Kokkwa_, and, in the British Museum collection, a wonderful study of Hotei, the god of contentment, frolicking with some children, must be seen before his full scope and great power can be realised. For he was in every sense a great painter; in each department his work is marked by lofty conception, great breadth of treatment, and an absolute certainty and ease of execution. His brushwork is very distinctive, and even by the novice may be recognised at a glance. Strong and vigorous, but angular and jagged like forked lightning, it often seems rude and clumsy when examined closely, but it never so asserts itself when we step back and look at the _picture_, but expresses exactly the effect intended. The British Museum possesses several very fine specimens of Sesshiu's work. Even of the most famous of his pupils--Shiugetsu, Sesson, and Keishoki--space will not permit us to deal. Mention must be made, however, of a makimono by Sesson. It consists of eight views in monochrome roughly dashed off. Nothing could be more sketchy than the treatment or yet more vigorous. It is a veritable _tour de force_ of caligraphic impressionism.

A secondary result of the Chinese renaissance was the foundation of the Kano school, which, based on the broad, caligraphic methods of the Chinese masters, gradually adapted them to their own use, evolving a freer and looser style of handling distinctly Japanese. The founder of the school was Kano Masanobu. When the artist Oguri Sotan died, in 1469, he was engaged in the decoration of the walls of the temple of Kinkakuji at Kioto, and, on Sesshiu's recommendation, Masanobu, then only known as an amateur, was engaged to finish the work.

[Illustration: SHORIKEN CROSSING THE SEA ON HIS SWORD From a Kakemono by MOTONOBU (_British Museum_)]

Masanobu's son Motonobu was even more famous, and to him is due the credit of forcing the new school into public favour. Born in 1477, in his youth he wandered over the country, carrying little but his brushes, painting everything he saw, and paying his way with the results. But those lean years of poverty and study stood him in good stead. Fortune smiled at last, and he became the most popular painter of his day. Goto Yujo, the famous metal worker, adopted his designs for sword ornaments, his painted fans were chosen as ceremonial gifts to the Mikado and Shogun, and, to crown all, Mitsushigé, the head of the exclusive and aristocratic Tosa school, gave him the hand of his daughter in marriage. He died, full of years and honours, in 1559. For landscape, birds, and figure subjects he is equally famous, and as a master of the brush he is unsurpassed. In the work of the Chinese schools the quality of

line, though often striking, is used in a more reticent way, entirely as a means to an end; but in the Kano school the line becomes a thing of beauty and life, almost an end in itself. The astonishing power and sweep of Motonobu's line may be seen to perfection in the Shoriken in the British Museum.

During the sixteenth century the Kano school numbered many famous names. Yeitoku, a grandson of Motonobu, became the favourite painter of the Shogun Hideyoshi. Kaihoku Yusho was noted for his beautiful misty effects; and more famous, perhaps, than either is Kimura Sanraku. Sanraku was at first a page in the service of Hideyoshi, who, discovering his talent, sent him to study under Yeitoku. His work has all the dash and swing of the Kano style, and his colouring is rich and harmonious, while his line is almost worthy to rank with that of Motonobu. Sanraku's adopted son Sansetsu carried on the tradition of the family, though his work has more of the restrained quality of Sesshiu and his followers than the dash of his more immediate predecessors. The British Museum has a beautiful rainy landscape by Sansetsu, slight in treatment--only some dim hills drenched in misty rain, with the suggestion of a bridge and a stream and a fisherman's cottage--but everything, even the cottage roof, looks wet. (See frontispiece.)

In the beginning of the seventeenth century the Kano school took a new lease of life with the advent of the three brothers, grandsons of Yeitoku, Tanyu, Naonobu, and Yasunobu.

Of the three, Tanyu is the most famous, and is recognised as one of the greatest masters of the Kano school. He is distinctly a painter's painter, and delights in what we should call fireworks. Handling his brush with careless ease he makes a smudge, a few blots, and a swirl, and behold a landscape! A very Japanese Whistler; but it marks the difference between the two publics that, while Whistler is with us still "caviare to the general," the Japanese substitute is one of the most popular of all their painters. His two large pictures of Kwannon, however, in the British Museum, stamp him as no mere swaggerer but a great and serious artist. In the private collection of Mr Arthur Morrison are two magnificent sixfold landscape screens, which show him to rank with the first of Japanese landscape painters, and, among other unique examples of his work, a dainty little study of birds and convolvulus, touched with the utmost lightness and delicacy.

[Illustration: KWANNON, THE GODDESS OF MERCY From a Kakemono by TANYU (_British Museum_)]

Naonobu, the second brother, died at an early age, and from this cause, and from the fact that he seemed to spend much of his time in hunting out and destroying his earlier work, his paintings are rarer than Tanyu's. There could hardly be a greater contrast than the work of the two brothers--the first exulting in its strength, and full of a superb recklessness and dash; the second restrained and quiet, though not lacking in force, and full of a soft, liquid quality. Some charming examples of his work are in the British Museum.

The third brother, Yasunobu, was known chiefly for his landscapes, full of delicacy and feeling, and recalling the work of Sesshiu and Sansetsu.

Naonobu's son Tsunenobu, born in 1636, was a worthy successor, and, in the opinion of many, is worthy to be ranked with Tanyu and the other great men of the Kano school.

Then we have one of the most striking personalities among Japanese painters--Hanabusa Itcho, the last of the great Kano painters. A born humorist, his faculty for practical joking was always getting him into trouble. Indeed, on more than one occasion he found himself in prison owing to liberties he had taken in the pictorial representation of those in high authority. But he is no mere caricaturist. His drawings are pictures first and humorous afterwards, and as a colourist he ranks high even in Japan.

Another pupil of Yasunobu was Sotatsu, one of the greatest flower painters of Japan. He also studied under Sumiyoshi Jokei, a Tosa painter, but can hardly be classed with either of these schools.

It must not be supposed, however, that with the coming of the Sesshiu and Kano schools the old Tosa style had been driven out. It continued to exist alongside the newer schools, and many artists changed from one style to the other according to subject. The Tosa school at this time was distinguished by a minuteness of detail, and also by a richness of colour which gradually came to affect the Kano artists, whose work became much brighter in colour as time went on. Sesshiu, Masanobu, and Motonobu worked chiefly in monochrome, using colour sparingly; but Sanraku's work, a hundred years later, is full of fresh, bright tints. A curious convention of the Tosa painters in their historical subjects was to leave out the roof of a house in order to expose the interior to view.

[Illustration: BIRD AND PINE BRANCH From a Kakemono by NAONOBU (_British Museum_)]

We now come to Ogata Korin, one of the most individual of all Japanese artists. Born in 1661, he is said to have studied under Yasunobu, and the influence of Sotatsu seems to appear in his work; but he can be classed with no existing school, striking out an entirely new line for himself. A wonderful draughtsman, Korin possessed in the highest degree the Japanese faculty for spacing and balance. Slight, and often almost bizarre, as his compositions are, one feels that it would be impossible to alter a line. He is more frankly decorative than any of his predecessors, and is even more famous as a lacquerer than a painter. Indeed, often in his painting, especially in the enamel-like quality of his colour effects, one sees the hand of the lacquerer rather than the painter. Japan, perhaps, possesses one or two greater artists, but none more original, or whose work exercises a more subtle fascination. To commemorate the centenary of his death his follower Hoitsu issued several volumes of woodcuts from the master's designs. Slight as these are they are never trivial, nothing is expressed but what is necessary, the non-essentials are absolutely ignored, and the results are masterly in their telling arrangements of black and white.

We must now retrace our steps a little and return to the beginning of the seventeenth century, when Iwasa Matabei founded the style which was known as the Ukioyé, or "pictures of the passing world" school, and which soon became the great popular school of painting. The distinction between the Ukioyé and the older classical schools, however, was not one merely of subject. Many of the earlier men had turned to the scenes of everyday life for their subjects. Toba Sojo, Sanraku, and Itcho, to name but a few, and, on the other hand, the Ukioyé painters, frequently treated of classical subjects. The real difference is one of treatment, not of subject, and the starting-point of variance was the mental attitude of the painter. It was a departure from the subjective attitude of the older men. The Ukioyé and later schools took the standpoint of the poet: "The earth--that is sufficient; I do not want the constellations any nearer"--and their works are frankly decorative or frankly naturalistic. Materialists, in a sense, they turn from the beauties of the ideal world to show us the beauties of the natural world around us. This does not necessarily mean that their treatment was what we term realistic; but, while with the classical schools one looked through the picture, as it were, to the thought beyond, in this case one looks at the picture for the beauty which it presents, and which is inherent in the subject itself. The fact that the rise of the Ukioyé school was more or less a popular revolt against the old classical traditions which had governed the art for a thousand years will help to explain to us why its masters were hardly esteemed as highly by the cultured classes in Japan as, by their undoubtedly fine qualities, they deserved to be. On the other hand, we must admit that they never attain to the power and dignity of the older schools.

[Illustration: FLOWER PANEL By KORIN (_From a Woodcut in the Korin Hiakuzu_)]

The works of Matabei are excessively rare. He was a fine draughtsman, his figures of dancing girls being particularly graceful in line and of quiet, harmonious colouring.

The next great artist of the school was Hishigawa Moronobu, who flourished during the latter part of the seventeenth century. Formerly a designer of embroideries, the inexhaustible fancy with which he adorns the costumes of his figures adds a special charm to his work, and his drawing of the figure is marked by a wonderful lightness and grace. He was the first artist of importance to devote himself to the production of the woodcut prints which afterwards attained such popularity, and during the next two hundred years became a separate branch of art industry.

During the eighteenth century the school obtained many adherents, whom, for lack of space, we can do no more than name. Torii Kiyonobu, the first of the Torii artists, noted for their treatment of theatrical subjects; Miyagawa Choshun, Nishikawa Sukenobu, Okumura Masanobu, Nishimura Shigenaga, and Suzuki Harunobu are but a few. But as most of these painters of the Ukioyé school were more famous as producers of colour prints we shall leave their further consideration to the next chapter.

[Illustration: MONKEYS AND PLUM BLOSSOM From a Kakemono by SOSEN (_British Museum_)]

A great painter of the eighteenth century who did not follow the Ukioyé or older schools, but, like Korin, struck out a line of his own, was Tani Buncho, who was born in 1763 and died in 1841. As a painter of landscapes, figures, birds, and flowers he was equally a master.

Another artist who struck out for himself is Maruyama Okio, 1733-1795, sometimes regarded as the founder of the Shijo or naturalistic school. According to the old critics, "the art of painting may be pursued according to either of two systems: the one in which the spirit of nature is expressed; the other in which its outward forms are copied." Okio broke away from the old traditional method, and instead of endeavouring to interpret Nature endeavoured to so present Nature that she should deliver her own message. His favourite subjects were birds, fish, and flowers, and in their naturalistic treatment are more akin to European work than that of his predecessors, though in grace and elegance they are still essentially Japanese.

In the hands of his followers the Shijo or naturalistic school soon became popular. Even more famous than Okio was Mori Sosen, 1747-1821, now recognised as one of the world's greatest animal painters. He is especially noted for his paintings of monkeys, whose habits he studied for years, often living in the woods for months at a time. He has two styles: one rough and bold, generally on paper; the other on silk, and often of extraordinary delicacy and fineness. That his abilities were not by any means confined to the depicting of monkeys may be seen from his exquisite studies of deer and other animals.

To landscape Mori Ippo applied the principles of the Shijo school, employing a much more naturalistic colouring than had hitherto been the custom, and Hoyen depicted birds, flowers, and insects with charming delicacy and refinement.

In 1749 was born another great independent artist--Ganku, who founded a school of his own, combining with the naturalism of the new something of the suavity and dignity of the older styles.

Though treating of him more fully in the next chapter mention must be made here of the great Hokusai--in Whistler's words, "the greatest pictorial artist since Vandyke." To European ears his name is more familiar than that of any other Japanese artist. As a draughtsman he ranks with the very first, and as a painter his brushwork was bold and free and often masterly, though lacking just the grace and finish of the old Kano masters, and, at its best, his colour is superb. Some of his figure subjects have the grandiose quality of a Velasquez. His versatility was extraordinary, every style of subject coming within the range of his brush.

[Illustration: A PEACOCK From a Kakemono by IPPO (_British Museum_)]

Of nineteenth century painters the greatest is Kikuchi Yosai, the last of the great painters of Japan. In his youth he studied in all the schools, and afterwards made a tour through the country studying the great pictures stored in the various temples. His own style is strongly individual, combining the dignity of the older schools with the realism and rich colouring of the modern. A fine example in the British Museum is his painting of Fukurokujiu, the god of longevity--an old, old man with worn, wrinkled features. It is said to be a portrait of the artist, and was painted in his eighty-fifth year. He had many pupils but no successors; and on his death, in 1878, the only painters worthy of mention are Zeshin, better known as a lacquerer, who died in 1891; and Kawanabé Kiosai, a humorous draughtsman of remarkable dexterity, who died in 1889.

CHAPTER III

COLOUR PRINTING

The art of colour printing, which, as pointed out in the previous chapter, was an offshoot of the Ukioyé school of painting, is one of the most interesting of the minor arts of Japan. It was the colour prints that first aroused the interest of the European in Japanese art, and it is from them that in most cases he still receives his first impressions. And though, indeed, these impressions require largely to be corrected in the light of further knowledge, yet on the whole this is the most natural introduction; for, fantastic though these prints may at first appear to the unaccustomed eye, yet in their frankly decorative feeling they approach more nearly the Western standpoint than the earlier and more ideal schools of Japanese art. In the colour prints, which we may buy for a few shillings, there are obvious beauties of line, of composition, and of colour which cannot fail to appeal to us; however strange or bizarre they may otherwise appear we at once recognise them as charming pieces of decoration.

And though on further acquaintance with the subject of Japanese art we find that those who produced this beautiful work were but the journalists of art, and that the real classics stand on another and higher plane, yet on their own merits we cannot grudge them unstinted praise. They have not the noble elevation of the old schools, they do not climb the misty heights of the ideal, but they realise with exquisite feeling and refinement the beauty of the passing world that lies around them.

And while Japanese paintings, especially of the older schools, are almost unknown except to the connoisseur, and are only to be seen in a few isolated collections, the colour print is more or less familiar to all who take an interest in matters artistic. Hardly a studio but possesses a print or two, and it would be difficult to over-estimate their influence on the work which goes on around them.

But the art of the colour printer has this additional interest for us: it was a truly democratic art, its followers men of the artisan class, its customers the common people. And at a time when the upper classes of society were suffering from a gradual degeneration, when the arts became less and less alive and more and more a repetition of outworn conventions, this growth from below of a school of living art shows that the popular masses were beginning to stir, and that even two hundred years ago the bonds of

feudalism were getting weaker, and the growth of a popular art was only one manifestation of the tendencies which finally overthrew the old system and substituted for it a democratic government.

The colour print artists were, for the most part, ignored by the cultured upper classes. They were men of little or no education. Toyokuni I. was the son of a maker of puppets; Kunisada was at one time the keeper of a ferry-boat; and Hokkei was a fish-hawker before he found his vocation. Then there was another reason for this social boycotting--the subjects of which they treated in their pictures. A large proportion of these were representations of actors in character. Now, in Japan the fondness for the theatre was an overwhelming passion with the common people, but by the nobility and aristocracy the stage was utterly tabooed. No person of good family dared openly to attend a theatrical performance. Actors, therefore, were ranked in the social scale as the lowest of the low--beneath even the humblest artisans. Even the colour print artists, who earned their living by depicting them, would never dream of associating with them on terms of equality.

Then another favourite subject was the delineation of the famous beauties of the Yoshiwara and the tea-houses. It is evident that the nature of the subject in this case also would be sufficient to damn the prints in the eyes of the better classes.

But, with the alien, "where ignorance is bliss, 'tis folly to be wise"; and where the educated Japanese would see vulgarity and coarseness--where, perhaps, such was even intended--we, happily, see only a beautiful decorative effect.

So in Japan the colour print was the picture of the poorer classes. Costing a mere trifle, it occupied in their humble homes the place of the more expensive kakemono.

It is a matter of surprise to the cultured Japanese to find how these despised objects are prized by European collectors; and, valuing them little themselves, they have exported them wholesale, till comparatively few remain in Japan, the bulk of fine prints being now in Europe or America.

Though far surpassing in delicacy and beauty the colour prints of Europe and elsewhere, the Japanese prints are produced by means wonderfully simple, and depend for their fine qualities entirely on the wonderful skill of the craftsman.

The process is as follows:--The drawing is first made by the artist, with brush and Indian ink, on a sheet of thin paper. After being oiled to make it transparent this paper is pasted, face downwards to ensure the necessary reversal, on a block of soft cherry-wood. The engraver now proceeds to outline the picture with a knife. Then with gauge and chisel the superfluous wood is boldly cut away, and the result is a key block in line. From proofs coloured by the artist a further series of blocks are cut, one for each colour used. It may be mentioned here that the cherry-wood blocks are not cut across the grain, as in the case of the boxwood blocks we use for wood engraving, but in a line with the grain.

Then comes the work of a third craftsman, the printer. He mixes his colours for each printing, and applies them carefully to the block with a brush. Then the paper is damped and laid on the block. No press is used, but with a rubber or baren, made of a bunch of twisted fibre in a sheaf of bamboo leaf, the impression is carefully rubbed off. And so each block is used in succession until the picture is complete, accuracy of register being obtained in the most wonderful manner by rough guiding marks cut on the blocks. Sometimes metallic dusts are used in printing, and again a kind of embossing or high relief is obtained by pressure on an uninked block. It is said that this pressure is often applied by using the point of the elbow as a rubber.

The prints were issued by publishers chiefly in Yedo, the engraver and printer being simply workmen in the publisher's employment. Sometimes the artist, too, was employed entirely by him, living in his house, and occupying a position somewhat equivalent to that of a designer for a commercial firm.

The first Japanese artist to make drawings for the wood engraver was Hishigawa Moronobu (1637-1714). These, however, were not colour prints but merely woodcuts in black and white. He illustrated quite a number of books during the latter half of the seventeenth century.

A further development was the colouring of the prints by hand, which was introduced largely by Torii Kiyonobu (1664-1729), the founder of the long line of Torii artists who devoted themselves almost entirely to theatrical subjects. It is among the immediate successors of Torii Kiyonobu that the art of printing in colours direct from the blocks appears to have arisen--at first only one or two tints being used.

The perfecting of the process is due to Suzuki Harunobu, who, going beyond a few tints on the main objects, filled in the whole picture with colour. And, though the first of the great colour print artists, in many respects his work has never been surpassed. Most

of his prints are small in size, containing only a single figure, exquisitely poised, and characterised by extreme elegance and grace of line. His colour schemes were quiet and refined--grey, a pale red, one or two tints of olive green, being the components of some of his most delicate harmonies. His prints are rare, and his signature has been paid the doubtful compliment of being more extensively forged than that of any of his fellow-artists. His style, however, was more difficult to reproduce. Many of his successors fell under his influence, but even in their most successful efforts they never quite caught his peculiar elegance and charm.

[Illustration: A FIGURE GROUP From a Colour Print by UTAMARO]

Of his contemporaries the most noteworthy was Koriusai. Less delicate and refined than Harunobu, he worked in a bolder style, his drawing being particularly vigorous. His bird studies are very fine; and South Kensington Museum contains some excellent examples of his work--notably one, a clever contrast of a crow and a white heron against a grey-green background.

Reflecting Harunobu more decidedly is Shunsho, who became the master of the great Hokusai. His studies of female figures are particularly graceful and of charming colour, and his prints of theatrical subjects vigorous and striking. He died in 1790, at the age of sixty-seven.

Contemporary with Shunsho was Torii Kiyonaga, an artist who not only did fine work himself but exercised a great influence on the artists who followed him. Working with fuller colour than his predecessors he increased the number of blocks considerably, and his charming drawings of the gorgeously-dressed beauties of the Yoshiwara set the fashion afterwards so largely followed.

We now come to one of the chief of the colour print artists--Kitagawa Utamaro, next to Hokusai the most famous of all. His female studies were something quite new and distinctive, superb in line and composition, the heavy masses of black being used with consummate ease and mastery. There is an exquisite quality in his drawing, too; the features are delineated with the utmost fineness and delicacy. Indeed, to distinguish a forgery from a genuine Utamaro, one has only to examine the drawing of the hands and the face. His colour is delightful, and beautifully subtle--lavender, pink, green, and grey--but always saved from weakness by the dexterous use of the masses of solid black. Besides his female figures we have a few landscapes and flower studies, and a particularly fine little volume of insect drawings. It is related by his father in the preface of this book that, when a child, Utamaro was continually catching and examining insects, till he was afraid that the boy might acquire a habit of killing the harmless creatures. The book, however, is not entirely devoted to harmless insects, one of the drawings being a masterly study of a snake. A touch of mica used in the printing gives it a slimy sheen, and the long, coiling body, every inch of it alive and moving, is a wonderful piece of drawing. To rival it one would require to turn to the work of another Japanese artist--the netsuké carver.

Yeishi, Yeizan, and Kiyomine, who followed immediately after, adopted his style and followed his methods closely; but rich though their effects are, and full of detail, they lack the dignity and simplicity of the earlier workers.

One of the most characteristic of all the great artists, and worthy to rank with Harunobu and Utamaro, is Toyokuni I., born in 1769. His work also was at first affected by the ornate style of Kiyonaga; and among his earlier prints are studies of gorgeously-dressed ladies, a riot of rich colour and elaborate detail, but later he turned his attention to theatrical prints, and evolved the style, distinctively his own, which became afterwards the recognised method of treating such subjects. In his lines the grace and suavity of the earlier masters become hardened to a certain severity, but what was lost in grace was gained in strength. The violent action in some of his prints is an illustration of the forcible manner in which the truth can be conveyed by a judicious exaggeration; and again, in repose, his figures have a dignity which is monumental. This effect is heightened, too, by the reticence and restraint with which he uses colour--full, strong tints, but few, and laid on in broad masses. Breadth of effect was what he aimed at and secured. In Japan he was more popular than any of his contemporaries, Utamaro not excepted; and, whereas their followers were limited to a few immediate successors, he was the founder of a regular school. Of these the best is Kunisada, known as Toyokuni II., whose early work especially was almost worthy to rank with that of his master.

But the greatest master of all the colour print artists, and one who by European critics has been acclaimed as worthy to rank with the great artists of the world, was Hokusai. It is a mark of the power of his personality that, though he lived and died in poverty and obscurity, the facts of his life are recorded with some degree of fulness; while, as a rule, little record is left of his contemporaries but their work. Born in 1760, he was apprenticed at the age of eighteen to Shunsho, but was too original in his methods, and too independent, to remain in that position long. For some years he drifted about, being reduced at one time to hawking red pepper, calendars, and other small wares in the streets of Yedo, but all the time he was getting more and more command over his art.

[Illustration: A FIGURE STUDY From a Colour Print by TOYOKUNI]

In the preface to the "Hundred Views of Fuji" he thus summarises his life: "From the age of six I had a mania for drawing the forms of things. By the time I was fifty I had published an infinity of designs; but all I have produced before the age of seventy is not worth taking into account. At seventy-three I have learned a little about the real structure of nature, of animals, plants, trees, birds, fishes, and insects. In consequence, when I am eighty, I shall have made still more progress. At ninety I shall penetrate the mystery of things; at a hundred I shall certainly have reached a marvellous stage; and when I am a hundred and ten everything I do, be it but a dot or a line, will be alive. I beg those who live as long as I to see if I do not keep my word. Written at the age of seventy-five by me, once Hokusai, to-day Gwakio Rojin, the old man mad about drawing."

And, indeed, this was no idle boast, for he lived to a great age, and steadily gained power. When finally stricken down the old man's lively spirit is still unsubdued, and he writes playfully to a friend: "King Yemma [the Japanese Pluto], being very old, is retiring from business, so he has built a pretty country house, and asks me to go and paint a kakemono for him. I am thus obliged to leave, and when I go shall carry my drawings with me. I am going to take a room at the corner of the street, and shall be happy to see you whenever you pass that way."

To the end his mind was absorbed by his art. On his death-bed he was heard to murmur: "If Heaven could only grant me ten more years." Then a moment after: "If Heaven had only granted me five more years I should have become a real painter." He died on the 10th of May 1849, in his ninetieth year.

On his tomb is inscribed this little verse, composed, according to the national custom, during his last hours:

"My soul, turned Will-o'-the-wisp, Can come and go at ease over the summer fields."

All his life beset with poverty, unhappy in his domestic life, his dauntless spirit sustained him, and his incessant industry never flagged. He lived for the most part with one daughter, an artist also, in a bare room, with little or no furniture beyond his painting materials. When the room became unbearably dirty--and they were not squeamish--they changed to another house. Always poor, dressed like a pauper, ascetic in his mode of life, he had an utter contempt for money. When he received payment for his work the money lay uncounted at his side, and when importuned by a creditor he threw him one of the unopened packets and went back to his work.

In 1817 he published the first volume of the "Mangwa," a collection of rough sketches, which, in its fifteen volumes, forms a veritable encyclopædia of Japanese life and industries, and is sufficient alone to establish him as one of the great draughtsmen of the world. These sketches were printed from woodblocks in a scheme of black, grey, and light red, and included studies of every kind--street scenes, architecture, birds, beasts, flowers, and insects. The "Hundred Views of Fuji," similar in style, added still further to his reputation.

But even more striking and distinctive is the great series of colour prints illustrating the landscape of his country--the waterfalls, the bridges, and the "Thirty-Six Views of Fuji," which are something quite new in Japanese art, not conventional landscapes of the old Chinese style, abstract and ideal scenes, but pictures of certain places, each with its individuality strongly stamped upon it. They are, however, equally far from the Western realistic standpoint, each picture being an audacious decorative arrangement both as regards line and colour. Most daring of all are the waterfalls, superb in their boldness of conception and rich, full colour, but equally fascinating are the quieter harmonies of the "Thirty-Six Views of Fuji." To study such pictures is to be lifted out of the commonplace view of things and to look at nature through the temperament and with the eyes of a poet.

But, while so highly esteemed by European connoisseurs, Hokusai is by no means so highly thought of in Japan. And this is not entirely due to the fact that he was a man of the people, a painter of the vulgar and the commonplace. Though it is hardly possible for us to overrate the magnitude of his genius, still, the more we learn of the great painters of the older schools the more we see the reason of the Japanese verdict, for even we would hesitate to place his work alongside that of Cho Densu, of Sesshiu, and of the great Kano masters. The fact is that no man, however great, can afford to do as Hokusai did--to set aside altogether the accumulated benefits of centuries of experience and work absolutely fresh from the beginning. The greatness of his achievement shows the power of his personality, but the greatest results of all are built on the foundations of others. And in spite of its amazing originality and its force we must recognise that in Hokusai's style there is a lack of the dignified reticence and grace--the culture, in fact--of the best work of the classic schools.

[Illustration: ONE OF THE THIRTY-SIX VIEWS OF FUJI From a Colour Print by HOKUSAI]

But the distinction lies even deeper. His outlook, keen and marvellously accurate to catch any passing phase, has not the deep seriousness of the older masters. He was a modern of the moderns--materialistic, humorous, somewhat flippant--while they were mystics, striving to pierce through the veil and discover the truths lying beyond. Each represents the spirit of his time, and, though the comparison is interesting and needful, it is due more in justice to the older men than to Hokusai, whose reputation, it is safe to say, will in Europe mount higher and higher, while the qualities of the old classic painters will appeal to but a few kindred spirits.

One other colour printer of the first rank remains--Hiroshigé I., worthy to rank with Harunobu, Utamaro, Toyokuni, and Hokusai. His landscape prints are particularly charming in their delicate renderings of effects of atmosphere and light, and no one could portray better the peaceful effects of quiet evening light.

But the art which culminated in the work of these great men entered now into a period of decline. The latest artists brought nothing that was new; and, charming though much of their work was, it merely repeated, with continually lessening effect, what had been said before.

With the opening of the country to European influence came the final degradation--the introduction of violent aniline dyes to take the place of the old soft Japanese tints.

Since 1880 a slight revival of the art has taken place, but it has, as yet, produced nothing to rival the productions of even fifty years ago.

[Illustration: A LANDSCAPE From a Colour Print by HIROSHIGÉ]

CHAPTER IV

SCULPTURE AND CARVING

Like the sister art of painting, the art of sculpture arose in Japan with the coming of the Buddhist priests from Korea in the sixth century. But though both existed together in the great Buddhist monasteries the latter seemed for the first few hundred years to entirely eclipse the former, for the first great products of Buddhist art in Japan were seen in the figures carved in wood or cast in bronze which adorned the shrines of the temples.

Time, too, has dealt less severely with these relics, or rather, less perishable in their nature, they have been better able to survive the dangers that so often swept away the frailer kakemonos of the painter, and in many of the old temples are preserved the works of these early sculptors. Such statues were rarely or never in stone, but either of wood--which material always seems as plastic as clay in the hands of the Japanese craftsman--or cast in bronze. Why this should have been it is difficult to say. Perhaps the lack of a suitable stone at hand, and the difficulty of transporting large and heavy blocks long distances in a rough and hilly country, had something to do with the matter. In any case, wood and bronze were at first entirely used for the work. Some centuries later a fine grey clay, found at Nara, mixed with vegetable fibre, like the bricks of Egypt, and, like them, hardened without baking, came into use. Another interesting method of working was the covering over with thin lacquer, mixed with powdered bark, a model made of coarse cloth stiffened with glue. Works in both these last styles were frequently gilded or painted.

Arising in India, Buddhist art spread northward with the spread of the creed through China to Korea, and as it went farther north its characteristics were largely altered and moulded by the different types of the northern Buddhists. The Hindu sensitiveness gave place to a Chinese solidity, which, again, was mellowed and softened by the gentler influences of Korea.

The early Buddhist altar-pieces of Japan are marked by a sweet and dignified serenity. Unlike the great Greek sculptures, they do not represent the ideal of the natural human form, but rather endeavour to express in terms of the human form an abstract or spiritual beauty. Their figures are personifications of abstract qualities--Reason, Pity, Charity, Fortitude, Beauty, Divine Love, for the northern Buddhist doctrine was a gentle one; the world was not a hopeless dream, as in the Hindu form, but a storehouse of forms to be idealised.

The temple of Horiuji at Nara, the first Buddhist temple built in Japan, is one of the richest of all in art treasures, and contains many fine examples of the old work. One of the earliest known specimens there is a life-sized seated figure of Kwannon, said to be the work of Prince Shotoku himself, and, in any case, dating from about the end of the sixth century. The figure is nude from the waist upwards, and is modelled with great severity of style, so that the anatomical forms are almost lost; but this, with the simplicity of the drapery, only concentrates the attention on the serene dignity of the expression, and adds to the power and impressiveness of the

statue.

During the seventh century there arose at Nara a school of bronze casters, who produced a number of beautiful altar-pieces, more than a hundred of which still exist. They are of small size, varying from six inches to three feet in height, and in delicacy of modelling and elegance of style they far surpass any of the Indian, Chinese, or Korean work. The triumph of the school is seen in a little group of three at Horiuji: a seated Buddha with two standing figures, backed by a richly-wrought folding screen.

It is a beautiful piece of work, the lines graceful and flowing, the modelling subtle and of exquisite finish. Perhaps the finest part of all is the openwork halo, pierced with a floral design, behind the head of the central figure. In its own way this group, executed about 680 A.D., is one of the gems of Japanese art.

Towards the end of the seventh century a wave of Greek feeling, which had slowly spread from India and had produced what was known as the Greco-Buddhist art, reached Japan, and its influence is seen in a certain ampler sense of human dignity and proportion absent in the earlier works. In 695 A.D. an attempt was made to cast three large bronze figures of about twelve feet high, but it was a failure. In 715 A.D., however, Giogi, who ranks among Japan's greatest sculptors, successfully cast an altarpiece for the temple of Yakushiji, Nara, of even greater dimensions--a trinity of a seated Buddha and two standing figures. In the opinion of many this work represents the culmination of the art of bronze casting in Japan. For largeness of conception, easy grace and elegance of pose, richness and beauty of finish, it has never been surpassed.

[Illustration: COLOSSAL BRONZE IMAGE OF A BODHISATWA (_South Kensington Museum_)]

But a still more astonishing development was yet to come in the colossal bronzes, which exceed in size any other pieces of casting the world has seen. The largest of all, a seated Buddha, is at Nara, and, no less than fifty-three feet in height, is the greatest bronze statue that has ever been cast. A figure of great dignity, it has, however, suffered much by the lapse of years. The head was damaged by an earthquake in 855 A.D., and later by a fire, and was finally replaced by another in the sixteenth century. Much finer as a work of art, though slightly smaller, being forty-nine feet seven inches in height, is the Daibutsu, or Great Buddha, at Kamakura, which is considerably later in date, the best judges placing it at 1252. The seated figure, with hands folded in contemplation, is of almost oppressive dignity and power. The modelling is simple and severe, the drapery hangs in large ample folds, and the face bears an expression of profound and majestic calm. In the history of art we have met such an expression before; there is something akin to it in the strange, inscrutable smile of the Sphinx. But the calm of the Buddha has a deeper and more spiritual quality: it is the calm of perfect knowledge; it speaks of the conquest of human passions and a spiritual peace elevated far above all earthly things.

The statue was originally surrounded by a building fifty yards square, the roof supported by sixty-three massive pillars; but this shelter was swept away by a tidal wave in 1369, and again in 1494. Since the latter date it has not been rebuilt, though the stone foundations may still be seen. In the rather irreverent phrase of the Japanese, the Daibutsu has become a "wet god."

The process of casting these colossal bronzes is not known in detail. In all probability a full-sized model was first built up, and from it the mould made in several pieces. The Kamakura Daibutsu is formed of sheets of bronze, each cast separately, then brazed together, and finished on the outside with the chisel.

With the decline of this old Buddhist work in bronze appeared another phase of the sculptor's art, which continued to a much later date, and exhibited a different side of the national character. I refer to the grotesque figures of gods or demons which are so characteristic of early Japanese carving. These vary in size from a few inches to between twenty and thirty feet in height, and are chiefly executed in wood, several pieces being joined together in the larger works.

The most famous exponent of the school was Unkei, who lived at the end of the twelfth, and beginning of the thirteenth century. At the gateway of the temple of To-Dai-ji at Nara stood a pair of Nio, or Temple Guardians--huge figures of sinister aspect and terrific power, hewn out of wood--the one by Unkei, the other by Kwaikei, his contemporary. It is said that after Unkei's death the king of the nether world objected that, whereas the sculptor had many times endeavoured to depict him, he had never succeeded in doing him justice. Accordingly, Unkei was sent back to the earth that, having seen the god himself, he might carve his portrait faithfully.

Though on a small scale, only standing two and a half feet high, a pair of little wooden demons by Koben, the third son of Unkei, exhibit the same grotesqueness, combined with an almost terrible power. The masterly representation of the straining muscles shows clearly that the Japanese artist could model the human figure realistically when he pleased, and that when he conventionalised he did so knowingly, and for a given purpose, as has been the custom of the decorative artist from time

immemorial.

The third phase, which marks the early sculptures, is the series of portrait statues, chiefly carved in wood, and it is curious to know that most of these extremely realistic studies were executed during the highly idealistic Buddhist period. The statues of two saints, for instance, Asanga and Vasubandhu, in Kofukuji, which are said to date from the eighth century, are absolutely realistic in style. The drapery certainly is treated in a broad and simple manner, but the face and expression is obviously a portrait, a study of an individual. Many of these portraits exist, dating chiefly from the eighth to about the thirteenth century, and are all strong and characteristic presentments of actual men--speaking likenesses.

[Illustration: PORTRAIT OF SENNO RIKIU, CARVED IN WOOD AND LACQUERED (_British Museum_)]

Towards the end of the thirteenth century the sculptor's art gradually fell into disuse, the traditions of the craft only surviving in the beautiful carving which adorned the temple buildings, but which was looked on not as the work of an artist but merely as that of a carpenter.

The legitimate successor of the old sculptors appeared some hundreds of years later, and not as the maker of colossal images and life-sized portraits, but as the netsuké carver, the greatest master of the art of _multum in parvo_ that the world has seen. In the narrow field of a cubic inch or so the sculptor, for he is no less, combines a largeness of conception with a breadth and vigour of execution which are absolutely astonishing. But there is between the old Buddhist sculptor and the netsuké and okimono carver the same difference which divides the painter of the old classic schools from the more modern exponent of the Ukioyé-Riu--the change from the ideal point of view to the material. The art of the netsuké carver, often bold and vigorous, sometimes elaborately finished, is always frankly realistic.

The netsuké (pronounced netské) is a toggle or button varying in size, but often little larger than a marble. The Japanese gentleman in native costume has no pockets other than his wide sleeves, and so his pipe and tobacco pouch, his inro or medicine-box, and other small objects, are carried slung by a cord to his girdle, like a chatelaine. At the end of the cord was the netsuké, which prevented the objects from slipping to the ground.

It is said that the use of the netsuké dates from the fifteenth century, but the great majority have been made within the last two hundred years. In the opinion of the expert the finest specimens date from the eighteenth and early nineteenth centuries. As the nineteenth century advanced a loss of breadth in the treatment is observable, with a greater elaboration of detail, and this tendency caused the gradual degeneration of the art, until it became little more than a wonderful exhibition of perfect manual skill, lacking the life which breathed in the older work.

The netsuké is made of various materials, of which the two chief are wood and ivory, and is pierced with one or more holes for the passage of the cord. In the eyes of the connoisseur the wooden specimens are generally the most valuable; and justly so, for not only are the Japanese most masterly artists in wood, but the material lends itself to a freer and bolder style of work than the harder and unsympathetic ivory, retaining the slightest impression of the artist's individuality. Between the two there is much the same difference as between the free and spontaneous clay sketch of the sculptor, recording the very print of his fingers, and the coldly severe and more pretentious marble.

Still, it must be admitted that even in ivory the Japanese carver attained in a wonderful degree the qualities of freshness and ease which we are accustomed to look for only in more ductile materials.

The shape and size of the netsuké is regulated by the purpose for which it is intended. It must be large enough not to slip through the girdle, and we usually find that they range from about the size of a walnut to nearly three times that size. Any excrescences or projections would, of course, be liable to snap off, and so, especially in the older specimens, the outline is generally rounded, and without sharp angles. The holes through which the cord passes are often ingeniously made to form part of the design. The fact that many netsukés were also used as seals, and also that so many early examples are of triangular form, so as to stand firmly on their base, is looked on by some authorities as evidence that the netsuké was evolved from the seal.

Often the wood used was coloured, lacquered, and gilt. Sometimes wood and ivory were combined, often ivory and metal, but almost every material was used on occasion. Porcelain netsukés were not uncommon, and gold, silver, jet, coral, and enamel were all applied to the ornamentation of the netsuké.

The Kagami-buta were buttons of metal with a shank at the back. This was enclosed in a circular hollow dish of ivory or wood, which had a hole in the back through which the cord attached to the shank passed. These examples are often very beautiful, the combination of the metal centre, often chased and adorned with gold and silver, with the plain outer ring of ivory being very pleasing in effect.

The Manju netsuké, a round, flattened disc, so called from its resemblance to a Manju, or rice cake, is another well-known form.

[Illustration: A GROUP OF NETSUKÉS (_British Museum_)]

As to subject, the whole field of Japanese mythology, history, and literature is recorded in their netsuké. Perhaps the finest of all are the miniature representations of the masks used in the No dance--sometimes beautiful, sometimes comical, often grotesque, but always artistic. Then we have the beautifully finished carvings of insects; snakes twisted in lifelike coils; a goose with its bill caught in a closed clam shell, and vainly flapping its wings; fishes, tortoises, mice--all varieties of animal life: it is a veritable illustrated natural history. Then in lifelike groups we have the whole world of legendary folklore laid before us. The Tongue-cut sparrow, Motomoro the peach child, and many other old fairy tales, are here retold; while men and women in all the occupations of their trades and callings give an epitome of contemporary Japanese life.

The names of the famous netsuké carvers are too numerous to record here. One of the most celebrated was Shuzan, who lived early in the eighteenth century, a volume of whose designs was published in 1781.

Of late years, since the use of the netsuké has begun to die out, the carver has turned his attention to okimono--small pieces not pierced for the cord, and intended merely as cabinet ornaments. Many of these little ivories are exquisitely beautiful. European work, even of the best, looks weak and poor beside them; and even the best Chinese carving, though perhaps equally dexterous in manipulation, seems dull and mechanical contrasted with their never-failing fertility of imagination.

[Illustration: Rider on Horseback]

CHAPTER V

METAL WORK

We have already treated, with some fulness, of the beautiful bronze statues which adorned the old Buddhist temples; but though his highest achievement, these represent only a small part of the work of the Japanese bronze caster. The old temple bells, the incense burners, the great temple lanterns, all were of exquisite workmanship. And the art was also applied to domestic uses, the ordinary cooking utensils, the more ornamental vases, and the dainty bronze mirrors being but a few of its products.

One of the finest and oldest bells is at the temple of To-Dai-ji at Nara. Cast in 732 A.D., it stands 13 feet 6 inches high, the diameter across the rim is 9 feet 1 inch, while the weight of metal is over forty tons.

The method of ringing such a bell is different from that to which we are accustomed. Instead of a loose tongue hung inside, a heavy swing beam is mounted outside the bell, which it strikes on the rim. The vibrations of each stroke are allowed to die away ere the next is struck, and the great waves of sound go pealing for miles over the quiet countryside.

The casting of a temple bell was made the occasion of a great religious festival. A large kiln was built, worshippers attended from all the surrounding country, women casting their ornaments into the melting-pot. The priests announced with a loud voice the successful accomplishment of each stage of the work, and the concluding operations took place amid scenes of great rejoicings.

At To-Dai-ji is also a very fine specimen of a temple lantern, ornamented with beautiful openwork panels; while at the temple of Kofukuji, Nara, is a masterly piece of bronze in the shape of a musical instrument, a sort of gong, called the Kwagen-Kei, surrounded by four twining dragons--a most fantastic but vigorous piece of modelling.

The mirrors of polished bronze are said to have been first cast in the reign of Keiko, about 100 A.D. They are of two kinds--the first fitted with a handle, or with a stand of metal or carved wood; and the second much smaller, often not more than four inches in diameter, with a hole at the back through which a cord passed. The face was burnished, and the back beautifully wrought in designs of great delicacy.

[Illustration: TWO BOWLS OF CAST BRONZE (18TH CENTURY) (_South Kensington Museum_)]

The method of casting employed in these and similar articles, which is still characteristic of Japanese work, was as follows:--An exact model of the object, with the ornamentation complete as in the finished article, was made in wax. A slip was then prepared with very fine sand, clay, and water, and the model carefully coated with the mixture, special care being taken to run it into all the hollow places, so that a complete skin covered the wax at every part. When the first coat dried another was added, and another and another, a slightly thicker paste being used for each successive coat. A coarser and stronger mixture was used for the outer layers, till the model was encased in a hard, solid crust. Vent holes were then drilled and the wax melted out. After being carefully heated the moulds were ready to receive the molten metal, which was then poured in. When the casting was cold the moulds were broken off and the metal exposed to view. This system not only ensured individuality in the work, a fresh mould being made for each piece, but allowed of a depth of modelling and under-cutting which would have been impossible had the mould been in pieces to be drawn apart and afterwards used again.

The metal work of Japan may be conveniently grouped in three classes. First, the early work characterised by extreme elegance, ornament being used sparingly, though with great taste and often marvellous vigour. Then comes a middle period, dating from the coming of the Tokugawa dynasty at the end of the sixteenth century, when a class of work highly ornamented and rich in detail came into vogue. And, lastly, we have the more modern naturalistic school, wonderful in technique, but lacking the inspiration of the older styles, and beside it appearing dull and commonplace.

South Kensington Museum is particularly rich in Japanese metal work, especially bronzes, of all these styles. There are several fine temple lanterns, notably one pair, standing about eight feet high, of very elegant design, and ornamented with great reticence and taste. A smaller pair, evidently later in date, contain some wonderful casting, but in their more ornate quality lack the dignity of the first pair.

A piece much esteemed by some critics is the large Koro, or incense burner, of quite modern work, cast in 1878--a life-sized study of peacocks, doves, and sparrows. It is certainly a wonderful piece of realism. The poses are natural, the texture of the feathers is imitated in the unyielding metal with marvellous fidelity, single plumes standing out in full relief; but, placed beside the best old work, the whole thing seems trivial and even vulgar. The birds are lifelike to just this extent: if they were only coloured we should think they were stuffed specimens. But from the true artist we get more than this camera-like reproduction of nature; he can also give us the spirit. Turn from this case to the Miochin eagle beside it. As a piece of realism it is worthy to compare with the other, but how much more it conveys. There is a marvellous poise about the bird, a vigour and sweep of line that makes it live and breathe the intense ferocity of its nature. It is alive, while the other merely irritates by its close resemblance to life. Of iron, partly cast and partly made up of hammered plates, it is the work of Miochin Muneharu, a member of the famous Miochin family of armourers, and dates from the sixteenth century.

The smaller pieces in the collection--the vases, trays, bowls, and candlesticks--are also well worthy of study, and illustrate the same tendency--the older work charming by its stately simplicity, and sometimes also by its vigorous treatment of the grotesque; the modern apt to become a mass of exquisitely executed decorations of a highly naturalistic but rather trivial nature.

But in the early years of Japan the implements of war chiefly occupied the attention of the metal worker, and during the bitter civil wars that devastated the country the swordsmith and the armourer became persons of great importance.

The famous family of Miochin has been associated with the making of arms and armour as far back as records extend. An authentic member of the family, Masuda Munemori, wrought helmets and armour in 75 A.D.; and, further back still, there is the legendary founder of the line, who is said to be the grandson of the god Takara himself, who taught him the art of working in metals. From the twelfth to the eighteenth centuries they held the position of armourers to the Court.

[Illustration: THE MIOCHIN EAGLE Cast and Hammered Iron, 16th century (_South Kensington Museum_)]

The armour of the Miochins was formed of thin iron plates, very light, but wonderfully strong. One specimen, a helmet of the sixteenth century, though 12 inches in length, 10 in width, and 8 in height, only weighs 2 lbs. 2 oz. The usual shape of helmet was a domelike headpiece, strengthened with ridges of iron plates, while flaps formed of a number of narrow plates hung at the sides, and covered the back of the neck. From the centre, just above the forehead, rose two curious curved horns, called tsunomoto, and between them was worn the crest of the warrior. In a famous suit of Miochin armour of the twelfth century the helmet has a dragon worked in repoussé coiling round it, the head, with open mouth, glaring from between the tsunomoto, while the tail forms the spike on the top. Although wrought in so hard a metal as iron the dragon's head stands up in relief at least an inch from the background. Similar work in repoussé adorns the breastplate and armpieces.

But much of the finest work of the Japanese metal worker is found in the two-handed swords, which were the chief weapon of the soldiers, and which, in feudal times, became the distinctive mark of the Samurai, the aristocratic military class. The Japanese blades are unsurpassed by the most famous swords of Damascus, India, and Persia, and the craft of the swordsmith was looked on as the most honourable of all handicrafts. Men of aristocratic birth often took up its duties, and the famous swordmakers had the highest titles conferred upon them. The name of the greatest of them all--Masamuné--passed into the language as a term signifying supreme excellence, for a Masamuné blade was unequalled, and would sever a floating hair carried against its edge by the gentle current of a stream, or cleave through a solid bar of iron.

The sword, indeed, was the centre of the old military life of Japan. To know its history, its etiquette, was part of the education of all Samurai youths, and it was a grand moment for them when, at the age of fifteen, they entered on man's estate and girded on the coveted weapon.

A fine sword was handed down from father to son as an heirloom; it was their most cherished possession, and especially in the more peaceful times which followed the establishment of the Tokugawa dynasty it was enriched with the finest work that art could produce.

The forging of a sword was conducted with almost the solemnity attending a religious rite. The katanya, or swordsmith, fasted for days before, and when all was prepared he went to the temple and prayed for a blessing on his work. In the forge was hung a consecrated rope of straw and clippings of paper to drive away evil spirits; and, having first propitiated the five elements--fire, water, wood, metal, and earth--the smith donned the ceremonial robes of a Court noble, and, binding back the wide sleeves, was ready to take hammer in hand.

First a strip of steel is welded to a bar of iron, which serves as a handle; other strips are placed upon it, and it is wrought into a bar of the required dimensions. Carefully coated with a paste of clay and ashes, and never touched with the naked hand, this bar is heated in the charcoal furnace, notched in the middle with a chisel, doubled over, and then beaten out to its former size and shape. This folding process is repeated fifteen times, then four such bars are welded together, and the doubling and welding repeated five more times, so that if each bar consisted first of all of four flakes this has now been increased to 16,777,216 layers of metal. Many different textures are obtained by flattening the bar in different manners, some giving the appearance of a grain as in wood. The preparatory welding being finished, the blade is then drawn out to its full length, shaped, and roughly ground.

But the most critical part of the process, the tempering of the steel, is now to come. And the peculiar combination required--an extremely hard edge, with the rest of the blade soft and tough--the Japanese swordsmith, unlike others, produces in one operation instead of two. The blade is coated with a mixture of fine clay and powdered charcoal. This covering is then scraped away along the edge, leaving exposed a strip of metal about a quarter of an inch wide. Raised in the furnace to the required heat, the blade glowing dull red while the edge is white hot, the sword is then plunged into a bath of water at a certain temperature, and the operation is finished.

The process of tempering was always conducted by the forger himself, no one else being allowed to enter the precincts of the forge, so jealously were his professional secrets guarded. It is said that a famous swordsmith paid for this knowledge by the loss of his hand. He had learned all but the heat of the tempering bath, and this vital secret his master refused to impart to him, so at the critical moment he burst into the forge and plunged his hand into the water. The furious master struck off his hand with one blow of the unfinished sword, but the apprentice had learned his secret.

The old smiths used to sing while tempering a blade, and the spirit of the music was said to enter into the metal. Masamuné chanted a refrain: "Tenku, taihei, taihei"--"Peace be on earth, peace"--and his swords never failed their owner, but always bore him to victory. But the blades of his saturnine pupil Muramasa always brought trouble with them. Their owners were ever in quarrels, and, once unsheathed, the sword was never satisfied without blood, so that it could not even be handled with safety. The reason for this was that, as he tempered the blades, Muramasa sang grimly: "Tenku tairan, tenku tairan"--"Trouble in the world, trouble in the world."

After tempering, the blade was slowly ground on a series of whetstones, getting finer and finer, finishing with a careful polishing with stone-powder, and oil.

A volume might be written on the decoration of the sword. The tsuba or guard, the handle of the ko-katana or little knife, carried in the side of the scabbard; the fuchi and kashira, or mounts of the handle, especially were marked by the most exquisite

ornamentation.

In his knowledge of the properties of different metals and their alloys, and in his combinations of these for one general effect, the Japanese metal worker is unique. Many of the alloys used by him were quite unknown to us, and were chosen chiefly for their colours. For the metal workers' designs were in reality colour studies, and in metal he possessed a palette of really astonishing variety. For black he had shakudo, a rich, deep tint, flashing in some lights a violet blue. Oxidised iron gave a very dark brown, almost black, and also a rich chocolate colour. Light browns, running from coffee colour to saffron yellow, were obtained from different kinds of bronze. Copper gave a deep ruddy tint, coban and other combinations of gold and silver a pale greenish yellow, gold a rich, full yellow, shibu-ichi a dull grey, while white was obtained by the use of silver or polished steel.

In South Kensington there is a vase, a very fine specimen of this work in colours. The vase itself, beautifully shaped, is of iron, a warm chocolate brown. On this is inlaid a graceful design of birds and flowers, gleaming and sparkling in gold and silver, copper colour, green, blue, and violet.

In sword mountings this style of decoration was extensively used, and effects of great richness and beauty were obtained.

The tsuba, or sword guard, is a flat plate of metal, usually circular or slightly elliptical in form; but other styles, such as diamonds, squares, octagons, and irregular shapes decided by the exigencies of the design, are not uncommon. In size they vary from three to four inches in diameter, according to the size of the sword, and weigh from two to three ounces. The tsuba usually contains three openings--the central one wedge-shaped, through which the tang of the blade passes, and two other smaller openings, one on each side, to allow for the passage of the kozuka and kogai to their sheaths in the sides of the scabbard.

The earliest guards were made entirely of iron, and in many later tsuba this still forms the basis. But bronze in its various forms was also much used as a ground for ornamentation; and an alloy, sentoku, containing copper, zinc, tin, and lead, and of a soft yellow tint like brass, was another favourite material. In the latest periods other substances, such as bone, ivory, tortoiseshell, wood, leather, and papier-maché, the last three being coated with lacquer, were sometimes used.

One of the earliest methods of ornamenting the iron tsuba was what is known as kebori, or hair-line chasing. This was not executed with a graving tool but with a small chisel held in the left hand, and driven towards the worker with blows from a light hammer. This style of ornament reached its height during the sixteenth century, and may be seen in great perfection in the work of Goto Yujo.

A development of this style was the hira-zogan. In this lines were first engraved to a uniform depth and then undercut. Soft gold or silver wire was then hammered in, the wedge-shaped opening retaining it firmly without the use of any solder. Kebori-zogan was a combination of the two styles.

[Illustration: A GROUP OF TSUBAS (_From the Collection of Mr M. Tomkinson_)]

The kata-kiri-bori style depended for its effect not on the inlay of different metals but on designs in relief or intaglio. Often the design was defined by piercing, and the detail brought out by chasing and modelling in relief. In most cases the work was entirely that of the chisel and the hammer, untouched by any subsequent grinding or polishing.

In the kata-kiri-bori-zogan style--figured, sculptured, and encrusted work--we find the latest and most elaborate productions of the more modern schools, enamels being also used to add richness to the effect.

The iron, which forms the most usual material, is of exceedingly fine quality and of unusual softness. In many cases it was left rough from the hammer and punch, the marks, seemingly so careless, forming essential parts of the decoration. Etching with acids was sometimes adopted to bring out into greater prominence the twists and foldings of the wrought iron. In some cases, also, a surface grained like wood was obtained by welding together many strips of iron of different qualities and then treating with acid, which, of course, affected more strongly the softer layers.

It is doubtful when the tsuba first began to be an object of art, no specimens of an earlier date than the fourteenth century existing even in representations. Most of the tsubas on the older swords are much more modern than the blades to which they are attached. In the olden times, when the Samurai fell into evil days, he sometimes stripped off and sold the rich embellishments of his sword, retaining only the trusty blade.

Kaneiye, who worked about the end of the fourteenth century, is regarded as the first maker of tsubas artistically ornamented.

In the fifteenth century were produced many iron tsubas decorated with saw-cut silhouettes of birds, leaves, or animals, and with hammer or punch marks. Those last were probably the work of armourers, as in the case of Nobuiye of the Miochin family, whose iron tsubas were greatly valued. Some of these are of openwork, some with heads or masks in relief, others with punch marks. Another of the most famous workers in iron is Umetada, who lived about the middle of the seventeenth century.

Another of the fathers of the art was Goto Yujo, the founder of the Goto school, who lived between 1434 and 1512, and often worked from the designs of the painter Kano Motonobu. By this school, it is said, was introduced the peculiar ground of raised dots known as manako, or fish roe ground, and also the free use of gold, the excess of which marred so much their later work.

To the sixteenth century belong most of the beautiful specimens of saw-cut work in iron, chrysanthemums, kiri, and other crests being the favourite motives, though a number of conventional floral designs showing a strong Portuguese influence are also found.

In the early part of the seventeenth century the use of enamel in the ornament of the tsuba was introduced by Hirata Donin, and continued to be characteristic of the work of the Hirata family till the present century.

The time which produced much of the finest work of all is known as the Joken-in period, 1681-1708--the rule of the Shogun Tokugawa Tsuneyoshi--perhaps the most famous artist being Somin, who worked largely from the designs of the Kano painter Hanabusa Itcho. About this time the wonderful palette of colours in metal came into full use, and the range of subjects became more and more varied. As in the case of netsuké, so in tsuba one may read the whole history, legends, and mythology of Japan.

But the art had now passed its zenith, and a gradual degeneration set in, the work produced in later years being rich and ornate, but lacking the distinction of the earlier schools.

A few words must be said of the kozuka, the handle of the small knife, called the ko-katana, which is sheathed in the scabbard of the wakizashi, or short sword. The kozuka contains much beautiful ornamentation, and from its more sheltered position this is often of greater delicacy than that applied to the tsuba. The manner in which the problem of filling the long, narrow field is solved is a perpetual source of charm to the student of design.

The fuchi, or ferule, at the lower end of the handle of the sword, and the kashira, its lozenge-shaped cap, are also finely ornamented, the two combined usually forming one design.

South Kensington Museum has a varied collection of sword furniture, including many fine specimens, but, unfortunately, probably from lack of space, the objects are arranged in tall cases placed so closely face to face as to render the study of their contents almost impossible without the help of a candle.

[Illustration: Rider on Horseback]

CHAPTER VI

KERAMICS

Though the golden period of Japanese Keramic art was attained during the Tokugawa dynasty, 1603-1868, yet its origin is lost in the mists of antiquity. An interesting passage in an old Japanese chronicle shows that in the times of the Emperor Suwinin, about the beginning of the Christian era, the craft of the potter was the recognised industry of certain tribes. After giving an account of the death and burial of the Mikado's brother the record proceeds:

"On this they assembled those who had been in his immediate service, and buried them all upright round his sepulchre alive. For many days they died not, but day and night wept and cried. At last they died and rotted. Dogs and crows assembled and ate them. The Mikado, hearing the sound of their weeping and crying, felt saddened and pained in his heart. He commanded all his high officers saying: 'It is a very painful matter to force those whom we have loved during life to follow us in death, and though it is an ancient custom why follow it if it be bad? From now and henceforth plan so as to stop causing men to follow the dead.' On the death of the Empress, some time afterwards, the Emperor called his advisers together, and asked them: 'What shall be done in the case of the present burying?' Thereupon Nomi-no-Sukune advanced, and said: 'It is not good to bury living men standing at the sepulchre of a prince, and this cannot be handed down to posterity. I pray leave now to propose a convenient plan, and to lay this before the sovereign.' And he sent messengers to summon up a hundred of the clay-workers' tribe of the country of Idzumo, and he himself directed the men of the clay-workers' tribe in taking clay and forming shapes of men, horses, and various things, and presented them to the Mikado, saying: 'From now and henceforth let it be the law for posterity to exchange things of clay for living

men, and set them up in sepulchres.'"

The result of Mr W. Gowland's excavations of the dolmens, or burial mounds, which date from about 200 B.C. to 600 A.D., has been the discovery of a great deal of the ancient pottery--coarse ware unglazed and unpainted, and decorated only with simple patterns of lines incised in the clay while soft. The shapes, however, are often graceful and pleasing. In the dolmens were also found the rude terra-cotta figures of men above referred to.

For many centuries the art of the potter remained in very much the same primitive condition. A coarse ware sufficed for the domestic utensils of the common people, and lacquered vessels supplied the wants of the more luxurious. There is, indeed, mention of Korean potters having been brought over to Japan after the Empress Jingo's victorious campaign, and it is said that the art of glazing was practised at Hizen in the eighth century.

Little real advance, however, was made till the thirteenth century, when Kato Shirazayemon, better known as Toshiro, a native of Seto in Owari, and the father of Japanese pottery, appears. Dissatisfied with the results of the native kilns he visited China in 1223 to study the methods practised there, and after six years' absence returned to Seto. His pottery is a brown stoneware of firm and dense texture, and is covered with a glaze of a deep rich brown, sometimes mottled, altogether a great advance on the previous product of the country. The vessels made by him, mostly cha-ire, or tea-jars, used in the tea ceremony, are now valued at fabulous prices by the Japanese dilettante.

A certain authority states that Japanese history has been denominated by three factors: the sword, the tea-cup, and the paper house. The effects of the first and the last have been already indicated, and a few words here as to the second may not be out of place.

Legend ascribes a supernatural origin to the tea-plant. The Buddhist saint Daruma, he who sat wrapt in meditation for eight long years so that he quite lost the use of his lower limbs, once at his devotions was overpowered by sleep. On awakening, filled with shame at his frailty, he took a pair of scissors, and, snipping off the offending eyelids, cast them indignantly from him. They took root where they fell, and from them sprang a plant whose leaves had the magic quality of driving away sleep from weary eyes. In the temples it was much valued by the holy men, and a certain degree of ceremony or ritual attended its use.

It was in the time of Yoshimasa, in the fifteenth century, that the cha-no-yu, or tea ceremony, began to assume public importance. In his peaceful retirement, surrounded by artists and philosophers, it was practised by the ex-Shogun. The priest Shuko drew up a code of its rules, characterised by a severe and dignified simplicity. The room used was small, and plain to bareness, the utensils were unornamented, but, though to the ordinary eye crude and rough, were much prized by the connoisseur. Indeed, Yoshimasa often rewarded important services not by a grant of land but by the gift of a valued tea-jar.

A hundred years later Hideyoshi revived the ceremony, and its rules were revised by the famous philosopher Rikiu, the greatest of all the Cha-jin, or tea professors. Rikiu considered that the essentials of the tea ceremony were: "Purity, peacefulness, reverence, and abstraction." "It was important for the guest to come with clean hands, but much more so with a clean heart." Social rank was ignored: those present took rank according to their standing and reputation as Cha-jin. The most perfect courtesy and politeness governed all the proceedings. Frivolous or worldly talk was forbidden, and the conversation chiefly turned on the merit of the kakemono adorning the room, the flower decoration hanging before it, and the implements used in the ceremony.

A special ware was used for the tea bowls termed Raku ware. It is said first to have been made by a Kioto potter Ameya from a design by Rikiu, and so delighted Hideyoshi that he presented the maker with a gold seal, with the characters "Raku" (enjoyment) inscribed upon it, with permission to use it as a stamp. The ware is soft and porous, and covered with a thick, soft glaze. Not turned on the wheel but shaped by hand, it is rough and uneven in shape, and usually bears no ornamentation. Coarse and unsightly and rough as it may appear to the uninitiated, to the eye of the connoisseur it possesses many beauties; its irregular shape is comfortable to the hand, its soft glaze pleasant to the lips, and is said even to impart a flavour to the tea.

As the relaxation of the most cultured of the land, the tea ceremony had effects of far-reaching importance. As a corrective to the military spirit its glorification of the gentler virtues was invaluable, and to it in no small degree it is said the Japanese owe their character as the most courteous nation in the world. In art, though most strongly felt in the field of Keramics, its influence extended widely, affecting to no small extent the various branches of the minor decorative arts, and dominating, almost in a sense creating, the arts of landscape gardening and flower arrangement.

With Hideyoshi's revival of the tea ceremony, and the importation of Korean potters, the real history of Japanese Keramic art begins. Kilns were founded in many different parts of the country, and as each produced its own distinctive ware the development of these local art industries can best be traced separately.

The province of Hizen, lying in the south of the island of Kiushu, and the nearest point of the Korean mainland being only some two hundred miles away, it is natural that here the borrowed industry should first take root.

The most ancient kiln was erected at Karatzu as early as the seventh century, and a hundred years later glazing was there used for the first time in Japan. So famous did the Karatzu ware become that Karatzu-mono, "things of Karatzu," became the current name for all sorts of pottery. The Old Karatzu ware, however, was coarse and rough in quality, though some of its rich brown glazes were not without beauty.

In the sixteenth century Gorodayu Shonzui visited China and learned the art of making porcelain, and on his return to Japan brought a quantity of the clay with him. On the supply being exhausted, however, the manufacture stopped.

After Hideyoshi's invasion of Korea, towards the end of the century, many captives were brought back, including a Korean potter, Risampei, who discovered on the hills of Hizen a clay suitable for the making of porcelain. Kilns were erected, and the new manufacture started in earnest.

When the Dutch traders dealt with the port of Nagasaki the chief article of their export was the porcelain ware of Arita--known as Imari ware, from which port it was shipped to Nagasaki.

It is this ware that was distributed through Europe and gave the first and totally erroneous idea of the Keramic art of Japan. For the "Old Japan" ware, as it is called, was deliberately manufactured to suit the vulgar taste of the barbarous foreigner, who demanded copious and crowded decoration. It is almost ludicrous to compare it with the ware manufactured at the same time for home use. The one, the work of the artist Kakiyemon, is decorated with dainty and graceful designs, which in their reticence and simplicity are the embodiment of good taste; the other is quite un-Japanese in style, the ornament crowded and overloaded with colour, and often a mere gaudy jumble. But the "Old Japan" ware formed the models for half the factories of Europe, and we only need to turn to the Old Crown Derby porcelain to find its atrocities repeated with ludicrous fidelity.

In 1660 Prince Nabeshima established a kiln at Okawachi. It was reserved for the finest porcelain only, which was made for his private use, the sale being prohibited. Beautiful ware with a fine blue under the glaze was the chief product, and at a later date fragile imitations of flowers were made, of wonderful delicacy.

[Illustration: A GROUP OF PORCELAIN (_British Museum_) 1. Large Plate, Kutani ware (purple, blue, and green, on yellow ground) 2. Plate, Imari ware (design by Kakiyemon, red, blue, green, and yellow, on white ground) 3. Plate, Nabeshima ware (blue, on white ground)]

Another famous factory of Hizen is that at Mikawachi, where the Hirado ware, perhaps the finest of all Japanese porcelains, was produced. The factory was founded towards the end of the sixteenth century, and its first manufacture was an earthenware covered with a blue-grey glaze. In 1712, however, the discovery of fine porcelain stone was made in the vicinity, and in 1751 Matsura, the feudal chief of Hirado, took the kiln under his patronage, and for the next hundred years the ware may be assigned the first place among Japanese porcelains; for not only is the ground a pure and clear white, but the paté, free from gritty particles, is of a fineness of texture which is not possessed by other similar wares. With rare exceptions blue is the only colour used in its decoration, not the deep Chinese blue nor yet the rather weak tint of Nabeshima, but a delicate shade between the two. The favourite decorative motive was a scene with pine-trees and children at play. In ware of the finest quality seven children were introduced, in the second quality five, and in the third three. Many charming pieces were also made in plain white ware with pierced patterns or designs in relief, and at a later date the factory became famous for a delicate blue-and-white eggshell porcelain. Since 1830, however, the wares of the factory have declined greatly in quality.

Until within the last forty years the Keramic arts of Japan were only known to Europe by their porcelain, and only crude and inferior specimens of that, but the pottery and faience which merited even more attention were utterly unheard of. Since then matters have changed very much, and the faience of Satsuma is now the most sought after of all Japanese wares. But though Old Satsuma ware has become almost a household word, and there are few collections but boast of a specimen or two, the bulk of these objects are more or less clever imitations of a later date, excellent often in themselves, but not the rare and wonderful old Satsuma with its soft, ivory tint and its almost imperceptibly crackled glaze.

The original kiln appears to have been founded by Prince Shimazu Yoshihiro, chief of Satsuma, on his return from the Korean expedition, from which he brought back seventeen skilled Korean potters. In 1598 a kiln was opened close to his castle at Chosa, in the neighbouring province of Hiuga, which manufactured chiefly objects for the tea ceremony not unlike those previously made at Seto; but the glazes were of many varieties and very beautiful, some of them being exceedingly rich and brilliant. Prince Yoshihiro took great interest in the manufactory, settling handsome annuities on the most skilful potters, and stamping the finest pieces of work with his own seal.

In the year 1618 Boku, one of the original seventeen Korean potters, discovered in Satsuma a fine white clay or sand and other materials suitable for the manufacture of a finer quality of faience, and the result was a great improvement in the ware.

In 1630 the kilns were removed to Nawashiro, and by 1675 the ware had reached a high degree of excellence. About this time Tangen, a pupil of the great Kano painter Tanyu, was employed to paint or furnish designs for the potters, and Satsuma Tangen now constitutes one of the greatest treasures of the Japanese connoisseur. The decoration of such pieces as remain is slight and sketchy, the designs usually landscape, bird, and floral subjects, and the colours few and simple, often a reddish brown only being used.

Towards the end of the eighteenth century two Satsuma potters, Hoko of the Tatsumonji factory and Chiubei of the Tadeno factory, were sent by Shimazu Tomonobu, the chief of the clan, to travel all over Japan, visiting the different factories and learning the processes used in each. They visited Hizen, Kioto, Bizen, Owari, and other places, and particularly seem to have profited by their insight into the methods used in the production of the enamelled faience of Awata, for after their return, in 1795, may be dated a large increase in the manufacture of enamelled Satsuma faience, Nishiki-de, and it is this faience that is so widely known and valued as Old Satsuma.

The characteristics of this beautiful ware may be briefly noted. The paté is close as pipeclay and almost as firm and hard as porcelain. The chalky, porous nature of the newer work at once proclaims its late date. The old glaze is soft, lustrous, and mellow, with an exceedingly fine crackle. The decoration is simple, chiefly diapers and floral subjects in comparatively few colours, and the pieces are invariably small--tripod incense burners of about seven inches high being, perhaps, the largest objects. The large examples profusely decorated with human figures, peacocks, and other designs, are all of later date belonging to the period of forgeries which set in with the great increase of European trade after 1868.

[Illustration: VASE IN FORM OF LOTUS, SATSUMA FAIENCE (18TH CENTURY) (_From the Collection of Mr M. Tomkinson_)]

Of imitations there are many varieties. But first it may be mentioned that, prior to 1868, undecorated white faience was largely made at Satsuma, which was afterwards decorated at Tokio, but the refiring necessary completely takes away, in most cases, the distinctive and beautiful qualities of the crackled glaze.

The rarity of Old Satsuma ware may be judged from the fact that the average number of genuine pieces offered for sale in Japan during the last fifteen years has probably not been more than ten, and not more than half of these have left the country.

Though the Satsuma faience has the distinction of being the most beautiful ware produced in Japan, it is in association with the Kioto factories that we find most of the great names of Japanese Keramics--Ninsei, Kenzan, and Hozen.

The wares of Kioto may be divided into three classes: first, the Old Raku ware used in the tea ceremony; second, the decorated faience of Awata and the neighbouring kilns; and third, the porcelain which was the product of the early part of the nineteenth century.

During the civil wars which preceded the Tokugawa period the city of Kioto, though the seat of the Imperial Court, dwindled rapidly in importance; even the Mikado and his Kugé, or Court nobles, lived in dire poverty. Its tide of prosperity did not turn until the seventeenth century, and it is with the advent of Nomura Seisuke (also called Seiyemon and Seibei) that the great period begins. His native place was Ninnaji, near Kioto, and, taking the first syllable of that name and adding to it the first syllable of his own, he adopted the name Ninsei, with which he stamped his work.

As already described, the porcelain makers at Hizen had learned the secret of vitrifiable enamels as early as 1620, but it was guarded by them most jealously. It is said, however, that between 1650 and 1655 Kurobei, a Kioto dealer in porcelain, obtained the precious secret from an Aritu potter, Aoyama Koemon. The miserable man was immediately put to death by his irate lord; but the secret was out, and passed from the dealer to Ninsei, to the great future benefit of Japan. He applied it to the decoration of faience

with the most excellent results, for his taste and skill as a decorative artist were unrivalled among his contemporaries, and to his influence may be traced many of the most charming developments of later years.

A man of birth, he was not actually a potter by profession, and had, therefore, no fixed workshop, working at the factories of Awata, Iwakura, and Mizoro. He seems to have made no secret of the processes he had mastered, but gladly imparted them to those with whom he came in contact, and to this fact is doubtless due the rapid rise in the quality and increase in the output of the Kioto ware.

A word as to the Kioto kilns, which were all within a radius of a few miles, may be here advisable. The best known were Awata, Iwakura, and Mizoro; the others were grouped together under the general term Kyomizu.

Ninsei's faience is almost worthy to compare with the best ware of Satsuma, but is marked by a slightly darker colour, and is a trifle fragile in appearance, lacking the firm solidity of the Satsuma ware. Its crackle is fine and beautifully regular, giving the appearance of a covering of fine netting. His glazes range from a metallic black to a pearl white, through which a pink flush seems to spread.

His designs for decoration are simple and chaste, and the clear, pale greens and blues and rich reds of his enamels are of exquisite quality.

After Ninsei's death the next great name at Awata is that of Ogata Shinsei, or Kenzan, a younger brother of the still more famous Ogata Korin, painter and lacquerer, perhaps the greatest decorative artist Japan has produced. Kenzan was also a decorator of great power and originality. In complete contrast to the delicate harmonies of Ninsei, his designs are rough and bold, but his colour is superb and his decorative sense unerring. His work was at first confined to the coarser wares of the cha-no-yu, and here the singular force of his decoration harmonises well with the rude shapes, rough earthenware, and rich glazes, so that the Kenzan Raku ware is indeed a thing of beauty. But in faience he had equally great success. Once seen, his style can be recognised anywhere; a rough sketch of a landscape, a branch in blossom, a flight of birds, or the conventional shape of a flower, dashed in with seeming carelessness, but each touch placed in exactly the right spot for decorative fitness. A very fine specimen of his work--a brown pot decorated with an extremely rich design of peacock's feathers, blue-green and purple--may be seen in the British Museum.

The third great name of the Kioto group is that of Nishimura Zengoro, by Keramists known as Hozen. Born towards the end of the eighteenth century, he was one of a long line of potters. In 1801-3 he studied at the Awata factory, and soon his celadon and blue-and-white porcelain became celebrated. His fame attracted the notice of the feudal chief of Kiushu, who, in 1827, invited him to his province, and built a kiln for him in his private park, at which he produced the well-known ware called, from its stamp, Kairaku-en ware. Zengoro had made a special study of glazes, and the great beauty of this ware is the rich harmony of purple, blue, and yellow glazes which he obtained.

His versatility is shown by another ware which has an equally high reputation--the "Eiraku," or Kinrande (scarlet and gold brocade style). This is a porcelain ware of great delicacy and beauty, and usually made only in small pieces. The ground is of a soft coral red, upon which is traced a wealth of decoration in gold, with here and there a mass of rich blue.

Of the many other well-known names remaining among the Kioto potters only passing mention can be made. In many families the same stamp was used by one generation after another, rendering it difficult to distinguish their individual work.

The Kinkozan, Hozan, Taizan, and Tanzan families carried the traditions of Ninsei in Awata faience right down to the present day; while in the beginning of the nineteenth century the Dohachi family and the Kyomizu potter Rokubei followed in their decoration the newer naturalistic school. Mention must also be made of Shuhei and Kantei, potters of the end of the eighteenth century, who are regarded as the most eminent masters of the little Japanese tea-pot, or kuisu, and also of their contemporary Mokubei, a potter of so great ability that it is a pity he confined himself almost entirely to imitations of Chinese and other wares.

The history of the founding of the Kaga factories, which turned out the Kutani ware, is interesting and curious. Maeda Toshiharu, feudal lord of Daishoji, having discovered a bed of fine porcelain stone near Kutani, established a kiln about 1650, under the charge of two well-known potters--Tamura Gonzaemon and Goto Saijiro; but the venture was not a success owing to the lack of knowledge of the workers. Not to be outdone, Saijiro went to Hizen to learn there the secrets of porcelain making. The only way in which he was able to do this was by becoming a permanent member of the community. The manner in which he accomplished this was peculiar. He took service in the house of a potter, married a woman of the district, and worked there for several years. When he had learned all there was to learn he calmly deserted wife and family, and fled home to Kaga, where he imparted the needed information. Shortly after this time, about 1664, the Kutani potters were turning out wares of great beauty and individuality.

[Illustration: A GROUP OF VARIOUS WARES (_British Museum_) 1. Tea-Jar, by Toshiro I. 2. Tea Bowl--Raku Ware. 3. Tea Bowl after Ninsei. 4. Tea Bowl--Omuru, Kioto. 5 and 6. Tea Bowls, by Kenzan. 7. Kairaku-en Ware. 8. Kioto Ware. 9. Soma Ware. 10. Yatsushiro Ware. 11. Bizen Ware. 12. Banko Ware.]

Of these there were several kinds--the first, Ao-Kutani, was so called from the deep green glaze (ao = green) which was largely used in its decoration; and other glazes--yellow, purple, and soft Prussian blue--made up a rich, low-toned harmony of great beauty. In the second class of ware the Arita style of decoration was followed, except that the Kutani potter used blue under the glaze very seldom, and only in subordinate positions. Their chief colours were red--a soft, dull, rich colour varying from Indian red to a russet brown--and yellow, purple, and blue, supplemented by silver and gold.

Their designs were largely made by Morikaga, a pupil of Tanyu-- landscapes, birds, and flowers being the chief subjects.

A third famous ware of Kutani, which may be termed the red Kutani as distinguished from the green, had a ground of rich red, with diapers or medallions decorated in yellow, green, purple, and red enamels. Another style had the ground entirely of red, to which designs were applied in silver and gold, light green, and sometimes yellow and purple enamels.

For some reason the activity of the Kutani factory only continued for about sixty years, and during the next hundred years there followed a period of inaction. In the middle of the nineteenth century the manufacture was revived, both the red and the green Old Kutani wares being imitated, but with doubtful success. The modern colours, especially in the case of the red, lack the softness of the old, and are, comparatively speaking, harsh and glaring.

In 1827, at Edamachi Kanazawa, a kiln was founded which produced a beautiful faience known as Ohi-yaki, which is characterised by enamelled decoration of great delicacy and refinement.

The foregoing are the most important of the old Keramic arts, for the most distinguished products of the pre-Meji days may be summed up as the porcelain of Hizen and Kutani and the faience of Satsuma and Kioto.

A number of wares of lesser importance remain, chief among these being the Owari wares.

It will be remembered that it was to Seto in Owari that Toshiro returned after his visit to China in the thirteenth century, and founded the industry which entitles him to the name of "The Father of Japanese Pottery." But from that time till the beginning of the nineteenth century little change took place in the character of the Seto wares, which continued to be stoneware and earthenware vessels, and little else. About 1801, however, a Seto potter visited Hizen, and after studying in the factories there returned, and founded a porcelain manufactory in Seto. Soon they attained great proficiency in the production of a blue-and-white ware which rivalled the products of Hizen. Their large pieces were particularly fine examples of firing, the technical difficulties to be overcome being enormous. The quality, however, of this ware rapidly deteriorated after 1850.

At about the same time a soft-crackled faience was made at Nagoya by a potter called Toyosuke. It is a soft-crackled faience of the Raku type, covered on the inside with a greenish white glaze decorated with bold floral designs, and on the outside with a thin coat of lacquer.

And now, for the remaining smaller branches of the industry a passing mention must suffice.

In the province of Bizen was manufactured a curious hard stoneware of a bluish grey colour, which chiefly took the form of vigorously modelled figures of gods, men, animals, and birds. Indeed, in the Bizen stoneware you find repeated in another form, but with the same vigour and originality, the achievements of the netsuké carver and the tsuba worker--Hotei, the pot-bellied god of contentment, being a favourite subject for treatment.

At Ise a wealthy amateur named Gozayemon founded a kiln in 1736, executing a ware which was known as Ko Banko. In the beginning of the nineteenth century a potter, Mori Yusetsu, conceived the idea of imitating this old ware. The imitator, however, was a much better artist than his prototype, and soon the new Banko ware was both widely different from, and of a much finer quality than, the old. This ware was worked on a mould, which was placed inside the article, and the clay pressed in with the fingers, the mould being afterwards removed in sections. The decoration was vigorous and artistic, consisting often of dragons, storks, etc., in relief.

In Higo a very beautiful ware called Yatsushiro was made. It is a dense faience coated with a film of pale grey clay by immersion in slip; the design, usually a delicate diaper, is then engraved and the lines filled in with white clay--the whole being covered with a

finely-crackled glaze.

Mention must be made also of the beautiful eggshell ware of Mino--delicate little saké cups and other vessels encased in envelopes of bamboo basket-work; and also of the Fujina ware of Idzumo--a faience decorated with beautifully executed designs of insects.

At Nakamura, in Iwaki, a kiln was opened in 1650, and here the ware known as Soma ware was produced. It is said that the Kano painter Naonobu, drew as a crest for Soma Yoshitane the galloping horse which in varying forms is seen on almost every piece of this ware.

Other lesser kilns are too numerous to mention, and existed in almost every province.

The British Museum possesses a good and varied collection of Japanese Keramic ware, but, unfortunately, the lack of a catalogue and the absence of any systematic arrangement, or even of proper labelling, takes away much from its usefulness to the student.

[Illustration: A Japanese Fan]

CHAPTER VII

LACQUER

The most wonderful of all Japanese arts is their lacquer-work, and, perhaps, in this more completely than in any other medium does the peculiar genius of Japan find expression. For the combination of qualities required for the production of a piece of fine lacquer are such as could have been found in no other people. And it comes to us with a shock of surprise that this work, so free and spontaneous and yet so delicate, is wrought in, perhaps, the most difficult and intractable material ever used by man, and built up slowly and by infinitesimal stages, layer by layer, through weeks and months of labour.

Even were the same brilliant faculty of design the gift of the European, the amazing and unfaltering precision of hand, and the limitless patience and unceasing care required by the technical processes, place lacquer-work far beyond his scope. It is only the Eastern who can combine the imagination of the artist with the technical powers and steady perseverance of the ant or the bee. For, indeed, in examining one of these marvellous Japanese works, so full of exquisite detail, so perfect in every part, one is irresistibly reminded of the honeycombs which form the monument of the humble insect worker; but where the one is the repetition of a single design fixed unalterably the other is free and spontaneous, the product of an ever-varying fancy.

It is difficult to imagine anything more perfect than a piece of really fine lacquer--the smooth, translucent surface pleasant even to the sense of touch; the design simple and slight, and sensitively placed so as to cause the blank spaces to form essential parts of the composition; and the whole glowing with soft gold of varying tints, or, perhaps, relieved with a boldly inlaid piece of mother-of-pearl, flashing with its brilliant irridescent hues.

To one who has seen specimens of the finest work--the glorious lacquer of old Japan--the words of the French critic, M. Louis Gonse, exaggerated though they may seem to the uninitiated, appear no more than a mere statement of fact: “Japanese lacquered objects,” he says, “are the most perfect works that have ever issued from the hands of man.”

But specimens of really fine lacquer are rarely to be seen outside Japan, where they are treasured in the collections of the wealthy. The British Museum possesses hardly anything which is really fine, South Kensington only a few small pieces. The bulk of the fine lacquer in this country is divided between a few private collections, chief among which is that of Mr M. Tomkinson at Franche Hall, near Kidderminster--a marvellous collection, rich in examples of all periods, and containing many exquisite pieces of work.

Though tradition says that lacquer-work was known in Japan as early as 392 B.C. it is supposed that the art, like others, came originally from China. At first its uses were purely utilitarian. Drinking-vessels were coated with lacquer to render them water-tight, and as the surface was hard as glass, and withstood considerable heat, it was also used largely for cooking and other household utensils. Indeed, this explains the slow development of the potter’s art in Japan, for where we would use glass or earthenware the Japanese used lacquered vessels. The armour of an old Japan warrior was often leather coated with lacquer; the sword was in a lacquered scabbard. He ate off a lacquered tray, drank out of a lacquered cup, and rode in a lacquered carriage.

The lac is a natural product--the gum exuded by the urushi-tree (_rhus vernicifera_), a species of sumach. The finest lac of all was obtained from very old trees; but, as the tapping and drawing of the sap resulted in the death of the tree, the supply had to be continually renewed, and so in mediæval times landowners were compelled by law to plant annually a certain number of trees, and

the export of lac was strictly forbidden. Even the Dutch traders of Nagasaki were not allowed to include it in their shiploads of porcelain and other wares, with the exception of a few pieces of inferior quality, specially manufactured, like the Imari ware, for the European market. It is safe to say that until the Paris Exhibition of 1867 no really fine lacquer had ever been seen in Europe.

[Illustration: OUTSIDE OF LID OF SUZURI-BAKO OR WRITING-CASE _In Green, Gold, and Silver, on Black Ground. Koma, Early 18th Century_ (_From the Collection of Mr M. Tomkinson_)]

At what date lacquer began first to be ornamented is unknown. The earliest known examples are preserved in the Todaiji and Shosoin temples at Nara, and date from the sixth and eighth centuries, and by the tenth century some very fine work had been produced. It was not, however, until the seventeenth century, when the country, under the firm hand of the Tokugawa Shogun Iyeyasu, after centuries of turmoil and civil war, had settled down to a peaceful existence that the period of the great lacquer workers set in. For in lacquer, as in many of the minor arts, the Tokugawa period marked the highest point of excellence. In the households of the wealthy Daimios the artist was freed from the more sordid cares of life. He need take no thought for the morrow, what he should eat or what he should drink, but could give his whole life to his art. And it was by the quality of his work, and not by the quantity, that he was judged. He had no idea of increasing his output in order to double his returns, but would spend months of labour on an object no larger than a few inches square. The larger pieces of work, exquisitely wrought outside and inside, the more delicate work being reserved for the inside, as there less liable to damage, in many cases represent the work of years.

For the process is long and tedious, and bristling with technical difficulties. First the wooden foundation for the box or other object to be lacquered is made of specially selected wood, generally a hard wood called by the Japanese hi-no-ki, which is not liable to warp, and admits of a very fine finish. These wooden objects are examples of beautiful cabinet making, often little thicker than cardboard, but fitting with great exactness. This foundation is strengthened with a layer of thin hempen cloth, and after laying on one or two preliminary coatings of a sort of paste mixed with lacquer, and carefully grinding down on a whetstone to ensure a perfectly smooth and even surface, the object is ready for the lacquering proper.

With a flat, short-haired brush--the hair used being generally human hair--the coating of lacquer is laid on in a thin, even layer, and the object set aside to dry, the period required for this varying from twelve hours to several days. Lacquer has this peculiar quality, that it dries best in a damp atmosphere, the moisture in the air seeming to draw out that in the lacquer. The articles are, therefore, placed to dry in a damp cupboard. On removal from the cupboard the surface is then carefully smoothed and polished by rubbing with charcoal. Coating after coating is added in this way, the final polishings being made with a fine ash of calcined deer's horn, applied with the fingers.

Such are the complicated processes in the production of a piece of plain, unornamented black lacquer--the number of separate operations being no fewer than thirty-three, each one requiring the greatest skill and care; while for the production of one of the more elaborately ornamented pieces the number may extend to sixty or more, for the methods of decoration are many and varied, several being frequently applied to the same piece of work.

First of all we have the varieties of carved lacquer. There was the old Kamakura lacquer, in which the wood was first carved, then covered with a foundation of black lacquer, to which a red surface was added. In tsuishu and tsuikoku, carved red and black lacquer respectively, the article was first thickly coated with lacquer and afterwards carved. The process is said to have been invented by a Kioto workman in the fifteenth century, and in the time of Iyeyasu an artist, Heijuro, so excelled in it that he took the name Tsuishu Heijuro.

Chinkinbori is a form of incised lacquer, generally on a black ground. The lines are engraved with a rat's tooth, as being less easily blunted than a metal tool, and are usually filled in with gold. Ninomya Johei, a physician of Yedo in the eighteenth century, was especially famed for this work. Raden is a form of lacquer in which mother-of-pearl and other shells, either in irregular or shaped pieces, are largely used, the colour effects obtained being of great brilliancy. A form of raden called aogai, a mosaic of green or purple irridescent shell crushed small, is especially used for the decoration of sword scabbards.

Togidashi is a style in which no rigid outline is used, but the forms left soft and blurred, being brought out by a series of rubbings. The greatest masters of this class of work were Yamamoto Shunsho and Koma Kiuhaku.

A curious and interesting form is guri lacquer. Here many layers of different coloured lacquers are applied, and the surface is then carved with conventional designs, in deep V-shaped incisions, exposing the different layers of colour.

The most gorgeous of all, however, is gold lacquer, the generic term for which is makiye, but this includes many varieties. In the same piece the gold will vary from solid masses standing up in relief to a dim, impalpable dust blending imperceptibly into the rich black ground. When the decoration is smooth and level with the ground it is termed hiramakiye, when in relief takamakiye. Kirikane is an inlay of small squares, hirakane or hirame an inlay of small pieces made from filings of gold flattened on an anvil. In okibirame, another inlay, the pieces are not dusted on but inserted singly by hand.

Giobu is a variety in which gold leaf is laid down on an irregular ground. This is covered with a deep red lacquer coloured with "dragon's blood." After drying the surface is rubbed down flat, and the gold is visible below, taking different tints according to its varying depth from the surface.

Nashiji (pear ground), one of the most famous styles, is a rich ground of powdered gold with the quality and texture of the rind of a ripe pear, and is largely used in conjunction with other forms of decoration.

A silver ground is also often used with charming effect. In Mr Tomkinson's collection two very fine pieces of silver lacquer by Goshin, a lacquerer of the eighteenth century, deserve special mention. The ground is of a dim, misty grey, and on this is depicted a landscape with fir-trees on black lacquer. The nearest trees stand out bold and clear, those farther off seem embedded in the mist.

Another style largely used for sword scabbards was samé-nuri, shark-skin lacquer. The skin of a species of ray was stretched over the surface, the rough nodules filed down partially, and the whole covered with black lacquer. On the lacquer being rubbed down smooth and polished the nodules show as white discs on a ground of black.

Such are a few of the leading styles of lacquer; but numberless variations exist, and one piece often includes work in several different styles.

As already pointed out, the use of lacquer was at first entirely utilitarian; its adaptation to the purposes of ornament belongs to a later date. Perhaps the first ornamental lacquer was that applied to sword scabbards, horse furniture, and other warlike trappings. With the growth of a more peaceful civilisation came its application to the arts of peace.

[Illustration: A GROUP OF INRO (_From the Collection of Mr M. Tomkinson_) 1. Cock and Flowers (in gold and shell on brown ground). Kajikawa, 18th century. 2. Flowers and Paper Packets for Perfumes (ivory and gold, on black ground). Kajikawa, 19th century. 3. Pier of Bridge (in gold and shell, on black ground). By Kwoyetsu (Korin's master). 4. Well overshadowed by Tree (gold and shell on black ground). Kajikawa, 18th century.]

A very favourite object for the lacquerer is the inro or medicine-box--a little box made in three or four separate sections and hung from the girdle by a cord. On the small surface here available he lavished all the resources of his art, and in inro we find many of the finest specimens of lacquer-work. Indeed, few things are more beautiful than a fine inro, with its rich but exquisitely judged ornamentation, for the Japanese artist possesses in a marvellous degree the power of working on a small field without loss of power or dignity. Even a specimen in plain black lacquer, unornamented, is a thing of beauty, pleasing to touch and to handle, and so perfectly made that the divisions between the sections are often invisible until they are pulled apart. This perfection of fitting is one of the tests by which the work of the old masters can be distinguished from that of their modern imitators.

Of the larger pieces of work the chief is the suzuri-bako, or set of writing materials. Then we have the jisshu kobako, or implements of the perfume game, comprising a cabinet containing the koro or miniature brazier, the kobako or perfume-box, fuda-bako or counter-box, and several other articles; and the sagé-ju, or portable picnic case, containing boxes, trays for sweetmeats, saké bottle, and so on.

Japanese authorities divide the history of lacquer into four eras--that of Nara, prior to 784 A.D.; Heian, 784-1185; Nanbokucho and Ashikaga, 1397-1587; Toyotomi and Tokugawa, 1597-1867. Of the earlier lacquerers little is known. In the fifteenth century, during the reign of the Ashikaga Shoguns, fine work was produced by Igarashi, the first of a line of lacquerers of that name. Little progress was made, however, until the beginning of the seventeenth century, when, after years of strife, the turbulent Daimios were finally subdued by Iyeyasu, the first of the Tokugawa Shoguns, and the country entered on a period of peaceful development. Towards the end of the seventeenth century began to rise the first of the great lacquerers, whose works are still the envy and wonder of their successors.

As in other branches of art, the traditions of this craft were handed down from father to son, and certain families became famed for lacquer. Two stand out especially as masters in the art--the Koma and the Kajikawa families.

The Komas were Court lacquerers for more than two hundred years, the first of the family, Koma Kiui, who died in 1663, being lacquerer to the Shogun Iyemitsu, and the line lasted until the nineteenth century.

The rise of the Kajikawa family was somewhat later; the first, Kajikawa Kujiro, one of the most excellent artists in lacquer, and famous for his giobu nashiji, lived about the end of the eighteenth century. He also was followed by a line of famous artists.

Both the Koma and the Kajikawa families were especially famous as inro-makers, and in this branch of the art it is difficult to say which was the greater. The Koma were remarkable for their coloured decorations, in which the design looked at by oblique light appears to be of gold but by direct light shows in brilliant colour.

One of the earliest lacquerers of whom there is any record is Honami Koyetsu, 1590-1637. Korin is said to have founded his style on that of Koyetsu, whose work certainly resembles to some extent that of the later and more famous artist. In Mr Tomkinson's collection are two inros by Koyetsu and Korin respectively, each decorated with the same design--the pier of a bridge in mother-of-pearl and gold--and treated in an almost identical manner.

The greatest of all names in lacquer is that of Ogata Korin, born 1660, died 1716. As a painter he is entitled to a place among the highest, but as a lacquerer he stands alone. His absolute originality and boldness of conception, his masterly instinct in design, and his splendid draughtsmanship are seen equally in his lacquer as in his paintings, but it is in his lacquer only that his unrivalled decorative powers find their fullest scope.

If the Japanese decorative artist has a fault it is that he is too pictorial in his methods, that he is almost invariably endeavouring to tell a story. But Korin does not lacquer like a painter, he paints like a lacquerer. He is first of all boldly and frankly decorative--the literary appeal is secondary. And though to one not thoroughly in sympathy with the artist there is much in his work that appears obscure or unintelligible, to the eye of the enthusiast these "obscurities" are splendid and triumphant pieces of decoration. Mere prettiness appealed little to Korin, but his work has on this account the greater dignity. Even when at first sight it startles and almost repels it soon grows on one; the longer one looks the stronger is its fascination.

[Illustration: A GROUP OF INRO BY KORIN (_From the Collection of Mr M. Tomkinson_) 1. Deer (in lead on gold ground) 2. Biwa in the Waves (gold and shell on black ground) 3. Fukurokujiu (lead and shell on gold ground) 4. Storks and bamboo (in pearl and lead on gold ground)]

The breadth of his treatment is the amazing thing about Korin's work, large masses of mother-of-pearl, the body of a bird, for instance, being laid in boldly in one piece, as in the inro with cranes here reproduced. Metals also, such as lead and pewter, were used just as daringly. But in the refinements of his art Korin was equally great. His gold mat grounds were especially famous, and were imitated by many of his successors. They are characterised by a steady, rich, full tint with a glow in it, and vary from a silvery to a deep copper hue, and in texture from an impalpable dust to an inlay of square dice. Then from the solid mat the gold will thin out into the lacquer till lost in its depths. His bolder work earned the same sincere flattery of imitation, but the imitator can easily be detected. Mr Tomkinson's collection is especially rich in fine specimens of Korin's work, and through his courtesy I reproduce one or two characteristic examples.

Ritsuo, a pupil and contemporary of Korin, was born in 1663. Like his master, he was celebrated in many branches of art; not only a lacquerer, he was a skilful metal worker, a carver, a potter, and a painter. In his more richly decorated lacquer, that known as hiaku-ho-kan (a hundred precious things inlaid), he often introduced pieces of his own pottery. His work is very distinctive, bold, and strong, with firm modelling and rich, full colouring. In his suzuri-bako he appears to special advantage; the outside of the box rough and bold, the inside enriched with work full of delicacy and refinement. One fine example in Mr Tomkinson's collection has the outside in rough wood, the grain being made more prominent by the soft parts having been eaten out with acid. In the centre the wood is cut away, and a figure of Daruma, in pottery, is inlaid. The inside of the lid is a complete contrast to the rudeness of the exterior, and is wrought with the utmost delicacy and beauty of finish.

Ritsuo's pupil Hanzan also did very fine work in a similar manner. South Kensington Museum possesses a very beautiful little inro from his hand, inlaid with fish in rose-tinted mother-of-pearl.

Of modern masters the most famous is Zeshin, born in 1807, died in 1891, and both as a lacquerer and painter he was worthy to rank with his great predecessors. Zeshin is almost the only one of the moderns whose work could at all compare with that of the old masters, but he lived and died in poverty and obscurity.

Modern industrial conditions hardly admit of the same patient workmanship--months, and perhaps years, being expended on one article. Speedier results are required, and this causes the use of inferior but quicker drying lac, which has neither the beauty nor the durability of the finer quality. A proof of this was given after the Vienna Exhibition of 1872. The vessel which was taking back a number of pieces of lacquer, old and new, was wrecked off the coast of Japan. Eighteen months after the pieces were recovered, the new utterly ruined, but the old work entirely unharmed, bright and untarnished, as if fresh from the maker's hands.

CHAPTER VIII

LANDSCAPE GARDENING AND THE ARRANGEMENT OF FLOWERS

No review of Japanese art, however superficial, can pass over without mention one of the most interesting of all its phases--the application of its conventions to the living and plastic forms of nature in the sister arts of landscape gardening and the arrangement of flowers. And here, as in other departments, the Japanese artist does not seek dully and slavishly to copy nature, but by a frank and dexterous use of these conventions he endeavours to suggest its spirit. By this departure from mere literal truth he attains a wider fidelity to nature. In the limited space at his disposal he knows that he cannot transplant a piece of natural scenery--he must work to scale--but his miniature rocks, trees, hills, and streams are so exquisitely proportioned as to express within the area of a few yards the breadth and expanse of nature.

So, too, in flower arrangement, the master secures the appearance of naturalness by the most careful and daring manipulation. Twigs and stems are twisted and broken, leaves and petals even shaped and cut, to produce the effect apparently so spontaneous, so free from artificiality.

And the reason is obvious. The defect or incongruity that would pass unnoticed amid the wealth and profusion of the living plant, balanced with superb ease by countless other points of interest so that the eye could not dwell on the deformity, when transferred to the narrower field of the flower vase, stands out with awful distinctness, and assumes an importance which formerly it did not possess. The artist dare not take the liberties which Nature allows herself. Her keyboard is limitless, but his harmonies must be built up of a few carefully selected chords.

The rise of both arts dates from that wonderful period of awakening--the coming of the Buddhist priests in the sixth century. The first gardens were those of the old Buddhist temples; the first flower arrangements were placed as offerings before their shrines.

Among the earliest examples of landscape gardening were the temple groves of Biodo-In at Uji, and Todaiji and Kofukuji at Nara, and this old style of temple garden, simple and severe, was called Shinden-Shiki, but little is known regarding the details of its arrangement.

With the Kamakura period, from the twelfth to the fourteenth centuries, we come to more familiar ground. Then the landscapes took a freer form--hills and valleys, lakes, streams, and waterfalls being represented. A curious form was the Kare-sansui, or dried-up water scenery, where the bed of a stream or the hollow of a lake was shown dry, as if in time of drought, and this style was usually combined with a bare mountain or moorland scene.

But a great impetus was given to the art when, in the fifteenth century, Yoshimasa, retiring from active life, and surrounded by a group of artists and sages, revived the ancient tea ceremony, and made it the nucleus of so many forms of art. The wide-reaching effects of this quaint ceremonial on art generally have already been indicated in a previous chapter. A special form of garden was devoted to its use; while also the art of flower arrangement flourished for long merely as an adjunct of the cha-no-yu.

In the first group of Cha-jin, or tea professors, were Shuko (the teacher of Yoshimasa), Showo, and the famous artists No-ami and Oguri Sotan; while a little later we have the names of Gei-ami, So-ami, and later still Senno Rikiu and Enshiu. So-ami was one of the greatest masters of landscape gardening, and in his quiet and dignified compositions one sees the hand that produced the delicate landscape paintings of misty hill and lake. Examples of his gardens exist to this day, the best known being that of the Silver Pavilion at Ginkakuji, which was laid out about the year 1480.

A hundred years later Enshiu was the founder of a new school, which afterwards became very popular. One of his greatest works was a palace garden near Kioto, through which flowed the river Katsura, and so highly esteemed was this garden that for one hundred and fifty years after his death not a stone or shrub was altered.

During the luxurious Tokugawa period it became the custom for the wealthy Daimios to have their gardens laid out by well-known artists; and the art grew still more in importance, a modern style being introduced by Asagori Shimanosuke of Fushimi in the early part of the nineteenth century.

The training of the landscape gardener was long and arduous, for it was by no means the same thing to compose an actual landscape as to paint one. The novice was sent direct to nature to sketch and study natural forms, not, as in painting, from one point of view only, but so as to realise how a scene would appear from all sides.

In designing a garden the first step was a careful survey of the site; its drainage, levels, size, and shape had all to be taken into consideration. The aspect then was chosen, and this was generally south or south-east, so as to be sheltered from the cold west wind, though near Tokio a vista to the west was always left open commanding a view of Mount Fuji. Then the style of the garden had to be decided. Was it to be a hill garden or flat plain land? Was it to follow the "Rocky Ocean," the "Wide River," the "Mountain Torrent" or the "Lake Wave" style? The character of the surrounding country would largely determine the answer to this question, for a garden was designed to fill harmoniously its place in the natural scene. The artist also, while endeavouring to obtain a result that would look well from any point, had to bear in mind that the best view of all should be from the house itself.

A striking characteristic of Japanese gardens is that water, in the form of cascade, lake, or stream, is almost universally present, its cool and refreshing properties being considered well-nigh indispensable.

The main levels fixed, the hills and valleys modelled, the next important feature consisted of the rocks and stones which represent the crags and precipices of nature. Great care is taken in the selection of these, which are termed the bones of the garden. Certain stones, which are highly valued are often brought great distances, the larger ones sometimes carefully split to render carriage more easy, and pieced together again on their arrival. Fancy prices were paid for such stones; and, indeed, to such a height did this form of extravagance attain, that early in the nineteenth century an edict was issued limiting the price to a certain sum.

The size of the garden, which varied from about fifty square yards to a few acres, gave the scale of the stones, and these again in their turn fixed the size of the shrubs, the trees, the fences, and other furnishings of the garden. In a large garden there were no less than one hundred and thirty-eight of these stones, each with its special name and purpose assigned to it.

In the arrangement of the trees, shrubs, and flowers a regular or symmetrical arrangement was avoided, the growths and forms of nature were carefully followed, and the result made to appear as free and unstudied as possible. Contrasts of form and line, and of colour in the foliage, were sought after. No garden was deemed complete without maple-trees, so placed that the light of the setting sun would enhance the richness of its crimson leaves. Deciduous trees were not so largely used as evergreens on account of their bareness in winter; but exceptions were made in the case of the plum and the cherry, so highly prized for the beauty of their blossom.

Flowers were chiefly grouped round the house, and were sparingly distributed among the foliage; but here again we have exceptions in the case of the iris and the lotus, which were used in large masses with gorgeous effect.

Miniature pagodas appeared among the trees in the larger gardens, little bridges crossed the streams, and large stone lanterns cast a dim and mysterious light over the scene when darkness had fallen.

But now let us turn to the sister art. The love of flowers has long been a characteristic of the Japanese people. As long ago as the ninth century the Emperor Saga held garden parties during the flowering of the cherry blossom, at which the literati of the day composed verses in honour of the flowers; and now, after the lapse of ten centuries, the transient glory of the cherry blossom is still a national festival, observed alike by the rich and the poor.

Nowhere but in Japan has the flower motive been so extensively used in art or with such grace and charm. The Japanese flower paintings stand in a class by themselves, beside which all others seem clumsy and coarse, alike in conception and execution, but it is in the applied arts that their fancy is allowed to run riot. In lacquer floral designs are wrought wonderfully in gold or inlaid in mother-of-pearl; in metal they appear in chasing, embossing, inlaying, and many other forms; they form the chief decorations of pottery and porcelain; but it is perhaps in the textile fabrics of Japan, in the gorgeous silk brocades, that they are seen in their

greatest glory.

This being so, need we be surprised that in Japan the arranging of living flowers has for hundreds of years been recognised as a fine art, has had its schools, its laws, and its traditions, and has numbered among its exponents such great artists as So-ami, Oguri Sotan, and Korin? The flower artist, they say, "must be thoroughly imbued with a sympathetic feeling for the character, habits, virtues, and weaknesses of the members of the floral kingdom from which he seeks his material, till he possesses the same love and tenderness for their qualities as for those of human beings."

And so to the arrangement of flowers the Japanese bring an enthusiasm, a delicacy, and a refinement of dainty pedantry that, even in its most stilted and artificial forms, is full of charm, for the spirit underlying the formality and giving life to the most mannered productions is this genuine and reverential love for the beauties of nature. It is related of Rikiu, the famous flower artist and philosopher, that he once observed a fence covered with a beautiful growth of convolvulus. After standing for a while rapt in admiration he plucked one flower and one leaf, which he carefully arranged in a vase. "Why so humble," asked his friends and pupils, "when the whole plant is there at your disposal?" "Nay," answered the master; "it is impossible to rival nature in magic of design, and so any artificial arrangement should be marked by modesty and simplicity. But even one leaf and one flower are sufficient to call for admiration."

The Japanese art of the arrangement of flowers deals not only with blooms but also with many non-flowering plants characterised by a graceful habit of growth. The effects aimed at are pre-eminently those of line and balance, colour being more or less subordinated to these qualities.

The earliest flower studies, placed as offerings before the shrines in the temples, followed a style of erect composition known as the Rikkwa school, and with their vertical central mass and supporting side groups approached more nearly to symmetry than is usual in Japanese art.

In the later styles symmetry was carefully avoided, and, perhaps, to no department of art does the style of asymmetrical yet balanced composition seem more suited than to those delightful arrangements of freely growing natural forms.

The most popular school is that of Enshiu, which groups the essentials under three heads. First, the quality of giving feeling and expression to compositions, for the Japanese artist is no mere copyist of nature; each group must mean something, must convey some idea. Second, truth to nature in the sense of presenting correctly the style of growth of the plants used; and third, truth to nature in the strict observance of the laws of season and locality.

The different parts of the composition have each a special name, as also have many of the faults into which the novice is liable to fall.

[Illustration: A FLOWER COMPOSITION]

Nagashi, the arrangement of long, streaming sprays on each side of a group, is, as approaching the symmetrical, especially to be avoided. "Window-making," the crossing of stalks in such a manner as to give the appearance of loopholes, and "lattice-making," where the crossing suggests lattice-work, are both grave faults, as is also any suspicion of parallelism in the main lines.

It is not sufficient either that the finished study should look well from the front. It must bear the test of examination from all points of view.

There are also distinct rules regarding the vessels employed to hold the compositions. Sometimes beautifully wrought bowls of bronze are used, sometimes vessels of wood or porcelain, sometimes a simple wicker basket.

The shallow bronze bowl is the most usual, as in it little vices of wood may be conveniently fixed across to hold together the stems, and metal crabs, dragons, tortoises, and frogs are often used to hold the cuttings in position, and at the same time form part of the design. Sometimes the vessel is made in the shape of a boat, a style said to be first inaugurated by So-ami, and since forming a class of composition by itself.

A favourite combination is a rough wooden tub used for horses to drink from and a bronze horse's bit. Its use dates back to a time when a famous general of old, during one of the duller intervals of a campaign, employed his leisure in composing a flower study, using as vessel and vice the only articles at his disposal.

Holders of bamboo are used in various forms, as many as forty-two different methods of cutting and notching the hollow stem being recognised. Some of the names of these are delightfully expressive--such as “lion’s mouth,” “singing mouth,” “flute,” “stork’s neck,” “conch shell,” and, most imposing of all, “cascade-climbing-dragon’s form.”

The plants themselves are grouped in many grades. Seven--the chrysanthemum, the narcissus, the maple, the wisteria, and the evergreen rhodea--are of princely rank, and form a veritable aristocracy of flowers. The iris, also, is of equal rank with the foregoing, but, owing to its purple colour, must never be used at a wedding.

Then, again, within the same species, the flowers take rank according to their colour, in most cases the white bloom ranking highest. Among chrysanthemums, however, the yellow takes precedence, with the peach and cherry pale pink, and with the camellia and peony red.

Certain plants, also, must never be used, and this “Index Expurgatorius” includes all strong-smelling or poisonous plants, and a long list comprising the aster, the poppy, the orchid, the rhododendron, and many others.

Male and female attributes are also applied to plants in many ways. The front of leaves is male, the back female; red, purple, pink, or variegated flowers are male; blue, yellow, and white female. So that a flower composition in Japan, apart from its intrinsic beauty, bears a wealth of symbolic meaning.

In all important rooms there is an ornamental alcove or recess, called the toko-no-ma, with raised floor polished and lacquered, and a handsome corner pillar of rare wood. On the back wall is hung the kakemono, or in some cases a pair, or set of three, and on the dais before it, or suspended from above, is placed the flower study. In this recess are displayed, one at a time, the choicest art treasures of the house, and in front of it is the place of the honoured guest.

There is an etiquette even in looking at flower studies, and in praising them only appropriate epithets should be used, always softly expressed. White flowers are “elegant,” blue “fine,” red “charming,” yellow “splendid,” and purple “modest.”

But the greatest compliment that can be paid to a guest on such an occasion is to ask him to make an extempore arrangement himself. And here the ceremonial is delightful in its graceful formality. The host brings a tray with vase, cut blooms and sprays, scissors, knife, and a little saw. If the vessel brought be a very valuable one the guest modestly protests that he can produce nothing worthy of so fine a setting, but, on being pressed by his host, should comply with his wishes. The host then removes the kakemono, for to allow it to remain would impose upon the artist the task of designing his group in harmony with it, and with the rest of the company withdraws to an adjoining room until, the work being completed, the guest summons them, having placed the scissors beside his composition as a silent request for the correction of its faults. When his host enters he apologises for the imperfections of his work, and begs that the whole may be removed. The host in his turn assures him that in beauty it is all that could be desired, and so the delicate interchange of compliments goes on.

Not the least attractive feature of this gentle art is the evanescent nature of its charms. The painter, the sculptor, the artist in lacquer or in metal, works for posterity: hundreds of years hence his fame may be greater far than it is to-day. But the artist in flowers can hope for no such permanence in his work, its creations are verily but “the lilies of a day,” his modest task but to give sweetness and beauty to the passing hour.

[Illustration: A Japanese Fan]

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TRANSCRIBERS' NOTES

Missing or incorrect punctuation, as well as obvious spelling errors (e.g., 'stonger' → 'stronger'), have been silently corrected.

The original spellings of Japanese names (people, places, and things) have been retained and have not been updated to reflect modern orthography.

In this text version, "_" was used to indicate words which were in _italics_ in the original text and all small caps have been replaced with capital letters.

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Claudius Saunier

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This edition of the book did not include a Table of Contents. For the convenience of the reader one has been created here:

Preface. Index. Part I. Arithmetic, Geometry, Drawing, Etc. Arithmetic. Some Signs Employed in Calculations. Powers and Roots. Proportion. Elements of Practical Geometry. Geometrical Drawing. Drawing Instruments. Geometrical Drawings. the Micrometrical Dividing Table. Other Methods of Dividing Into Equal Parts. to Subdivide a Circle. Time. Part II. Materials Employed in Horology. Iron. Cast Iron. Steel. General Observations. Special Observations. Determination of the Qualities of Steel. Preparations of Steel. Hardening. Tempering. to Whiten and Blue Steel. Case-hardening. Influence of Foreign Metals and Metalloids on the Qualities of Iron and Steel. Copper. Zinc. Brass. Hammer Hardening of Brass. to Anneal Brass. Cast Brass. Tin. Bronze. Sterro. Lead. Nickel. German Silver. Gold. Silver. Aluminium and Aluminium Bronze. Mercury. Platinum. Palladium. Characteristic Properties of Alloys. Soldering. Methods of Soldering. Bronzing. Gilding. Acids and Salts. Oil. Alcohol. Benzine, Etc. Polishing Materials. Preparation of Polishing Materials. Smoothing. Smoothing of Brass. Smoothing of Steel. Polishing. to Polish Steel. Cement, Wax, Resin, Etc. Enamel. Precious Stones. Working in Precious Stones. Part III. Health and Manipulation. Preservation of Health. the Sight. the Body in General. Use of the File and Graver. to File Flat and Square With Both Hands at Once. to File Flat With One Hand. to Turn Cylindrical Pivots, Etc., and Square Shoulders. Part IV. Tools and Appliances. Workshop Fittings. the Lathe. the Foot Wheel. the Bench. Idlers. Chucks. the Slide Rest. Gravers and Other Hand-turning Tools. Drills. Lathe Attachments. Miscellaneous Small Tools. Accessories and Miscellaneous Operations to Be Performed in the Universal Head. to Center an Object. Uprighting and Drilling. Production of Screw Threads. Screw Plates and Taps. Taps. Methods of Tapping Holes. Rapid Mode of Making a Screw. Screw-head Tools. Tools For Cutting and Rounding-up the Teeth of Wheels. Wheel-cutting Engine. Cutters For Forming the Teeth of Brass Wheels. Mill Cutters For Steel. Tool For Making Cutters. Tools For Correcting the Form of Teeth. to Test the Accuracy of Certain Tools. Part V. Repairing and Examining Watches. Method. External Examination of the Watch. to Examine a Geneva Movement. Accessories For Beginners. Cleaning the Watch. Putting the Watch Together. to Examine English Or American Movements. to Rapidly Time a Watch Or Clock. Timing in Positions. Horizontal and Vertical. Note on the Proportions of Balances. Demagnetizing. Part VI. Practical Recipes. the Plate. the Barrel. Including Arbor, Stopwork, Mainspring, Etc. the Mainspring. the Fusee. Chain. Wheels. Pinions. Set-hands Square. Pivots. Bushing Pivot Holes, Etc. Depths. on the Application of the Geometrical Laws of Depths to Practice. Pallets. Cylinder. Balance Spring. Dial Plate. Metal Dials. Hands. Glasses. Broaching. Solid and Hollow Squares. to Straighten a Rod, Plate Or Wheel.

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THE

WATCHMAKERS' HAND BOOK

INTENDED AS A WORKSHOP COMPANION FOR THOSE ENGAGED

IN WATCHMAKING AND ALLIED MECHANICAL ARTS

BY CLAUDIUS SAUNIER

ILLUSTRATED AMERICAN EDITION

REVISED AND ENLARGED BY HENRY G. ABBOTT WITH SPECIAL REFERENCE TO THE WANTS OF AMERICAN WORKMEN

CHICAGO: GEO. K. HAZLITT & CO., PUBLISHERS. 1894.

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PREFACE.

M. Saunier's writings occupy an unique position in Europe, as works of reference for all who are engaged in watchmaking, and it may not be out of place to observe that the American edition of his treatise promises to take a similar place among English-speaking communities.

A glance at the index will show that the information given is essentially practical in its character, and such as will be of use to the watchmaker in his daily work. The volume is thus in no sense an abridgment of the original edition, but on the contrary, it contains much more matter than the original work.

In recent years the work of the ordinary watch repairer has undergone considerable change. The apprenticeship he serves, if indeed it can be called a real apprenticeship, is shorter than formerly. The immense number of badly constructed watches that he is called upon to put in going order for a trifling remuneration, compels him to replace the older methods of procedure by others, whenever by so doing time can be saved. From this point of view, then, the value of the present Hand Book can hardly be over-estimated, since it contains, in a readily accessible form, many details as to the working of metals, and descriptions of various practical operations, new and improved forms of tools, etc.

But the volume will be found of daily use to a wider circle of workers than those above referred to. We believe that there is hardly a branch of the watchmaking trade which may not benefit by the numerous practical details that are given; indeed, although the work is specially designed for the use of watchmakers, a great portion of it will be seen to be no less applicable to other mechanical arts.

M. Saunier's original works, the _Guide-Manuel de l'Horloger_, and _Recueil des Procedes Pratiques_, which appeared as separate volumes, have been incorporated in this American edition, a large amount of additional information being at the same time added. As the second contained many details that more properly belonged to the first, and _vice versa_, it has been thought desirable to remodel the whole, and, as will be seen from an examination, the six parts that constitute the work are distinct in their character.

With a view to further facilitate the use of this Hand Book as a work of daily reference, an unusually full index has been added, which the reader is recommended in all cases to consult, and no effort has been spared to make the cross references in the body of the work as complete as possible.

It seems desirable here to give some explanation in regard to several of the practical methods described. Every watchmaker will at once recognize that recipes are included which are of the nature of makeshifts, and that it would in many cases be better to replace a piece by a new one rather than to repair it in the manner indicated. But, on the other hand, it has been felt that the work will often be appealed to by those who, from various circumstances, may be prevented from making or procuring a new part that will suit the watch under repair, while those who are not so situated will have no difficulty in deciding for themselves as to which method to adopt.

The original work of M. Saunier, and the English edition, both had the illustrations in the back of the work, which necessitated considerable inconvenience when consulting them. In this edition we have ventured to insert the illustrations in the text that describes them. The antiquated tools, like the bow, bow-lathe, the turns and mandril, have been omitted, and the modern foot-wheel, lathe and accessories substituted.

HENRY G. ABBOTT

INDEX.

NOTE—The references are in all cases to the pages, not to the paragraphs.

A

Accuracy of tools, to test, 366

" " rules, to test, 33

Acids, 127

Adjusting rod, to use, 433

Agate, 164

Akerman on hardening, 77

Alcohol, 132

" and glycerine on oilstones, 192

Alloys, 57

" properties of, 108

" that melt at certain temperatures, 82

Alum, 128

Aluminium, 103, 110

" bronze, 104, 110

" solders, 113, 116

Amalgams, 105

American chucks, 224

Ammonium, chloride of, 128

Angle of cutting edges, 235

Angles of escapement, to measure, 465

" measurement of, 26

" to construct equal, 44

" to subdivide, 44

Annealing brass, 96

" steel, 72

Anvil, to harden face of, 88

Appliances for watchmakers, 189

Aqua Regia, 127

Arbor, barrel, to make, 409, 420

" " " repair, 428

" " " true, 429

" chuck for wheel-cutting, 224, 337

" to straighten, 505

" nut, to drill, 425

" " diameter of, 425

" set-hands, to adjust, 451

" " " tighten, 294

Area, measurement of, 25

Arithmetic, importance of, 17

Arithmetical ratio, 22

Automatic blow-pipe, 201

Ayr stone, 135

Axis of crystallization, 166

B

Back rests, 253

Balance, pivots, form of, 400

" poise of, 401

" protector, 265

" spring stud index, 280

" to make plain, 436

" vibrations of, 460

Balances, proportions of, 401

Balance spring, action of, 473

" " collet tool, 286, 474

" " gauge, 475

" " to center, 377

" " " clean, 384

" " " draw, 47

" " " flatten, 477

" " " select, 478

" " " weaken, 477

Balance-springs, palladium, 107

" " platinum, 107

Balas ruby, 162

Bands, 219

Barrel-arbor, to make, 409, 420

" " " repair, 428

" " " true, 429

" cover, to make, 410

" going, to put together, 385

" hole to bush, 412

" hook, to fix, 411

" clock, to make, 420

" to examine, 379

" " make, 409

" " oil, 388

" " repair, 379, 412

" " true, 379, 413

" " upright, 413

Bars, to make, 409

Baths for hardening, 78

Beaupuy burnishers and files, 195

Beat block, 266

Beginners, aids for, 381

Bell-metal, 98

Belts for lathes, 219

Bench, 189, 221

Bent pivot, to redress, 454

Benzine, 133, 384

Berlioz rounding-up cones, 362

Berzelius pastile, 498

Black polish on steel, 154

Bleaching silver dials, 487

Blow-pipes, 199

Blow-pipe, gas, 201

" automatic, 201

Blue polishing stone, 135

Blueing steel, 86

Board, arrangements of, 177, 189

"Body" of steel, 70

Borax as flux for soldering, 128

Bouchons, movable, 456

" to make, 298, 456

" " rivet, 456

Brass, 90, 110

" cast, 86, 110

" dials, to silver, 491

" etc., drill blade for, 241

" influence of impurities on, 91

" plates, to harden, 92

" rods, to harden, 95

" to anneal, 96

" " bronze, 121

" " polish, 149

" " select, 91

" " smooth, 139

" wheel teeth, observations on cutting, 346

" wheels, to polish, 149, 135

Brazing, 119

Breguet spring, to set, 476

Broaches, 199

Broaching, 499

" a hole round, 499

Brocot method of hardening brass rods, 95

Broken screw extractor, 262

" " to remove with alum, 128

Bronze, 98, 110

" aluminium, 103, 110

" to render malleable, 98

Bronzing, 120

Brush, to clean with, 383

Brushes, preparation of, 382

Buff leather, 133

Burnishers, 198

" Beaupuy, 195

" to re-face, 198

Burnishing brass wheels, 135, 149

Burnt iron, 58

Bushing barrel holes, 412

" pivot-holes, 456

C

Caliper, figure-of-8, 197

" for heights, etc., 197

" micrometer, 270

" pallet, 466

" rest, jeweling, 249

" vernier, 278

Camphorated oil, 131

Cannon pinion, to tighten, 449

Carbon in cast iron and steel, 60

Carnelian, 164

Case hardening, 88

Case, to examine, 389

Cast brass, 90

" iron, 60

" steel, 61

Castings, malleable, 61

Catgut bands, to join, 219

Cement, application of, 156

" steel, 62

Center of circle, to find, 44

Centers, to test truth of, 366

" various, 266

Center wheel, 379

" " to oil, 388

Centering attachments, 253

" from circumference, 307

" in wax, 157, 314

" methods of, 305

" rods, 285, 385

Chain, fusee, to ease, 434

Chain hook, to rivet, 434

Chalk for cleaning, 382

Chamfering tools, 281, 283

Charcoal for polishing, 133

" used for smoothing, 133

Chinese bronzing, 121

Chloride of ammonium, 128

" of zinc as flux for soldering, 118

Chrysolite, 163

Chucks, 224

Circle, divisions of, 24

" sub-division of, 52

" to find center of, 44

Circular oil stones, 191

Circumference, ratio to diameter, 25

" to center from, 307

Cleaning brushes, 383

" files, 193

" gold or gilt objects, 125

" metal dials, 491

" nickel movements, 101

" rough steel, 75

" watches, 382

Clock barrel, to make, 420

" dials, to clean, 491

" hands, to blue, 86

" pinions, to polish, 443

" to time rapidly, 394

Closing barrel holes, etc., 295

Cocks, to make, 409

Colcothar of vitriol, 135

Cold gilding without mercury, 122

" hammering, 74, 92

Collet, balance spring, tool, 286

Coloring gold dials, 493

Compass, proportional, 37

Compasses, 196

Conductivity, 110, 112

Copper, 89

" alloys with gold, 102

" to bronze, 120

Cord of lathe, 219

Countershaft, 220

Counting vibrations, 394

Cover of barrel, groove for, 410

" " " to make, 410

Crocus, 135

Crossing out a wheel, 435

Crossings of wheel, to mark, 298

" to renew broken, 440

Crystallization, axis of, 166

Cube root, 20

Curb, to adjust, 415

Cutters, to adjust form of, 353

" for jewels, 165

" " making grooves, etc., 312

" " slide rest, 286

" " steel wheels, 347

" " teeth, various kinds, 339

" rose and star, 349

" rounding up, to make, 331

" tool for making wheels, 353

" to sharpen slide rest, 287

" wheel, to make, 339

Cutting a file, 194

" edge, angles of, 235

" faces of gravers, forms of, 239

" glass, 498

" wheels, observations on, 310, 348

Cylinder escape wheel, to test, 290

" to oil, 388

" " pivot a, 454

" " polish mechanically, 468

D

Dead smoothing, 143

" surface of gold, to restore, 126

Decantation, 136

Definitions, geometrical, 23

Degrees of circle defined, 24

Demagnetizing watches, 403

Density, 108

Depth caliper, 197

Depths, application of laws of, 458, 460

" in stem-wind work, 462

" theoretical and practical, 458, 460

" to ease, 365

" " secure good, 457

" visible and invisible, to test, 377

Depthing tool, to test accuracy of, 368

Design, to transfer, 30

Dial, enamel, to cut hole in, 484

" " " drill, 480

" " " reduce diameter of, 486

" " " remove figure from, 486

" plate, to cut, 479

" to file hole in, 481

" " remove enamel from back of, 482

Dials, enamel for, 160

" fixed by feet, 483

" " " screws, 482

" gold, to restore, 493

" metal, to clean, 491

" silver, to restore, 487

" to paint hours on, 495

" " repair, 161

Diamond, 161

" drill, to use, 169

" " and gravers, 162, 173

" for polishing, 162

" powder, drilling with, 168

" " to prepare, 135

Diamantine for polishing, 134, 154

Diameter, ratio to circumference, 25

Dies for screw-making, 315

" " wheel-making, 438

Dividing plate, 298

" scales, etc., 48

" table, micrometrical, 48

Dome, freedom of, 389

Douzieme gauge, 196

Draw-plate, 298

Drawing, geometrical, 28, 40

" instruments, 32

" scales, 33

" to reduce a, 40

Drawn steel, advantages of, 71

Drifting, 296, 415, 502

Drifts, to make, 296, 422

Drill, diamond, 162, 173

" rest, 267

Drilling a barrel-arbor, 423

" enamel dial, 480

" glass, 498

" in the lathe, 308

" lubricants for, 480

" precautions in, 242, 244

" tool, to test accuracy of, 366

" with diamond powder, 168

Drills for oil-cups, 281

" to make, 244

" " mount diamond, 173

" various, 241

Duplex ruby-roller, to make, 173

E

Elasticity of steel, 70, 84

Electro-gilding, 124

Elements of practical geometry, 23

Elevation defined, 28

Ellipse, to draw, 46

Emery, 134

" paper, to make, 134

" wheels and sticks, 134

Enamel, 159

" false, 161

" to apply cold, 160

" " remove from back of dial, 482

" dial, to cut hole in, 484

" " " drill, 480

" " " erase figure from, 486

" " " reduce diameter of, 486

" dials fixed by feet, 483

" " " by screws, 482

Endshake, 375

Endstone, to fix, 159

" " make, 171

Engine, wheel-cutting, 330

English movement, to examine, 389

Engraved design, to transfer, 30

Epicycloidal depths, 459

Equaling file, to cut, 194

Erasing figure from enamel dial, 486

Escapements, action of, 376

" gauges for, 465

" play of pivots in, 452

" to examine, 391

" " measure angles of, 465

" " oil, 387

Escapewheel, clip for holding, 289

" to test, 290

" cock passage, to turn, 312

Essences for cleaning, 133, 384

Examining watches, 371, 389

Expansion, 109

Extracting broken screws, 128, 262, 317

" square root of numbers, 21

Eyesight, to preserve, 175

F

Face-plate, 257

" universal, 257

False ruby, 163

Figure-of-8 calliper, 197

File, to cut equaling, 194

" " round-up teeth with, 363

" use of, 178, 193

Files, Beaupuy, 195

" to clean, 193

" " renew, 193

" " set in handles, 193

Filing block, 269

" fixture, 268

" flat, 179

" rest, 269

" square by hand, 179, 182, 500

Finger-piece, to make, 418

Flat filing, 179

" " device for, 182

" polishing, tool for, 302

Fletcher furnaces, 201

Fluxes for soldering, 117

Foot-wheel, 218

Fourth wheel, uprighting of, 379

Fraise, Ingold, 362

Freedom of various parts, 378, 375, 391

Frosted surface on steel, to produce, 144

Frosting silver dial, 487

Furnace temperatures, table of, 78

Furnaces, wind and muffle, 201

Fusee, advantages of, 432

" to adjust, 433

" " snail, 145

" watch, to examine, 389

Fusion, points of, 110, 112

G

Gauges, 196

" for balance-springs, 475

" " escapements, 465

" movement, table of, 462

" registering, 274

" staff, 275

Geneva movement, to examine, 374

Geometrical drawing, 28

" proportion, 22

" ratio, 20

Geometry, elements of practical, 23

" importance of, 17

German silver, 100, 110

Gilding, 122

" bath, to prepare, 124

Gilt objects, to clean, 125

Glass, to cement, 157

" " cut, 498

" " drill, 498

" use of, 175

Glue, application of, 156

Glycerine and alcohol on oilstones, 191

Gold, 101, 110

" to clean, 126

" " deaden surface, 126

" " prepare in powder, 128

" copper alloys, 102

" " dials, to restore, 493

" solders, 114, 116

" springs, 102, 478

Graduations of scales, etc., 49

Grain of steel, 68

Graining prior to gilding, 125

" steel, 144

Grammaire, 298

Gravers, diamond, 162

" to mount diamond, 162

" use of, 178

" various, 238

Grinder, traverse spindle, 258

Grindstone, 192

Groove, circular, to cut, 311

" for barrel-cover, to make, 410

" straight, to make, 312

" to turn, 312

H

Hairspring, _see_ Balance spring.

" stud index, 280

Hairspringing collet tool, 286

Hammer hardening, 68, 74, 92

Hand fitting pliers, 288

" holder, 287

" to enlarge hole in, 287

" " set in position, 497

" turning tools, 238

Hands, freedom of, 373

" to blue, 86

" " to redden, 497

" " tighten, 287

Handles, to set tools in, 198

Hard steel, to drill, 243

" " " turn, 185

Hardening brass, 92

" gold spring, 478

" solutions, 77

" steel, methods of, 77

" " precautions in, 79

" " temperature for, 68, 81

Hardness of jewels, to test, 166

" " steel, 82

" scale of, 111

Health, preservation of, 175

Heat, mode of applying, to temper, 84

" of furnaces, table of, 78

Homogeneity of steel, 68

Hone slates, 134

Holder, escape wheel, 289

" for watch-hand, 287

Holes, methods of tapping, 323

Hook, chain, to rivet, 484

" to fix in barrel, 411

Hooks for catgut bands, 219

Hooked gravers, 288

Hours, to paint on dials, 495

" wheel, freedom of, 374

Hydrochloric acid, 127

" " flux for soldering, 118

Hydrofluoric acid, 127

Hydrogen in palladium, 107

I

Idlers, 222

Impurities in brass, their influence, 90

" " steel " ", 88

Index, to ease, 478

Ingold fraise, 362

Inks for painting dials, 496

Instruments, drawing, 82

Involute depths, 458

Iridium, alloy with platinum, 107

Iron, cast, 60, 110

" for soldering, 118

" its properties and uses, 57

" oxides of, for polishing, 185

" to case harden, 88

" " distinguish from steel, 57

" " restore, 59

" wrought, 57, 110

J

Jewel in pallet, to advance, 463

" resetting tool, 299

" setting, cutters for, 137

" to find axis of, 166

" holes, thickness of, 400

" " to make, 168

" " " set, 171, 298

" " " smooth and polish, 169

Jeweling caliper rest, 249

Jewelry, alloys used for, 102

" to clean after soldering, 126

Jewels, 161

" to select, 166

" working in, 165

K

Keyless pinion, to drift, 503

" winding depths, 392, 462

" " wheel, to make, 441

" work, need of oil, 383

" " to examine, 392

L

Lamps, 190

Laps for jewelers, 165

Lathe, 210

" attachments, 247

" belts, 219

" care of, 213

" simple form of, 211

" for jewel making, 165

" large size, 216

" to center rods in, 285, 305

" band, 219

Lead, 99, 110

" use of, in brass, 90

Leaves of pinions, to polish, 445

Leclerre's vibration counter, 395

Left-handed screws, to make, 320

Lever escapement, to examine, 391

Lift, to measure, 465

Lines, to connect up, 45

" " draw parallel, 43

" " subdivide, 43

Liquation, 92

Local time, 54

Locking stones, to make, 172

Longitude, value in time, 55

Lubrication of whetstones, 191

M

Magnetism, to remove, 403

Mainspring, setting up, 385

" to blue, 86

" " make eye, 431

" " reduce height of, 432

" " select, 432

Malleability, etc., of steel, 70

Malleable bronze, 98

" castings, 61

" nickel, 100

Materials used in horology, 57

Measurement, exact, 38

" of angles, 26

" " triangles, squares, etc., 26

" " various solid bodies 28

Melting points, 110, 112

Mercury, 105, 110

" to purify, 106

Metals, 57

" to cement, 156

Methylated spirit, 132

Micrometers, 196, 270

Micrometer screw, 39, 48

Micrometrical dividing table, 48

Mill cutters for steel teeth, 347

Milling fixture, 258

Minute wheel, freedom of, 374

" " to cut, 310

Mixed oils, 131

Mortar for making diamond powder 138

Motion work, to examine, 374

Motive force, effect of variations in, 402

Movement, to examine English and American, 389

Movement, to examine Geneva, 374

Muffle furnace, 201

N

Natural steel, 62, 65

Nickel, 99, 110

" movements, 100

" to surface, 147

" " render malleable, 100

" silver, 100, 110

Nitric acid, 127

O

Oil, 128

" application of, 387

" necessary in keyless work, 393

" retention of, at center pivots, 378, 386

" " " on acting surfaces, 132

" tests of quality of, 129

" to secure permanency in, 130

Oil-cup chamferers, 281

Oil-cups, observations on, 282

" to polish, 153

Oilsinks, 131

Oilstone, 135, 190

Oilstones, circular, 191

Oilstone dust, to prepare, 137

Oriental chrysolite, 163

" ruby, 162

" sapphire, 163

Oxides of iron for polishing, 135

P

Paillard's balance-springs, 108

Painting dials, 495

Palladium, 107

" balance-springs, 108

Pallets, 463

Pallet-opening calliper, 466

" stone, to alter, 464

" " " cement, 159

" " " make, 172

" " " move, 463

Pallets, verge, to open or close, 467

" " " measure, 466

Paper used in cleaning watches, 385

Parallel lines, to draw, 42

Parallelogram, 27

Pendulum, counting vibrations of, 394

" spring, _see_ Balance-spring.

" vibrations of, 460

Permanency in oil, to secure, 130

Perpendicular, to erect, 41

Petroleum, use for cleaning, 384

Pewter, composition of, 99

Physical properties of alloys, 108

Pickling dials, 488

Pinion, cannon, to tighten, 449

" hollow, to replace pivot of, 453

" leaves, to polish, 445

" riveting tool, 294

" to drift keyless, 297

" " increase or decrease, 444

Pinions, etc., cutters for, 349

" high and low numbered, 460

" sizes of, 443

" to make, 442

Pivot-holes, cleaning, 382

Pivot polisher, 250

" to bush, 456

Pivots, balance, length of, 377

" " form of, 400

" center, 378

" play of, 378, 452

" replacing broken, 453

" to polish mechanically, 454

" " redress bent, 454

" " turn, 183

Pivoting a cylinder, 454

Plate, watch, to make, 407

Plates, brass, to harden, 92

" for screw-making, 315

" to straighten, 504

Plating, gold, 124

" silver dials, 491

Platinum, 106

" balance-springs, 108

" to solder, 131

Pliers, 196

" hand-fitting, 288

Poise of balance, 401

Polish, black, on steel, 154

Polisher, form of, 155

Polishing brass, 149

" circular grooves, 428

" cylinder lips, tool for, 468

" escape-wheel teeth, 153

" flat objects, 302

" jewel-holes, 168

" machine for pinions, 445

" materials, 133

" pivots in lathe, 454

" powders, to prepare, 136

" ratchet teeth, 427

" sinks and oil-cups, 153

" steel, 153

" stones, Cadot's, 136

Positions, timing in, 399

Post, to adjust, 415

Powers of numbers, 20

Precious stones, 161

" " working in, 164

Preservation of health, 175

Prime numbers, 18

Proportion of numbers, 22

" " balances, 401

Proportional compass, 37

Protractor, 33

Puddled steel, 62

Pulleys, 222

Pumice-stone, 135

Punch, centering, 285

" riveting, 198

Putty powder, 135

R

Radius defined, 24

Railway time, 55

Ratchet, to renew barrel-arbor, 425

" " smooth, 140

" " snail, 141

" teeth, to cut in lathe, 310

" to polish, 427

Ratio, 25

Receipts for watchmakers, 407

Red-stuff, 135

Re-facing burnishers, 198

Registering gauge, 273

Regulating a clock, 398

" " watch, 396

Renewing files, 193

Repairing watches, 371

Resetting jewels, 300

Resin as flux for soldering, 117

Resist for use in gilding, 125

Retention of oil on acting surfaces, 132

Riveting stake and punch, 198

Rods, brass, to harden, 95

" to straighten, 504

Roller remover, 264

" to make duplex, 173

Roots of numbers, 20

Rose cutters, 349, 357

Rottenstone, 135

Rouge, 135

Rough steel, to clean, 75

Roughing files, 193

Round hole, to broach, 499

Rounding-up attachment, 259

" " cones, 362

" " cutters, to make, 331

" " teeth by hand, 363

" " tools, 330, 359

Rubitine, 134

Ruby, 162

" false, 163

" roller, to make duplex, 173

Rust, to remove and to prevent, 58

S

Sal-amoniac as flux for soldering, 128

Salts, 128

Sapphire, 163

Sapphirine, 134

Scale, to remove, from steel, 75

Scales used in drawing, 33

Scratch-brushing, 125

Screw dies, 315

" head sinking tools, 260

" " to smooth, polish and slit, 143, 301

" micrometer, 39

" plates, to make, 316

" " and taps, 315

" rapid mode of making, 326

Screws, double and treble threaded, 381

" left-handed, 320

" to blue, 86

" " make internal and external, 315

" " extract broken, 128, 262, 317

" tray for, 381

Sealing-wax as cement, 155

Seconds circle, to fix, 484

" " " make hole for, 484

Sector, 36

Semi-cylindrical drill, 245

Series of holes, to drill, 309

Set-hands arbor, to adjust, 451, 294

" nut, to make, 449

" square, to make, 422, 449, 500

Setting jewel-holes, 171

" " cutters for, 236

Set-square, to center with, 286

Sharpening cutters, 237

Shear steel, 62, 66

Shellac as cement, 155

Shoulders, cutters for making, 236

" gravers for turning, 239

" to polish square, 155

" " turn square, 183

Sight, to preserve, 175

Signs used in calculations, 19

Silver, 103, 110

" dial, to restore, 487

" German or nickel, 100, 110

" solders, 114

" solution for dials, 490

" for plating, to apply, 492

" " " " prepare, 491

Sinks in watch plate, 131, 281

" to polish, 153

Sinking tools, 281

Slates, hone, 134

Slide rest, 233

" cutters, 236

" " to sharpen, 237

" turning with, 234

Sliding tongs, 196

Smoothing brass wheels, 149

" metallic surfaces, 139

Snailing, circular, 141

" steel, 145

" tool for, 146

Soap, application of, 383

Solders for various metals, 113

" hard and soft, 113

Soldering, 112

" fluid, 118

" fluxes used in, 117

" iron, 118

" methods of, 115

" to clean jewelry after, 126

Solid content, measurement of, 28

" geometry, 23

" squares, 500

Specific gravity, 110, 111

" heat, 110, 111

Spelter solders, 114

Spinel ruby, 162

Spiral, to draw, 47

Split chucks, 224

Spotting, circular, 141

" machine, 141

Spring, balance, 473

Springs, to blue, 86

Square hole, to drift a, 502

" measurement of, 26

" root, 21

" set hands, to make, 422, 449, 500

" shoulders, to turn, 183

" to file by hand, 500

" winding, to renew, 430

Squares, solid and hollow, 500

" to make, 422, 449, 500

Staff gauge, 275, 277

" to straighten, 505

Stake, riveting, 198

Staking tool, 293

Star cutters, 348, 357

" wheel, to true, 417

" " sink, to make, 410

Steel, 61, 110

" characteristics of good, 63

" drawn, 70

" drill blade for, 242

" influence of impurities on, 88

" maximum elasticity of, 82

" precautions in hardening, 79

" preparation of, 72

" to anneal, 72

" " braze, 119

" " clean rough, 75

" " determine qualities of, experimentally, 66

" " distinguish from iron, 58

" " polish, 153

" " restore, 59

" " snail, 145

" " smooth, 143

" " temper, 81

" " turn hard, 185

" " whiten, 84

" wheels, cutters for, 347

Stem wind pinion, to drift, 503

" " wheels, to make, 441

Stepping device, 227

Sterro, 99, 110

Stone, pallet, to cement, 159

Stones for polishing, Cadot's, 136

" precious, 161

" to make pallet, 172

Stool, 190

Stopping barrel holes, 412

" pivot-holes, 456

Stopwork, proportions of Geneva, 416

" to examine English, 389

" " examine Geneva, 374

Straight groove, to make, 312

Straightening rods, etc, 504

Stud index, hairspring, 280

Studs, to remove, 291

Subdivision of angles, 44

" " circle, 52

" " lines, 43

Sulphuric acid, 127

Surfaces, smoothing of metallic, 139

Surfacing nickel movements, 147

Synchrometer, Guilmet's, 398

T

Tailstock, 247

Tap, to increase diameter of, 323

Tapping holes, various methods of, 323

Taps for screw-making, 317

" left-handed screw, 320

Teeth, forms of, 365

" of escape wheels, to test, 290

" " lever escape wheel, to polish, 153

" " to cut, 330

" precautions in cutting, 341, 346

" steel, to polish, 427

" to renew in wheel, 439

" " round up, 363

" " true, 440

Temper, as indicated by blueing, 87

Temperatures, determined by melting alloys, 82

" determination of furnace, 82

" of furnace, approximate, 73

" of temper colors, 82

Tempering steel, 82

Tightening cannon pinions, 293, 449

" hands, 294

" set hands arbor, 294

Time, 54

" standard, 55

" to ascertain true, 54

Timing in positions, 399

" watches and clocks, 394

Tin, 97, 110

" solders, 114, 115

" use of, in brass, 90

Tinning surfaces, 119

Tool, form of, for turning, 238

" for balance spring collet, 286, 474

" " closing barrel holes, etc., 293

" " drifting, 296

" " flat polishing, 301

" " measuring verge pallets, 466

" " polishing cylinder lips, 468

" " " pinion leaves, 445

" " " pivots, 454

" " resetting jewels, 299

" " riveting pinions, 293

" " snailing, 146

" " spotting, 141

" " tightening cannon pinions, 293

" " " hands, 293

" " " set hands arbor, 293

Tools, ordinary small, 260

" need of good assortment, 187

" screw head, 329

" for hand-turning, 238

" " making jewels, 165

" " rounding up teeth, 359

" " sinking screw heads, 260

" " watchmakers, 189

" to set in handles, 193

" " sharpen turning, 237

" " test accuracy of, 366

" " " escape wheels, 290

Tool set, 237

Tongs, sliding, 196

Topaz, 164

Tourmaline plates, 167

Tracing, 30

" from dial, 495

Train, play of pivots of, 378

Trains of watches, usual, 394

Transferring, 30

Traverse spindle grinder, 258

Triangles, 26

Tripoli, 135

Trueing a barrel, 412

" " " arbor, 429

" " star-wheel, 417

" " wheel, 440

Truth of tools, to test, 366

Turning sphere, tool for, 241

" by hand, 238

" tools, forms of, 238

" " to grind, 237

" velocity in, 235

" with either hand, 186

" " slide-rest, 233

Turpentine, use of, in drilling, 480

" Venice, as flux for soldering, 117

Tweezers, 196

" for removing studs, 292

U

Universal face-plate, 256

" head, 256,303

Unlocking pallets, to make, 172

Uprighting a barrel, 413

" of center wheel, 378

" tool, to test accuracy of, 367

V

Velocity in turning, 235

Verge pallets, to measure, 466

" " " open or close, 467

" to straighten, 505

Vernier, 37

" caliper, 278

" gauge, 278

Vibrations of balance or pendulum, 460

" to count, 394

W

Watch-glass, to reduce, 499

" hand holder, 287

" " to blue, 86

" " " tighten, 293

" plate, to make, 407

" to de-magnetize, 403

" " time rapidly, 394

Watches, to clean, 382

" " put together, 385

" " repair and examine, 371, 389

" usual trains of, 394

Watchmakers' bench, 221

" receipts, 407

Water, annealing steel in, 73

" of Ayr stone, 135

Watered surfaces on nickel, 147

" surfaces, to produce, 139

Wavy surfaces, to produce, 139

Wax chucks, 157, 230

" to set objects in, 157

Weight of balance, 401

Wheel, cutters, 258

" " or punch, 438

" " tool for making, 354

" " to make, 340

" cutting engine, 330

" " " to divide a rule on, 50

" " " to polish in, 427

" foot, 218

" mode of holding in cutting, 337

" teeth, to cut in lathe, 336

" tooth, to renew, 439

" to divide, 333

" " make steel, 441

" " mark crossings of, 298

" " rough out, 435

" " straighten, 504

" " true, 440

Wheels, arbors for cutting, 337

" identical, 438

" observations on cutting, 346

" steel, cutters for, 347

" to ease depths of, 365

" " polish brass, 149

" " repair, 439

Whetstones, 190

White smoothing, 143

Whiting, 136

Wind furnace, 201

Winding square, to make, 422

" " " renew, 430

Wire-drawing plate, 298

" gauges, 272

Work-bench, arrangement of, 189

Y

Yellow copper or brass, 90

Z

Zinc, 89

PART I.

ARITHMETIC, GEOMETRY, DRAWING, ETC.

ARITHMETIC.

=1.= We often hear the theory advanced that in this country, at the present day, it is not necessary to have a knowledge of arithmetic, geometry, drawing, etc., because our interchangeable system of manufacturing watches, makes all knowledge in these lines superfluous, and that without any knowledge of arithmetic or geometry a man may become a thorough master of watchmaking. This is a mistake that too many of our young men make. The fact that the leading watch factories of the United States have adopted the interchangeable system, of course lessens the number of parts which the repairer will have to make and fit, but it by no means alters the situation as regards the repairing of foreign-made watches, nor even the changing of American watches from key to stem-winders. Without a thorough knowledge of arithmetic and, at least, an insight into the principles of geometry, no young man can hope to become a first-class watchmaker in the true sense of the word. Without these accomplishments he will be deprived of the pleasure of reading understandingly the best literature of the day, the works of those who are best fitted to impart knowledge to the members of the trade.

With a knowledge of geometry he will be able to comprehend the works of the best authors, to ascertain the dimensions of solid bodies, and be in a position to apply the rules that form the basis of linear drawing. Every watchmaker, worthy of the name, should be able to make and understand the drawing of any machine, or of any horological instrument. Many inventors, and even ordinary workmen, would avoid a large amount of hard work, often useless, and occupying much time, if, instead of at once putting an idea into practice with brass and steel, they were able as a preliminary, to make for themselves a correct design drawn to scale.

=2.= It is taken for granted that the reader is familiar with the rules of arithmetic at least, and we will touch upon some points in algebra and geometry that it will be well to mention. Should the reader have no knowledge of arithmetic, algebra and geometry, we would advise him to take up these studies during his leisure hours, using some of the standard text books for that purpose.[1] Besides possessing a knowledge of prime numbers, numbers which have no divisors but unity and themselves, the watchmaker should be able to determine the greatest common measure of several numbers, a rule which is of great importance in calculating a train of wheels that is complicated.

We shall confine our attention to the methods of extracting square roots and proportions, the rules for which may have been forgotten, owing to their being less frequently employed than the more common rules of arithmetic; they are of frequent use in horology.

SOME SIGNS EMPLOYED IN CALCULATIONS.

=3.= The sign of addition is an erect cross, +, called _plus_, and when placed between two quantities it indicates that the second is to be added to the first. Thus, 5 + 3 equals 8.

The sign of subtraction is a short horizontal line, -, called _minus_, and when placed between two quantities it indicates that the second is to be subtracted from the first. Thus, 8 - 3 equals 5.

The double sign, ±, is sometimes written before a quantity to indicate that in certain cases it is to be added and in others it is to be subtracted. Thus 5 ± 3 is read 5 _plus or minus_ 3.

The sign of multiplication, ×, when placed between two quantities indicates that the first is to be multiplied by the second. Thus, 3 × 5 equals 15.

The sign of division is a short horizontal line with a point above and one below, ÷, and when placed between two numbers or quantities it indicates that the first is to be divided by the second. Thus, 6 ÷ 2 equals 3.

The sign of equality is two short, horizontal, parallel lines, =, representing the words equal to. Thus, 6 ÷ 2 = 3.

Inequality is denoted by the angle >, the opening always being toward the larger number or quantity; thus, in 12 + 7 > 14, the sign >, indicates that the sum of 12 and 7 is greater than 14, and the whole expression is read, 12 plus 7 is greater than 14. The expression 9 < 4 + 7 is read, 9 is less than 4 plus 7.

A parenthesis, (), denotes that the several numbers or quantities included within it are to be considered together, and subjected to the same operation. Thus, (10 + 4) × 3 indicates that both 10 and 4, or their sum, are to be multiplied by 3.

A horizontal vinculum, ------, placed over the numbers or quantities, is frequently used instead of the parenthesis. Thus, @2 + 4 + 6@ × 7 is equivalent to (2 + 4 + 6) × 7.

Division is more usually indicated by a line between the two figures, the dividend being written above and the divisor below the line. Thus, 1■/■ indicates division, the same as 16 ÷ 8.

Algebra is that branch of mathematics in which the operations are indicated by signs or symbols, and the quantities are represented by letters.

The sign of ratio consists of two points like the colon, :, placed between the quantities compared. Thus, the ratio of _a_ to _b_ is written _a_ : _b_.

The sign of proportion consists of a combination of the signs of ratio. Thus,: :: :. The first two and last two dots are read _is to_, while the four in the middle are read _as_. Thus, if _a_, _b_, _c_, and _d_, are four quantities which are proportional to each other, we say _a_ is to _b_ as _c_ is to _d_, and this is expressed by writing them thus:

_a_ : _b_ :: _c_ : _d_.

POWERS AND ROOTS.

=4.= The power of a number is the product formed by successive multiplication of the same number by itself. Thus,

2 × 2 = 4, the second power or square of 2. 2 × 2 × 2 = 8, the third power or cube of 2. 2 × 2 × 2 × 2 = 16, the fourth power of 2, etc.

An exponent is a number written above a quantity, at the right-hand, to indicate how many times the quantity is to be taken as a factor, as 6^3 = 6 × 6 × 6.

The root of a quantity is a factor which, multiplied by itself a certain number of times, will produce the given quantity. Thus, in the above examples 2 is the square root of 4 and the cube root of 8.

The radical sign, √, indicates that the root of the quantity placed under it is to be taken, and the index of the root is expressed by a little figure placed outside of the bend. If a square root the index figure is usually omitted.

√4 = 2 or $^{2}\sqrt{4}$ = 2 and $^{3}\sqrt{8}$ = 2.

=5. Extracting the square root of whole numbers.= [2] I. Point the given number off into periods of two figures each, counting from the units place to the left. For example, we wish to find the square root of 399424, we point it off thus: 39,94,24.

II. Find the greatest perfect square in the left-hand period, and write its root for the first figure in the required root; subtract the square of this figure from the first period, and to the remainder bring down the next period for a dividend. Thus:

39,94,24(6 36 -- 394

III. Double the root already found, and write the result on the left for a divisor; find how many times this divisor is contained in the dividend, exclusive of the right-hand figure, and place the result in the root and at the right of the divisor. Thus:

39,94,24(63 36 -- 123 394

IV. Multiply the divisor thus completed by the last figure of the root; subtract the product from the dividend, and to the remainder bring down the next period for a new dividend. Thus:

39,94,24(63 36 -- 123 394 369 --- 2524

V. Double the right-hand figure of the last complete divisor for a new divisor, and continue the operation as before. Thus:

39,94,24(632 36 -- 123 394 369 --- 1262 2524 2524

PROPORTION.

=6.= It is often convenient to express the relations of qualities in the form of a proportion and from the proportion derive an equation.

Ratio is the quotient of one number divided by another. Thus the ratio of 30 to 6 is $^{3}\blacksquare/\blacksquare$.

=7.= Proportion is the equality of ratios: Thus if $^{3}\blacksquare/\blacksquare = 5$ and $\blacksquare\blacksquare/\blacksquare = 5$ then we may state that $^{3}\blacksquare/\blacksquare = \blacksquare\blacksquare/\blacksquare$ or the proportionality is usually expressed (=3=) thus:

30 : 6 :: 40 : 8

and this constitutes what is called a geometrical proportion, and 30 and 8 are called the extremes and 6 and 40 the means.

=8.= The product of the extremes is always equal to the product of the means. Thus: 30 × 8 = 6 × 40 = 240. Hence it follows that if we only know three terms we can always determine the fourth, or unknown term, which is usually represented by the letter _x_. Thus in the proportion

12 : 3 :: 16 : _x_

we find the product of the means, or 3 × 16 = 48; this product divided by 12, the known extreme, gives us the value of _x_, or the unknown extreme, as equalling 4.

=9.= If we know the two extremes and only one of the means the same rule is applied. Thus in the proportion

20 : 5 :: _x_ : 25,

we have: 20 × 25 = 500. $\blacksquare\blacksquare\blacksquare/\blacksquare = 100$, the value of _x_.

ELEMENTS OF PRACTICAL GEOMETRY.

=10.= The object of geometry is to measure the extent of bodies. A body has three dimensions, _length_, _breadth_ and _thickness_, and one of these latter is sometimes termed _weight_ or _depth_.

Either dimension taken by itself is measured by a straight line.

When the extent of a body is expressed by combining any two dimensions, it is termed _area_ or _surface_, and when three are employed we obtain the solid measure or _volume_.

Plane geometry only takes cognizance of figures situated in one plane or surface, and therefore only possessing two dimensions; _solid_ geometry, however, regards bodies as having all three dimensions.

Two lines are parallel when their distance apart is the same at all points. The same is also applicable to parallel planes.

Two lines or planes meeting each other will form an _angle_. The point at which they meet or intersect is termed the _apex_ or _summit_ of the angle.

A straight line is _perpendicular_ or _at right angles_ to another straight line, or to a plane, when all the angles which it makes with that line or plane are equal.

A _circumference_ of a circle is a curved line _l c d f_ (fig. 1,) such that all its points are equally distant from an internal point, _o_, termed the _center_. The _circle_ is the space enclosed by the circumference.

It will be noticed that in geometry these two words are distinguished, although they are frequently referred to as identical. Thus, the rim of a wheel or balance is generally termed a circle.

Two circles (_l c d f_ and _b r a_, fig. 1,) described from the same center are said to be _concentric_. When their centers do not coincide they are called _excentric_ with regard to one another.

Any portion of a circumference, such as _f n d_, is termed an _arc_ of the circumference, or, more commonly an _arc of a circle_.

A _chord_ is a straight line, _f d_, which unites the two extremities of an arc. When the chord passes through the center of a circle it is termed a _diameter_.

The _radius_ of a circle or circumference is a straight line drawn from the center to the circumference; and all the radii that can be thus drawn are equal. A diameter is, then, always double the radius, and, conversely, the radius, is always half the diameter.

A _tangent_ is a straight line that only touches a circumference at one point, as _g l_ (fig. 1); whereas a _secant_ cuts the circle, as _i j_.

A circumference is assumed to be divided into 360 equal parts, termed _degrees_. The degree is subdivided into sixty equal parts, or _minutes_, and the minute into 60 _seconds_. These are respectively symbolized by the marks ° ′ ″ placed at the right-hand top corner of the figure.

Such an expression as 18° 30′ 15.5″ would, then, be read 18 _degrees_, 30 _minutes_, and 15.5 _seconds_.

=11.= =Ratio of the circumference to the diameter.= The diameter of a circle is to the circumference as 7: 22; or, employing decimal fractions, as 1: 3.14159 (a number which, in algebra, is always represented by the Greek letter π.)

[Illustration: _Fig. 1._]

Knowing a diameter (D), the circumference, _x_, can be ascertained from the proportion:—

1 : 3.14159 :: D : _x_.

Knowing a circumference (C), the diameter, _x_, can be determined from the proportion:—

3.14159 : 1 :: C : _x_.

The latter proportion will also give the value of the radius, which is half a diameter.

=12.= The _superficial area of a circle_ is equal to the circumference multiplied by half the radius, or to the square of the radius multiplied by 3.14159.

A _sector_ is the circle enclosed between an arc and two radii bounding it, as _b_ O _r k_ (fig. 1.)

The area or surface of a sector can be ascertained by multiplying the length of the arc by half the radius.

A _segment_ of a circle is the portion intercepted between an arc and its chord, as _f d n_ (fig. 1.)

The surface of a segment, as _b k r s_, can be obtained by subtracting from the area of the sector O _b k r_, the area of the triangle, _b r_ O (=15=).

=13.= _Ring._ To determine the surface of a flat ring, the area of the inner circle must be subtracted from that of the outer circle; in other words, take the difference between the areas of the two circles that fix the inner and outer diameters of the ring.

The area of a flat ring can also be calculated by adding together the internal and external diameters; then multiply the number so obtained by their difference and by the decimal fraction 0.7854 (that is, 3.1415/4). The product will be the required area.

=14.= _Angles and their measurement._ When two lines meet one another, they form an angle, as we have already seen. If we take the apex as the center of a circle, the number of degrees intercepted between the two straight lines gives a measure of this angle.

The angle measured by a quarter of a circumference, or 90°, is termed a _right angle_.

An _obtuse_ angle is greater than a right angle, and an angle that is less is termed an _acute_ angle.

=15.= =Triangles, squares, etc., and their measurement.= The triangle or plane area enclosed within three straight lines joined two and two together (A, B, C, fig. 2,) is said to be _rectangular_ when one of its angles is a right angle; it is _equilateral_ when the three sides are equal, under which circumstances the three angles are also equal; and _isosceles_ when only two sides are of equal length.

The sum of the three angles of a triangle is always equal to two right angles. If only two of the angles are known, it is thus easy to determine the third.

Similar triangles are characterized by the fact that their homologous sides (that is, the sides opposite to equal angles) are proportional.

Peculiarity of the right-angled triangle. The square described on the longest side, termed the _hypothenuse_ (B, fig. 2,) is equal to the sum of the squares described on the two other sides. Hence, it follows that, if the lengths of the two shorter sides are known, that of the hypothenuse can be ascertained by extracting the square root of the number formed by adding together the squares formed on these two sides (=5=).

[Illustration: _Fig. 2._]

If the hypothenuse is known and one of the shorter sides, the third can be determined by extracting the square root of the number formed by subtracting the square of the known side from the square of the hypothenuse.

The _surface of a triangle_ is determined by multiplying one of the sides by half the perpendicular height of the angle opposite to this side.

=16.= The _surface of a square_ or of an oblong or _rectangle_ (_a b c d_, fig. 3) is equal to the product of the base multiplied by the height.

The sum of the squares described on the four sides is equal to twice the square described on a diagonal. This diagonal divides the rectangle into two equal rectangular triangles.

=17.= The _surface of a parallelogram or lozenge_, a plane figure with four sides, opposite pairs of which are parallel (_c f g d_ and _c i j d_, fig. 3,) is equal to the product of one side multiplied by the perpendicular height of the figure.

[Illustration: _Fig. 3._]

The sum of the squares described on the four sides of a parallelogram is equal to the sum of the squares described on the two diagonals.

=18.= =Measures of various solid bodies.= The volume of a cube of parallelopiped (that is, a body bounded by six four-sided figures, every opposite two of which are parallel) is obtained by multiplying the surface of the base by the height.

The _volume_ of a straight cylinder is the product of the surface of the circle which forms its base into the height of the cylinder.

The _area_ of the curved surface of a cylinder is obtained by multiplying the circumference of the circle forming its base by the height.

The _volume_ of a tube or cylindrical ring of rectangular section, such as the arbor-nut of a barrel, or the rim of a circular balance, etc., is equal to the product of the plane surface of its base (=13=) into its height.

The _volume_ of a _right cone_ or of a _regular pyramid_ is the product of the base into a third of the height.

The _surface_ of a _sphere_ may be determined by multiplying the square of the diameter by 3.1416 (=11=).

The _volume_ of a sphere is equal to this surface multiplied by a third of the radius.

GEOMETRICAL DRAWING.

=19.= An elementary knowledge of the art of drawing, an ability to represent the outlines of objects by simple lines, is of the first importance to the watchmaker.

Such a design is obtained by projecting on to one plane all the visible points of the object represented.

Projection on a vertical plane gives an _elevation_; the object is looked at from one side.

Projection on to a horizontal plane produces a _plan_; the object is observed from above, thus giving a bird's-eye view.

The projection of a point on a vertical or horizontal plane is the foot of the perpendicular, from the given point on to the plane. Assume the line _n m_ (fig. 4), to be fixed in space; its horizontal projection will give _c d_, and its vertical projection, _r s_.

[Illustration: _Fig. 4._]

Miscellaneous details. When one portion of the object to be represented is found to pass behind other pieces so that it cannot be seen, the continuation is frequently indicated by dotted lines.

Surfaces that are situated in planes one behind the other are shaded, the more deeply according as they are farther back. This shading is produced by a number of parallel lines which may be vertical or horizontal.

Parts that are in relief are indicated by projected shadows, or by increasing the thickness of a line that would cast a shadow.

In order to distinguish the several shadings or to emphasize the lines by which they are separated, it is a very usual, though not invariable practice to assume the light to be coming from the left-hand upper corner.

When drawing a square in relief, such as _a b c d_ (fig. 3), the lines _c d b d_, will be made darkest; but if it is a recess, the lines _a b_, _a c_ should be brought into prominence by means of dark lines.

[Illustration: _Fig. 5._]

These several directions will be found useful when a hole, any cavity, a pin, a round object etc., has to be depicted, as in fig. 5. As a general rule, the thick lines should indicate the position at which a shadow would form, the light being assumed to fall on the drawing in the manner indicated above.

A _section_ shows a body as it would appear if cut in two, and one portion removed in order to expose the interior, as in fig. 6. A section is indicated by a series of parallel lines drawn close together and at an inclination of about 45° to the vertical.

[Illustration: _Fig. 6._]

In order to leave more room for important details, or to show objects that are situated behind, a piece is often broken off by an irregular line, as shown in that drawing.

Lines formed by a series of detached points sometimes serve as a means of associating several figures representing the same object looked as in different directions.

=20.= =Tracing and transfering.= These two operations are resorted to when it is required to obtain one or more copies of a picture or design already drawn.

Tracing consists in laying a piece of tissue or other translucent paper over the drawing and copying it by following over the lines that are visible with a pencil. Or ordinary paper can be used for the purpose, providing it is not too thick, if the picture be placed against the pane of a window or, what is more convenient, on a sheet of glass used as a desk and illuminated from below. When either sheet of paper is too thick to allow sufficient light to pass, one or other of the methods of transfering indicated below must be resorted to.

=21.= This operation consists in reproducing a tracing on a separate sheet of paper or on metal that is to be engraved. Either of the following methods may be adopted:

1. The picture to be transferred is fixed to a table or drawing board if tracing paper is to be used, or to a sheet of glass if only ordinary paper is available. The lines are then traced with a black lead pencil that must not be too hard. When this is finished it is laid, face downwards, on a sheet of white paper, taking care that both sheets are so fixed that they shall not slip. Apply pressure to the upper surface by tapping with a small pad made on purpose and, at the same time, gently rubbing. Experience will very soon show how hard the pad should be. Now remove the tracing, still taking care to avoid any slipping, and a faint reproduction of the design will be found on the lower sheet of paper. It is only necessary to follow over the lines with India ink. The figures will be reversed but a transfer with it in the original direction may be obtained by inverting the picture and laying it on glass so as to make a reverse tracing.

2. Lay the picture on a desk or drawing board and trace it with ink on a very transparent sheet of paper. When the ink is dry, invert the tracing and blacken the back with a No. 2 pencil. Now lay the tracing, with the ink side uppermost, on a sheet of clean paper,

taking care to avoid slipping, and go over the several lines with an agate or metal style, avoiding excessive pressure on account of the risk of tearing the paper. On removing the upper sheet an impression will be found not reversed. Go over all the lines with India ink and clean the paper with India-rubber or stale bread.

Observations. The choice of paper and pencil is not a matter of indifference. All kinds of paper do not receive an impression equally well, neither do all pencils transfer with equal facility. The Faber pencil No. 3, will generally be found best suited to such work.

In preparing drawings which you desire to preserve, as drawings of escapements, etc., a good quality of light weight bristol board will be found more desirable than the best drawing papers. White wedding bristol, about two-ply in thickness, answers admirably, and India ink lines drawn upon it will not spread as they often do on drawing papers. The prepared liquid India inks now on the market are superior to any you can prepare by grinding the sticks.

=22.= =To transfer an engraved design.= This method is available when it is desired to obtain an impression, for example, of the engraved surface of a watch case.

Procure some of the inks used by copper-plate engravers, or, in its absence, ordinary stencil ink may be used. Taking a small quantity on the end of the finger, tap it on the surface of a glass plate, in order that the ink may be distributed, leaving only a small quantity evenly spread over the finger: tap with the finger thus prepared over the watch case long enough to make sure that all the surface in relief has received some ink; take a piece of writing paper and, after slightly moistening it, spread it over this surface. Lay above this a piece of paper folded in four and pass over it in all directions any round body, such as a small tool handle, and with some pressure; then raise the papers without allowing them to slide.

If the operation has been carefully performed a very clear impression will thus be obtained of the engraved surface. The relief will be black and the hollows white, but, of course, the figure is reversed like that in a looking-glass. If required in the right direction it must be traced through to the other side of the paper.

DRAWING INSTRUMENTS.

=23.= It is needless here to describe the rule, set-square, =T=-square, bow-compass, etc., as every one knows them.

To verify the accuracy of a rule. On a perfectly flat smooth surface carefully draw, with the rule in question, a fine straight line. Then turn the rule over, hinging it as it were on the line just drawn; if quite straight the edge of the rule will exactly coincide with the line, in this new position, throughout its entire length. Each edge should be thus examined.

To verify the accuracy of a set-square. Having fixed an accurate rule on a smooth surface, place one edge of the set-square against it, and draw a line along the edge perpendicular to the rule; then, having turned the set-square, hinging it on the line just drawn, bring it against the rule and along the line. If the square is true the edge and line will coincide throughout their length.

=24.= =The Protractor.= Fig. 7 represents a common form of this instrument. It is made of horn, or, if of metal, the inner portion is cut away, leaving only a base and a semicircular arc, which is divided into 180 equal parts or degrees; a complete circle would therefore consist of 360 such degree. The point indicating the center of the arc, should be very small in order to facilitate the exact setting of it at the apex of an angle.

[Illustration: _Fig. 7._]

When an angle has to be drawn with accuracy, the protractor is unsuitable; it will be better to adopt one of the methods described at paragraph =37=, or trigonometrical methods.

=25.= =Drawing scales.= When an object is represented by a drawing, if the dimensions are the same as those of the object itself, or, rather, as they would project on to a horizontal or vertical plane, the drawing is said to be full size; but the object is generally represented either on an increased or diminished scale, which is defined, the proportions between all the parts being still, however, maintained the same.

With a view to avoid the many calculations that such a change would involve, it is usual to employ drawing scales. The following notes will sufficiently explain their construction and use.

Let it be required to reproduce a large drawing on a small scale, in such a proportion that the dimensions are reduced in the ratio of 10 to 1.

[Illustration: _Fig. 8._]

Take a straight line of indefinite length, _a b_, fig. 8, and mark out on it spaces equal to _a_ 1, which represents any measurement taken on the original object; at _c_, the 10th division, draw a perpendicular, and on it measure _c g_ equal to _a_ 1, or one-tenth of _a c_ and join _a g_.

Through the points indicating the divisions into tenths draw lines parallel to _c g_, and you will thus have a series of triangles, _d a_ 1, _d′ a_ 2, _d″ a_ 3, etc., similar to the triangle _g a c_. In virtue of a well-known property of such triangles (=15=), _d_ 1 will be one-tenth of _a_ 1; _d′_ 2 one-tenth of _a_ 2; and so on.

Thus, if a measurement taken on the object, or on a large drawing, is equal to _a x_, it will only be needful to turn the compass on the point _x_ as a center, and to observe accurately the perpendicular height, _x z_, to ascertain the corresponding measurement on the reduced scale.

Such a scale can be employed to measure meters and decimeters, or feet and inches (but in this latter case, it would have been necessary to mark off 12 instead of 10 divisions from _a_). Since _a_ 1 might be made to represent one metre; _a_ 2, two meters, etc., in virtue of the principle of the triangle already referred to, _d_ 1 will be the tenth of _a_ 1, and will therefore represent a decimeter; _d′_ 2 will represent 2 decimeters, etc. The length required to represent, say 5.3 will be ascertained by taking the distance _a_ 5, to which the distance _d″_ 3 is added. Similarly 6 feet 2 inches would be given by _a_ 6, to which _d′_ 2 is added on a 12-division scale.

=26.= The following description of one of these decimal scales, which is engraved on metal or ivory, and often included in cases of drawing instruments, will suffice to enable any one to construct a scale on this principle, that goes to a still further degree of accuracy, measuring, for example, meters, decimeters and millimeters, or yards, feet and inches.

[Illustration: _Fig. 9._]

Let A B, fig. 9, be a flat rectangular rule, divided throughout its length by parallel equidistant lines into ten strips. At right angles to these are the lines _o o′_, _a a′_, etc., separated from one another by a distance of one centimeter (doubled in the drawing in order to make the details more clear.) The first centimeter is subdivided along the two edges, A _o_, _n′ o_, into 10 equal parts or millimeters, and the division, _o_, on the upper edge is joined by an oblique line with the 1 on the lower edge, and the others by parallel oblique lines as shown in the figure. Thus _c i_ will be one-tenth of a millimeter, _s j_ two-tenths, and so on.

If the compass is opened so as to reach from _x_ to _z_, it will be seen that it covers a space of 16 millimeters and 2-10ths of a millimeter, for there are one large division (or 10 mm.), 6 smaller divisions (or millimeters) plus a fraction of a millimeter equal to _s j_ or 2-10ths of a millimeter.

=27.= =Sector.= When it is required to reduce the scale of a drawing, subject to the condition that the dimensions shall be all diminished in the ratio of two given lines, we may state the problem thus:

The longer of the two given lines is to the shorter, as any given dimensions of the old drawing is to _x_. The value of _x_ thus determined will be the corresponding dimension of the new figure.

Such a rule of three proposition would involve a considerable amount of work, and the required result can be arrived at with greater facility by the geometrical methods which forms the basis of the scale just described, or, better still, by using the sector shown in fig. 10. It consists of two brass or ivory legs hinged about a center _m_ which is at the apex of the angle _n m c_ formed by two straight lines similarly divided into equal parts.

[Illustration: _Fig. 10._]

It is employed as follows: Let us assume that a drawing has to be reduced in the ratio of the line A to the line B; set off the length A along _m n_, and suppose its extremity to be at _s_, where division number 5 occurs. Open a compass to a distance equal to B, and placing one point on _s_, open the two legs of the scale until the second point coincides exactly with the corresponding division _t_, that is, with the 5 on the other leg, _m c_. Maintaining the scale open to this amount, it is only needful, after measuring a

distance on the original drawing or object, to set it off along _m n_, and to measure the distance between its extremity and the corresponding point on the other leg; this distance will be the dimension on the reduced scale.

=28.= =Proportional compass.= This consists of two equal stems terminating with points, fig. 11. They are cut through for a portion of their length, and provided with a slide forming a hinge, that can be clamped by a screw _a_ in any position. Graduations on the two slots and a mark on the slide indicate in what position of the slide _a_, the length _a b_ (equal to _a g_) is equal to ½, ■, ¼, etc., of _a d_; and thus show what is the ratio of _g b_ to _c d_, a ratio which is independent of the extent to which the arms are opened.

[Illustration: _Fig. 11._]

=29.= =The vernier.= The vernier consists of a small graduated slide which is adapted to a graduated rule or circular arc with a view to ascertain the value of small fractional parts of the divisions marked on the rule or arc.

Let A B, in fig. 12, be a rule divided into millimeters (the proportions are enlarged in the drawing so as to avoid confusion among the lines), and let it be required to determine a length to within the tenth of a millimeter.

As the measurement is required to the tenth, take ten less one or nine of the divisions of the scale; they will extend from O to IX, and this represents the acting length of the vernier.

Subdivide the vernier into ten equal parts; it is manifest that each graduation of the vernier differs from the original subdivisions of the rule by 1-10th of a graduation of the latter. In other words, unity on the vernier is equal to 9-10ths of unity on the rule.

[Illustration: _Fig. 12._]

When the rule and vernier are placed as shown in fig. 12, so that the o on both scales coincide, the successive divisions on the rule (marked with Roman numerals for distinction) will be progressively more and more in advance of the corresponding divisions on the vernier in the following proportion:—

The marks I and 1 are 1-10th apart; the marks II and 2, 2-10ths; III and 3, 3-10ths; and so on, the mark X being 10-10ths, or one complete division in advance of 10, this division being a unit on the scale.

Thus if the vernier is caused to slide along the edge of the rule, when 1 coincides with I the vernier has advanced 1-10th; when 2 coincides with II, it has advanced 2-10ths; and so on.

Let it be required to determine the distance P _d_, fig. 13. The division 6 on the vernier coincides with a division of the scale; hence it follows that the extremity _d_ of the vernier is at a distance of 6-10ths millimeters from III, the next division of the scale to the left. The distance between P and _d_ is thus 3.6 millimeters.

[Illustration: _Fig. 13._]

With a vernier showing tenths, if two consecutive divisions of the vernier fall between two divisions on the rule, and there does not appear to be a tendency towards one side more than towards another, even when observed with a strong glass, it is possible to take an approximate reading to the twentieth.

[Illustration: _Fig. 14._]

In measuring circular arcs a curved vernier is used in place of a straight one, and its graduations are made to correspond with those on the circle as shown in fig. 14.

=30.= =Micrometer screw.= By employing a micrometer screw it is possible to measure infinitesimal amounts, but the screw must be perfectly accurate, and must work without appreciable backlash or loss of time.

[Illustration: _Fig. 15._]

Assume V, fig. 15, to be such a screw, having a pitch of 1 millimeter. It will advance by this amount with each complete rotation.

To the head of the screw is attached a disc of such a size that its rim can be divided into a number of equal parts, say a hundred. These graduations may be marks on the edge or notches cut in it when an index is required to stop in them; but the index is less

frequently met with than a simple divided straight-edge almost in contact with the disc. The divisions round the disc are numbered in ascending order as the points _c_ and _a_ separate, so that zero comes under the index or rule when these points are in contact. Readings of the numbers will thus afford a measure of the displacement of the point of the screw.

When the disc is rotated the point a will move towards or from _c_ by 1-100th of a millimeter for each division passing under the straight-edge, and one millimeter for each complete rotation. It is thus possible to obtain the dimensions of an object when it enters without play between the two jaws to within an error of about 1-100th of a millimeter if the instrument is accurately made.

If, instead of passing the object between the two jaws, it is gripped by them, the measurement will be less exact, as no account is taken of the pressure exerted and of the elasticity. (=44.=)

GEOMETRICAL DRAWINGS.

=31.= =Sketches.= It is advisable from an early age to accustom oneself to make rapid freehand sketches of objects as they present themselves to the eye. Such a sketch will help in the preparation of a more exact drawing, which involves a knowledge of the several geometrical methods given below.

A drawing may be transferred, reduced or enlarged as follows:

Draw across the original picture a number of equidistant vertical and horizontal lines, forming perfect squares, and number the two sets of lines in succession. Then draw a similar series of lines on a clean sheet of paper, setting the lines at an equal, less or greater distance apart, and copy in succession the parts of the figure that are enclosed within the several squares.

As it is not always possible to draw lines across a figure, they may be replaced by a frame carrying fine threads or wires stretched in the two directions. The frame is laid over the original drawing, which can then be copied, as above explained, on a sheet of paper divided into squares (fig. 16).

[Illustration: _Fig. 16._]

The frame may, moreover, afford assistance in the drawing of solid objects. Having placed it above or in front of the object and in contact with it, copy on to the sectional paper the contents of each corresponding square, taking care to look at the object perpendicularly. With a little practice, and by placing the eye in the correct position and always at the same distance from the frame (a distance which may be regulated by a glass), a sketch in fair proportion may easily be obtained.

[Illustration: _Fig. 17._]

=32.= =To erect a perpendicular on a straight line.= Either the compass or a set-square can be employed; the use of the latter instrument is so simple that no further reference need be made to it. Assume _a_, fig. 17, to be the point in the line _n m_ at which a perpendicular is to be drawn. On either side of _a_ measure off equal distances _a n_, _a m_; from _n_ and _m_, with a radius about equal to the distance _n m_, draw two circular arcs cutting one another. If their point of intersection _b_ be joined to _a_, the line _a b_ will be the required perpendicular.

[Illustration: _Fig. 18._]

=33.= =To erect a perpendicular at the extremity of a line.= From the extremity _c_, fig. 18, mark off four equal parts towards _s_. From _s_, with a radius equal to five such parts, describe a circular arc, and from _c_, with a radius of three such parts, describe another arc cutting the first at _d_. The line joining _c_ and _d_ will be perpendicular to _s c_.

For the square of 5 is 25, and this is equal to the square of 4 or 16 plus the square of 3 or 9. Thus the triangle _s c d_ must be right-angled (=15=).

[Illustration: _Fig. 19._]

Or the following method may be adopted: With any center _i_ and radius _i g_ (fig. 19), as large as possible, describe a circumference passing through _g_. From the point _p_, where the circle cuts the line, draw the diameter _p i h_. If the point _h_ be joined to _g_, it is the required perpendicular; for, by a property of the semicircle, the angle _h g p_ is a right angle.

[Illustration: _Fig. 20._]

=34.= =To let fall a perpendicular on a straight line.= In order to let fall a perpendicular from the point _a_ on to the line _b c_ (fig. 20), describe from _a_ as a center, a circular arc sufficiently large, cutting the straight line in two points, _b_ and _c_. From these two points, with the same opening of the compass, draw on the under side of the line two arcs that intersect. The point of intersection _o_ joined to _a_ gives the required perpendicular.

[Illustration: _Fig. 21._]

=35.= =To draw parallel straight lines.= Having fixed a good straight-edge over the drawing, as many parallel lines as are required may be drawn with the aid of a set-square which is caused to slide along the rule. They will be vertical, horizontal or inclined, according to the position of the rule, which must be set exactly perpendicular to the direction in which the parallel lines are to be drawn (fig. 21).

[Illustration: _Fig. 22._]

To draw, from a given point, a line parallel to a given line. Let _d_ be the given point, and _a b_ the given line (fig. 22). From _d_ draw the circular arc _a c_, and from _a_ where it cuts _a b_, with the same radius describe the arc _d b_. From _a_ set off on _a c_, a distance equal to _d b_. The line joining _d_ and _c_ is the required parallel.

[Illustration: _Fig. 23._]

=36.= =To subdivide a line into equal parts.= Let it be required to divide the line _p v_ (fig. 23), into five equal parts. Draw a line _p q_ inclined at any angle, and mark off on this line five equal parts of any length; join _q_, the extremity of the five lengths, and _v_, and through the points _a_, _b_, _c_, _d_, draw lines parallel to _q v_. In virtue of a property of similar triangles these lines will divide _p v_ into equal parts. It is advisable that the lines _p v_ and _p q_ should not differ very considerably in length, as, otherwise the inclination of the parallel lines to _p q_ will render it difficult to observe the exact point of intersection.

[Illustration: _Fig. 24._]

To divide a line into proportional parts. The proposition can be solved in a similar manner. Let it be required to divide a line _t r_ (fig. 24), into two sections that are to one another in the proportion of 5 to 3. On _t s_ mark off a series of equal parts given by the addition of these numbers together, that is 8; and join the last point _s_ to _r_. Then draw through _c_, the fifth division, a line parallel to _s r_. This line _c d_ will cut _t r_ into two parts, which are to one another in the proportion of 5 to 3.

By an analogous construction a fourth proportional can be graphically obtained, as already indicated in articles =25=-=27=.

=37.= =To construct an angle equal to a given angle.= The angle may be measured by means of the protractor (=24=), which then enables us to draw a similar angle; but greater accuracy is obtainable by using the compass.

[Illustration: _Fig. 25._]

Let it be required to construct at _m_ on the line _m p_ (fig. 25), an angle equal to _b a d_. With as large a radius as possible, draw from the points _a_ and _m_ the arcs _b d_ and _n p_. Measure the distance _d b_ and mark it off with the compass from _p_ on the arc _p n_. A line drawn through _m_ to the intersection of the two arcs will give the required angle equal to _b a d_.

=38.= =To subdivide an angle into 2, 4, or 8 equal parts.= In addition to the use of the protractor, the following graphic method is often given in works on geometry.

[Illustration: _Fig. 26._]

An angle _e f g_ being given (fig. 26), from its apex _f_ as a center describe the arc _e g_, and from its two points of intersection with the sides, with a radius greater than half their distance apart, draw two short arcs cutting each other at _s_. A line drawn from _f_ through the intersection _s_ will divide the angle into two equal parts.

If four divisions are needed, repeat the process on the two angles _s f e_, _s f g_, and so on for a further sub-division.

The line that divides the angle into two equal parts will also bisect or divide into two equal parts the chord and the arc _e g_.

[Illustration: _Fig. 27._]

=39.= =To find the center of a circle or of a circular arc.= Take on the circumference, or on the arc, three points _b c r_ (fig. 27). Join _b_ to _c_ and _c_ to _r_. At the middle point of each of these lines[3] erect a perpendicular. The point of intersection of these perpendiculars is the required center.

A similar method should be resorted to when it is desired to describe a circle passing through three given points.

[Illustration: _Fig. 28._]

=40.= =To connect up or associate lines.= In order to join up a straight line, such as _i j_ (fig. 28), with the curve _l p_, erect a perpendicular at _j_, and through the middle point of a chord, _l p_, draw a second perpendicular cutting the first in _k_. This point will be the center from which the curve uniting the two lines should be struck.

[Illustration: _Fig. 29._]

To unite a curve _a b_ (fig. 29), with another curve, _c x_ or _c z_, at the point _c_, first find _o_, the center of the curve _a b_, draw the line _a o_, continuing it beyond the center; join _a_ and _c_, and erect a perpendicular at the middle point of this chord. The intersection of this perpendicular with _a o_, produced if necessary, should be taken as the center for a curve uniting _b a_ with _c_.

[Illustration: _Fig. 30._]

To join up two lines inclined to each other or parallel lines of unequal length, such as _a r_, _b s_, fig. 30, draw midway between the two another line, _z d_; join the two extremities _r_ and _s_, and from these points let fall perpendiculars _r i_ and _s c_; then from _d_ draw a line perpendicular to _s r_. The point _o_ thus obtained will be the center of the arc _r d_, and _c_ will be the center for _d s_.

=41.= =To describe an ellipse.= Let _a b_ (fig. 31), be the major axis of the ellipse; divide it into three equal parts, and from the two points, _c_ and _i_, at which it is divided, with a radius equal to _i c_, draw (in pencil) two circles, intersecting in the points _x_ and _z_. Through these points draw the lines _x i g_, _x c h_, _z i f_, _z c d_.

With the center _z_ describe the arc _d f_, and from _x_ draw _h g_; the ellipse will be completed by the two arcs, _f b g_, _d a h_, of the primitive circles.

[Illustration: _Fig. 31._]

If it be required to describe an ellipse that shall have a shorter minor axis, divide the major axis into four equal parts, thus obtaining three points of sub-division. With each point as a center and with a radius equal to one of the spaces describe circles. Those to the right and left will determine the extremities of the ellipse, and the central circle will intersect the minor axis in two points which must be taken as centers for describing the top and bottom portions of the figure.

[Illustration: _Fig. 32._]

When the length of the long and short axes are given, proceed as follows (fig. 32): From the center _a_, where they intersect at right angles, mark off the distances _a n_, _a o_, equal to the difference in the length of two semi-axes. Join _n o_, and add one half of _n o_ to _a o_ measured in the direction of _a v_, thus obtaining the point _k_; with the radius _a k_ describe a circle. On this circumference will lie the four centers; _k_ for the arc _r u s_, _m_ for the arc _p v q_, _t_ and _i_ for the short arcs _q j s_, _p e r_.

The figures obtained by the methods here given closely resemble the ellipse, but are not of the strict mathematical form. It is well to acquire some facility in drawing ellipses, for the projection of a circle on a plane, when the two are neither parallel nor perpendicular, is an ellipse, and one often has occasion to describe it.

=42.= The following may be added as a mode of describing an ellipse:

The major axis and the two foci (points in this axis) being known, fix two pins in these foci. Then tie a piece of string into a loop and place it over the pins; stretch it with a pencil, the point of which is on the paper, and on moving this around in a circular direction, the string being maintained stretched, an ellipse will be described. When the string is so stretched that it lies along the major axis, the length should be such that the pencil is exactly at its end.

[Illustration: _Fig. 33._]

=43.= =To draw a spiral curve.= Draw four lines forming a small square (fig. 33). The point _o_ is taken as the center of the first arc, _i j_; _s_ is the center of _j k_; _u_ of _k l_; _i_ of _l n_. Then, to continue the curve, _o_ is again taken as the center for _n p_, and so on. This method produces a volute in which the coils are at a considerable distance apart, such as has no special applicability to horology.

[Illustration: _Fig. 34._]

As the balance-spring of a watch is partially concealed by other pieces, it is generally sufficient to represent the parts that show themselves by concentric circular arcs, or arcs described from two centers. If a more accurate representation be required, the following method may be resorted to: when working on a small scale it involves the use of the eyeglass, for the figure (fig. 34,) here given is exaggerated in order to avoid confusion in the lines, numbers, letters, etc.

A small circle having been described, it is divided into an even number of equal parts, say four; a less number than this should never be adopted. From the same center describe another circle as small as possible, which will be cut by the two diameters drawn between opposite points of division numbered 1, 2, 3, 4.

Assuming _a_ to represent the starting-point of the curve, from the center 1 with radius 1 _a_ draw the arc _a b_; from 2 with radius 2 _b_ draw the arc _b c_; from 3 with 3 _c_ draw _c d_; from 4 with 4 _d_ draw _d s_; then recommencing with 1 and the radius 1 _s_ draw _s f_, and so on.

The less the radius of the small circle and the greater its number of divisions, the closer will the successive coils be together. To secure accuracy when working on a small scale, it is advisable that the center and the several points be in a thin brass or horn plate, which is maintained in position by steady pins.

THE MICROMETRICAL DIVIDING TABLE.

=44.= This instrument is no more than a simple application of the screw to dividing straight lines, but it will suffice to enable the reader to understand the principles on which the more complicated instruments are based.

[Illustration: _Fig. 35._]

A plate, P, fig. 35, supports a bracket _a_, in which a screw, similar to the one described in paragraph =30=, is engaged by means of a collet; it rotates, being supported between this bracket and the small bearing _b_, that receives the pivot at the end of the screw.

The screw is fitted carefully into a nut _n_, which is rigidly attached to the small plate _h_; this carries a fine marker, movable on an axis, and terminating with a chisel edge or a fine diamond point, according as the instrument is to be used for engraving metal or glass; or it may be provided with a fine pencil if the object is merely to make subdivisions on a drawing.

This being understood, it will be evident that, if a rule or rod of any form be fixed by screws or otherwise between _f_ and _g_, it can be graduated by means of the marker, the screw being made to advance; the millimeter screw can be used for dividing into millimeters and fractions direct, or, with a little calculation, into fractions of an inch. Each complete rotation of the head means a displacement of the marker by a millimeter; a half turn will be half a millimeter, etc.

OTHER METHODS OF DIVIDING INTO EQUAL PARTS.

[Illustration: _Fig. 36._]

=45.= =First method.= Having fixed a sheet of drawing paper on a smooth board, draw the line M N, fig. 36, longer than the rule which is required to be divided. Then, with a compass or graduated scale, mark off a series of equidistant points, commencing at N, equal in number to the required series on the rule, and let M be the last division. With the center N and radius N M describe the circular arc _p v_, and with M as a center and the same radius, describe a second arc _r s_, intersecting the first at O. Join O with M and N. Assume _a c_ to be the rule that is to be divided into equal parts; slide it on the paper parallel to M N until the extremities, _a_ and _c_, coincide with the lines O M, O N, and are equidistant from O. This position can be easily found by the aid of a compass with one of its centers at O. Now fix the rule in position with sealing-wax, or by some other means, and, with a firm upright

pin, center the brass rule R at O, so that it can rotate round this center on the pin as a pivot. It now only remains to trace a series of lines O _k_, O _b_, O _d_, etc., with the rule, to the division points of the line M N. The line _a c_ is thus divided into as many equal parts as the line M N. The graduations will be all the more exact according as the divisions of the line M N are longer.

=46.= =Second method.= By the side of the chuck of a wheel-cutting engine, arrange a horizontal slide _y f_ fig. 37, that can travel easily in a direction perpendicular to _a_ T. A watch fusee-chain, or a very flexible spring, is fixed by one end to the chuck, and by the other to the slide at _d_. The chain or spring is kept stretched by a weight which tends to draw the slide from _f_ towards _d_.

[Illustration: _Fig. 37._]

The rule to be graduated, _a_, is now fixed on the slide, and an initial division is marked on it with a pointed rotating cutter in the position usually occupied by the wheel cutter, or else by striking a small pointed or flat-edged chisel arranged for the purpose, in such a manner as not to be liable to derangement.

Rotate the table through a definite distance; the rule _a_ will advance through the same distance; mark the second division; then having moved the division-plate through a distance equal to its first displacement, mark the third graduation, and so on. Suppose, for example, that it be required to make 30 divisions on the rule between _f_ and _d_; select on the plate the circle corresponding to twice or thrice this amount, so that the radius of the chuck may not be relatively too short, and that the chain or spring may not act at a disadvantage; take the number 60 for example:

The two marks at _d_ and _g_ on the spring indicate the length that corresponds to the straight line to be divided.

The chuck is placed in the lathe and reduced in diameter until the half circumference is exactly equal to the distance between these two marks on the spring, which thus fall on a diameter, _i g_, of the chuck.

The spring having been fixed by its two extremities, the slide with the rule attached is placed in position, so that the mark _g_ is on the line _a_ T; it will be evident from the figure that each displacement of the division-plate through one-sixtieth of its circumference will cause _a_ to advance through one-thirtieth of the space between _f_ and _d_.

Remarks.—Knowing the relation of a diameter to the circumference (as 1 : 3.1416), we can determine the diameter of the chuck at once by calculation.

Its form should be a true cylinder, and it is well to place guides that will prevent the spring or chain from assuming a helical position.

The side that carries the rule should be strictly perpendicular to _a_ T; and the portion of the spring that is not coiled on the chuck should always be parallel to this slide.

The chuck and spring must be quite clean and smooth, and the latter should be very pliable. A greater weight will be needed to keep the spring stretched than will suffice for a chain, and it must be increased as the strength of springs is greater.

The slide, _y f_, may simply travel over a horizontal surface between pins planted in two parallel lines. But it would be preferable to adopt some other method, for instance, to make this piece (F, fig. 37), travel with a little friction along a perfectly true cylindrical rod.

=47.= =Third method.= This is merely an application of the arrangement mentioned in paragraph =44=. The lathe can be employed for marking off a series of equidistant points in a straight line. Knowing the pitch of the slide-rest screw, determine the distance apart in, say, millimetres, of the required divisions, and fix the rule perfectly flat on the face-plate, which must be rendered immovable by any convenient means. Then mark the first point with the drill-stock. Advance the screw by the amount previously determined upon and mark the second point. After withdrawing the drill, again advance by the same amount and mark the third point, etc. Always be careful, before making the first mark, that the screw has already traveled some distance in the direction it will continue to move, so as to avoid backlash, or loss of time.

TO SUBDIVIDE A CIRCLE.

=48.= =To divide the circumference into equal parts.= After having drawn the circle, A, fig. 38, draw two diameters, _d a_, _b c_, at right angles to each other, dividing the circle into four equal parts. Join the points, _c a_, and divide the line, _c a_, accurately into nine equal parts.

Draw a series of circles concentric with the first, at distances apart equal to one of the divisions of _c a_, and to the number of one, two, three, etc., according as it is required to subdivide the circle, say for a pinion, into seven, eight, nine, etc., equal parts.

[Illustration: _Fig. 38._]

With a fine-pointed compass, measure off the radius of the initial circle A. Placing one point of the compass at _c_, the other point will give the position of the next leaf, and so on, all around the circumference. If the innermost circle A be selected for sub-division, six divisions will be obtained, and there will be one more division for each larger circle.

The operation will be facilitated by selecting the first circle, so that the line _a c_ contains exactly nine divisions equal to those of some scale that is accessible. Such a circle can be easily found, by first drawing the two diameters, laying the scale in the direction _c a_, and determining by trial the radius for which the first and ninth divisions correspond to _a_ and _c_ respectively.

=49.= =To divide a surface into rings of equal or proportional superficial area.= The following solution is due to M. Brocot:

Let _a d_ be the radius of a circle (fig 39), that is required to be subdivided into four rings of equal area by concentric circles. Taking _a d_ as a diameter, draw the semicircumference, _a b d_; accurately divide _a d_ into four equal parts, and at each point so obtained, erect a perpendicular. Through the intersections of these perpendiculars with the semicircle, draw a series of concentric circles; they will trace out rings, 1, 2, 3, 4, that have equal superficial areas.

If it be required to divide the surface in a given proportion, divide the line _a d_, according to that proportion.

[Illustration: _Fig. 39._]

The right-hand side of fig. 39 gives a special application of this method to the division into two equal areas of the interior of a barrel exclusive of the space occupied by the arbor-nut. If the mainspring accurately covers _i c_ when wound up, and _i j_ when unwound, it will give the greatest possible number of turns.

TIME.

=50.= Solar time is taken from the revolutions of the earth, and the watchmaker can easily get the exact solar time of any point at which he may happen to be by a little calculation from known standards. These standards are: 1. The zenith. 2. The longitude of the point of observation. 3. The difference between noon at the point of observation and noon of a known meridian either east or west of the point of observation. The zenith is that point in the heavens where the rays of the sun are in a plane exactly perpendicular to the surface of the earth at the point of observation, and when the rays of sunlight are in this plane it is noon at that point. The circumference of the earth is divided into 360 degrees or meridians of longitude, so that as the earth revolves once every twenty-four hours, each of these meridians will pass the zenith, or fixed point, in that time. In twenty-four hours there are 24 × 60 = 1,440 minutes, so that the interval between the passage of one meridian and the next will be 1,440 ÷ 360 = 4 minutes. A degree of longitude is divided like an hour, into minutes and seconds, so that

1 degree of longitude equals 4 minutes of time. 1 minute " " " 4 seconds " " 1 second " " " ½■■ or .066 seconds of time.

=51.= Thus it happens that, at a town one degree east of a given point the sun will be visible four minutes sooner, and if to the west, four minutes later than at that point. The "local," or solar time, therefore, will be four minutes earlier at the first town, and four minutes later at the second town, than it is at the point of observation.

=52.= It will be readily seen that, having any two of the three factors given above, the other can be readily found. Thus having the time of a given meridian and the local noon or meridian time, the longitude can be readily found; or, having the longitude (which can be readily obtained from a surveyor) and the time of a given meridian, "noon," can be calculated, etc. The first method is followed in calculating distances at sea; the chronometer keeping Greenwich time, and the local noon giving the longitude.

When great accuracy is necessary, however, a fixed star is used as a means of observing the exact time when a revolution of the earth is completed, as the revolution of the sun in its orbit causes a slight variation during the year. For further information on this point the reader is referred to works on astronomy.

To obviate the constantly varying time in running east or west, the railroads use the time of a given meridian over each fifteen degrees of longitude, and as each degree of longitude equals four minutes of time, it follows that only the hour is changed in

changing from one standard to another. In Europe the zero of longitude, or the time of the meridian of Greenwich is used. In the United States the time of the 75th degree, which passes through Philadelphia, is used from the 67th to the 80th degree, which comprises the territory from Princeton, Maine, to a line drawn north and south, passing through Erie and Pittsburg, Pa., and is called Eastern time. The time of the 90th meridian is used from the 80th to the 102d meridian, and is called Central time. The time of the 105th meridian is used from the 102d to the 114th meridian, and is called Mountain time. The time of the 120th meridian is used from the 114th meridian to the coast (which ends at about the 124th meridian) and is called Pacific time. The time of the various standards is telegraphed through their various territories at noon each day, and furnishes an accurate standard of comparison to all watchmakers.

=53.= In very many cities the actual or solar noon has been discarded and the railway standard adopted, thus making but one standard and removing the source of confusion and annoyance to many people. In others, however, the two standards are still used, and it becomes necessary for the watchmaker to be able to calculate both standards, in case of accident or irregularity in his regulator. Hence he should calculate his longitude within one second by means of the difference between railroad and local noon, and have the nearest surveyor correct his reckoning; then, by means of the accurate longitude and the railroad time, correct the solar time; then by means of the solar noon and the longitude calculate the railroad time. When all these calculations check each other perfectly, he possesses all the time data he needs for that place, and can correct his standard or regulator if at any time it should become irregular. The calculations are very simple, and can be easily performed from the data given above.

FOOTNOTES:

[1] Loomis' Treatise on Arithmetic.

Loomis' Treatise on Algebra.

Loomis' Elements of Geometry.

Robinson's Algebra and Geometry.

[2] Adapted from Robinson's Algebra.

[3] Determined in the manner explained for erecting a perpendicular in par. 32 except that intersecting arcs are described on both sides of the line (_n m_, fig. 17); the perpendicular will be a line joining these points of intersection.

PART II.

MATERIALS EMPLOYED IN HOROLOGY.

IRON.

=54.= Iron is an elementary body, that is to say it cannot be decomposed. It is the most tenacious of the metals, having a breaking strain of about 75 kilo. per sq. mm. (or 106,000 pounds per sq. inch) of section. Two pieces can be perfectly welded together when raised to a white heat.

In the smaller horological appliances, the metal is not employed except after conversion into steel. In common clocks it is used from motives of economy, for forming pins, screws, etc. In turret clocks, however, considerable use is made of it, many of the parts after they are formed being cemented, that is to say, having their surface rendered hard in a manner subsequently indicated (=65=).

Such a mode of manufacture is particularly applicable to pieces that are subject to a constant succession of impacts; their hardened, steelified surface resists wear, while the iron core affords security against rupture.

It is important to carefully distinguish the cases in which iron is preferable from those in which its substitution for steel serves merely to augment the profits of the manufacturer.

The fracture of a good piece of iron is characterized by long twisted fibres of a brilliant white color.

If heated frequently or carelessly, the quality of the metal is impaired—it ceases to be fibrous and looses its tenacity: in this condition it is said to be _burnt_.

It is better to work with a charcoal or gas fire, as coal acts more rapidly in rendering the metal brittle. Cold hammering, or "hammer-hardening," also makes it brittle and diminishes its tenacity, but this is again restored by a suitable annealing.

Iron dissolves slowly in dilute nitric acid; if not diluted, this acid rapidly oxidizes it. Dilute sulphuric acid dissolves the metal easily, but if concentrated, it has no action in the cold, whereas, on heating to ebullition, the iron is dissolved with evolution of sulphurous acid gas. It is also dissolved by hydrochloric acid, or aqua regia.

Iron is less magnetic than steel, especially hardened steel, which, owing to its great coercive force, is magnetized with greater difficulty, but retains its magnetism for a longer period. Indeed, _soft iron_, if properly prepared, can be magnetized and demagnetized instantaneously.

Some workmen can distinguish iron from steel by the musical note emitted on striking. A more certain method, however, consists in using dilute nitric, or sulphuric acid. If the surface remains unaltered, or nearly so, when touched with a drop of either acid, the metal is iron, but, in the case of steel, a black mark will be left, owing to the liberation of carbon.

=55.= =To Remove Rust.= The usual mode is to rub the object with a piece of oiled rag, or emery paper. It appears that more rapid and more satisfactory results are secured by using very pure petroleum, and wiping with a hempen or woolen rag.

=56.= =To Prevent Rust.= Dip iron or steel articles in a mixture of equal parts of carbolic acid and olive oil, rubbing the surface with a rag. Others rub the metal with a mercurial ointment, leaving a thin layer over the entire surface. It is stated that, if iron be dipped in a solution of carbonate of potash or soda in water, the surface will be protected against rust for a long time, and objects can be protected for any period by burying in quicklime. Rubbing the surface with plumbago has a similar effect, and Barff has pointed out that, by exposing iron to the action of steam, heated above the boiling point of water, a coating of magnetic oxide of iron is formed, which is equally serviceable.

=57.= =To restore iron and steel that has been burnt, or badly forged.= When iron is burnt, or carelessly forged, it becomes crystalline and brittle; in order to restore it to its original condition, a fresh and very careful forging is generally needed. This can be avoided by having recourse to the following method, suggested by Caron: it consists in treating the metal somewhat after the manner adopted in hardening steel.

He experimented with a bar of good iron, which was easily bent when cold, without breaking or showing any cracks. It was then burnt and became brittle when cold, the fractured surface showing brilliant shining facets.

Prepare a boiling saturated solution of sea-salt, heat the piece of iron to a bright redness, and plunge it into the bath until it is of the same temperature (about 110° C. or 230° F.) After undergoing this operation, it is found that the metal can be easily doubled in the cold, exactly as it did before being burnt.

Perret states that steel which has been deteriorated by frequent hardening can be restored as follows: Heat it short of dull redness and quench in melted tallow, repeating the operation, if necessary, when the steel may be again hardened in the ordinary manner, and will be nearly, if not quite, restored to its original condition.

CAST IRON.

=58.= This is only used in the manufacture of tools and large clocks; the employment of cast iron wheels in the striking train of such clocks has materially reduced their price.

Like steel, it is a compound body, consisting mainly of iron and carbon. Cast iron, however, differs from steel in the quantity of carbon present, for, whereas its proportion in cast iron varies from 2 per cent. upwards, there is never, in steel, an amount exceeding 1.5 per cent., and even .5 per cent. renders an iron hard, converting it into "mild" steel.

Cheapness is not the only argument in favor of the use of cast iron. In virtue of its molecular structure, this material offers a considerable resistance to a crushing strain, so that the teeth of wheels, made of carefully selected cast iron, will work for a long time without sensible wear; moreover, the founder's art has made such important advances that there is no difficulty in casting, to a constant pattern, a wheel, together with the pinion that it carries, and any other projections, etc., that may be required; this economizes labor to a very great extent.

The use of cast iron in the construction of certain classes of wheels, and parts of tools, presents advantages which we cannot afford to ignore; but it must be carefully observed that this material is not suitable in cases where great accuracy in the acting parts is required, as it cannot, like brass and steel, be conveniently worked by the turning tool or file. In recent years, however, this difficulty has been overcome by the introduction of what are termed "malleable castings," produced as follows:

=59.= =Malleable Castings.= The object is first made of ordinary cast iron, and the invention consists in rendering this malleable by the removal of the carbon that has served the very important purpose of rendering the metal fusible. In large cast iron pots, the castings are laid with alternating layers of powdered red hæmatite, and the whole is kept at a temperature of about 900° C. (1,650° F.), or cherry-red heat, for 72 hours. On cooling, the castings are found to consist of nearly pure iron, and to be perfectly malleable, and, therefore, workable.

STEEL.

=60.= The treatment of steel involves some of the most prolonged and delicate operations in the entire range of horology. If the metal is badly selected and prepared, the working of it will be laborious, difficult and unsatisfactory; the resulting object will be distorted in the hardening, and will not harden uniformly; in short, it will occasion much toil and loss of time, with very little success.

Let the young watchmaker accustom himself from the first to study the steel that he uses, so that he may be thoroughly cognizant of both its advantages and defects; he will, in the practice of his art, be amply repaid for the brief time spent in making such an examination.

=61.= Steel is not an elementary body; it is usually regarded as a carbide of iron, that is to say a combination of carbon and iron. Analysis, however, proves other substances to be usually present in almost infinitesimal quantities; their remarkable influence on the physical properties of the metal has not yet been fully investigated, but much attention is being devoted to them at the present day.

The varieties of steel are very great. What are known as _puddled_ and _natural_ steel are obtained by acting directly on cast iron. _Cementation_ is a very old method of converting bars of malleable or pure iron into steel by enclosing them in charcoal and heating the whole for several days, until the carbon has worked itself into the center of the bars in such quantity as to covert the iron into steel.

The steel obtained by the above method is very heterogeneous; in other words, the composition is not uniform throughout a given block or bar. One part is highly carbonized, whereas another part, especially towards the center, will not be sufficiently so. The _grain_, although very fine in one part, will be more coarse in another; hard particles of pure cast iron, termed "pins," are to be met with that resist the action of the graver or the file and give rise to cracks in the hardening, hammering, etc., and portions or sometimes even entire layers that have taken up no carbon whatever. The differences in the density, hardness, malleability, etc., that can be shown to exist at different points in the same bar arise from this cause.

Such faults can in part be corrected by _shearing_, an operation which consists in binding together a number of bars in a bundle, raising them to a red heat and beating them with sledge or steam hammers so as to weld them into one. The bar thus obtained is again heated, folded several times on itself, again hammered, rolled, etc., when it is termed _shear steel_. If these operations are performed carefully and without a too great heat, the quality of the steel is much improved; it is more homogeneous and can be worked with greater facility.

=62.= The discovery of the earliest method of producing _cast_ steel, thoroughly homogeneous, was made by a watchmaker, B. Huntsman, of York, and metal produced by his method is very highly prized at the present day. Many other methods have been since introduced, amongst which may be mention the Bessemer and the Siemens-Martin processes, and steel is now produced from iron of very varying quality, so that the mark _cast steel_ is now far from being a guarantee of quality. The fusion of shear or cement steel will only secure a marked superiority in its quality under two principal conditions: (1) The metal must be carefully selected, since certain qualities do not intermingle thoroughly. (2) Very great care and skill must be devoted to all the operations, the successive heatings, forging, rolling, etc.

In short, in the case of steel it is exceptionally true that we must never accept the metal merely on its own recommendation. Whatever maker's mark is selected, the results obtained will never be satisfactory unless the degree of hardness, the elasticity, cohesive force, etc., are such as will suit the metal to the special purpose to which it is to be applied as well as to the working it will

have to undergo. _Experiment can alone make us fully cognizant of the qualities of a steel._

GENERAL OBSERVATIONS.

=63.= All steels, if of good quality to begin with, will deteriorate if subjected too often or too long (according to the character of the metal) to the action of either the fire or the hammer. They will become brittle and incapable of hardening, in the end even reverting to the condition of iron.

The quality of steel becomes worse as the number of flaws, blackish filaments, more or less carbonaceous veins, and occasional particles of pure iron in its substance are greater; as its surface is _cindery_, that is to say spotted with minute black marks which become more prominent after polishing, etc.; as its fracture presents an uneven grain, etc.

Such a metal is found to vary considerably as regards hardness, elasticity, etc.; not being uniformly affected in the hardening, it becomes difficult to work with the file and almost impossible to form into a perfect cylinder in the lathe.

Other conditions being equal, these faults are characteristic of natural steel rather than of the two other varieties. At the same time, if well sheared, it becomes very elastic, and has the great advantages of not being deteriorated under the hammer and of being less ready than the other varieties to be converted into iron.

Rolling, wire-drawing and hammering occasion a molecular re-arrangement; it is necessary, therefore, to anneal the metal from time to time, as otherwise it becomes brittle or cracks.

There is a certain temperature, corresponding to each variety of steel, which cannot be exceeded without the metal being injuriously affected; this temperature must, then, be previously determined.

The grain of a piece of steel that has been superheated or _burnt_ is characterized by brilliant diamond-like particles; the mass loses its beautiful color, and resembles iron more or less according to the degree of heat applied.

Some few workmen are enabled, by long experience and a very delicate touch, to judge approximately of the quality of a steel from its weight, feel, and resonance. Metal that is of a good quality, homogeneous, and very dense, they term _full_.

SPECIAL OBSERVATIONS.

=64.= =Natural Steel.= In the case of natural steels of low quality, the fracture is usually characterized by uneven grains, a somewhat fibrous nature and a bluish tint. The grain becomes finer and more even and the surface presents more and more the appearance of a piece of coke, as the quality of metal improves. In addition to these distinctive features a natural steel of high quality can be distinguished by the fact of its being more thoroughly hardened and less liable to break when hard.

In hardening it must be raised to a higher temperature than cement steel; in other words, steel of a low quality must be heated somewhat above bright redness, while the better qualities should be heated to an orange-red, or nearly so (=77=).

=65.= =Cement Steel.= The cement steel ordinarily met with has a lamellar fracture, the lamellæ varying in form and color from the center towards the circumference. The grain is usually finer and more uniform than that of natural steel, there is seldom any appearance of fibres, veins, or flaws. The color of the fracture is greyish, tending towards blue in the ordinary qualities.

The better qualities are marked by a closer grain, a more uniform, dull, greyish-white color, exhibiting neither streaks or black spots after hardening, and by the further fact that hardening can be effected at a lower temperature. If of the very best quality, it should not require heating beyond a clear cherry-red; often even a still less degree of heat will suffice.

=66.= =Cast Steel.= Cast steel is the most homogeneous, full, and beautiful of the three classes. Several varieties exist. The fracture of cast steel, as compared with others, is smooth, compact, and of a white-grey color, resembling coke. The grain is fine and very even. The metal must be hardened at a temperature much lower than can be safely applied to other classes of steel, since it is rapidly deteriorated by heat.

Cast steel is more fusible than ordinary steel, and will fracture with ease under the hammer when heated to a blue tint, so that great care is essential in hammering it.

The metal should never be heated beyond a dull or cherry-red heat, lest it be _burnt_.

The tenacity will be increased by forging at a low temperature or even by cold hammering.

The fineness in grain, together with its high density, afford an indication that the metal can be rendered very uniformly hard; that very fine cutting edges and the most minute rods can be made of it; and that, after hardening, it can be highly and uniformly polished; in other words, that it does not exhibit spots or streaks differing in color from the mass, as is always the case with natural and cement steels. For most horological purposes (such as making pinions, staffs, pivots, etc.) cast steel is preferable. It is the only kind that can with certainty be highly polished, turned perfectly round, and that does not get distorted in the smoothing. Moreover, when wear does occur it exhibits less irregularity.

Highly-carbonized shear steel exhibits a fine, close grain that would make it easily mistaken for cast steel. They can be best distinguished by the application of dilute sulphuric acid. The side of the bar when acted on by this means exhibits lines that indicate the junctions of the several layers constituting shear steel.

DETERMINATION OF THE QUALITIES OF STEEL.

=67.= It is unnecessary to observe that as we are writing mainly for the use of practical watch and clockmakers, we shall make no reference to those elaborate systems of testing that form a remarkable feature of the engineering of the present day, but shall confine ourselves to the tests which workmen can apply for themselves.

When the grain is fine, close and homogeneous, the fracture in even curved lines and the surface of a uniform grey aspect, the metal is considered to be of good quality. It is, nevertheless, unsafe to rely too much on such indications, for a steel that has been hammered until cold will exhibit a fine close grain, whereas the grain of the same metal will be coarse and open if it was still red hot when the hammering or rolling was concluded. The grain of hardened steel, moreover, depends on the degree of heat to which it has been subjected.

When of equal quality, even if from the same maker, the grain will be finer in bars of small dimensions than in those that are larger.

Cast steel even, especially in large pieces, is not always perfectly homogeneous, as can be easily perceived on applying the file, or still better, in the lathe; an object can with difficulty be turned perfectly round, and loses its shape in the smoothing. _As a general rule it is impossible to form a reliable opinion on a specimen of steel until after it has been worked, filed, turned, and tested according to the particular use to which it is to be applied; for a steel that is excellent for making, say, a spring or a cutter, may be quite unsuitable and give most unsatisfactory results if used for making staffs or fine pivots, or the converse may be equally true._

As a preliminary test, break a piece of the metal; after having examined the fracture, form a cutting edge, harden to what seems to be a convenient degree, then sharpen and employ for cutting small pieces of iron. If the edge is in no way damaged by the iron, this may be taken as a good indication that the metal possesses body and tenacity, and that it can be hardened as much as is required for such purposes.

The following are methods of obtaining more complete information as to the homogeneity, the character of grain, the degree of hardness a given sample can attain, as well as its malleability, body, elasticity, etc.

=68.= =Homogeneity.= Place drops of dilute sulphuric acid equidistant along the surface of a bar. If the metal is homogeneous all the drops will impart the same color.

Cold hammer or hammer-harden, and then fire-harden part of the bar. Break off the extremity in order to study the fracture; if the result of this examination is satisfactory, polish the hardened end carefully, and with the aid of a glass again examine into the homogeneity of the metal. The polish will be the better and more uniform according as the steel is more homogeneous.

=69.= =Grain, hardness and temperature of hardening.= All varieties of steel do not harden to the same degree, and each requires to be heated to its own particular temperature for hardening; moreover, the character of the metal, its color, and the size of its grains vary according to the degree of heat to which it is subjected. It would be difficult to draw any exact conclusions as to the character of grain and the hardness without the following practical method, which we owe to Reaumur:

At a temperature not exceeding a dull redness, forge a piece of the steel to be tested into the form of a razor-blade, that is to say, leaving it thick on one edge and thin on the other, in the direction of its length. Then heat the blade, holding it by one end, and when the other end has reached a bright red heat, plunge the whole into water. Part of the steel will then be hard hardened. Along the

entire length of the thinner edge carefully break off the metal with a hammer or otherwise, and examine the character of grain at different points of the exposed thicker edge thus left.

As the form, color, etc., of the grain depend on the degree of heat to which each portion was subjected, it follows that we shall observe four types of grains: (1) Large, white, sparkling grains; (2) Grains that are medium sized and intermixed, some being white and sparkling, others white and dull; (3) Fine dull grains; and (4) Grains that are medium sized, but dull and ill-defined.

According as the third class of grains is observed to be more numerous than the second class, so is the fineness of the steel greater, and conversely.

This method of testing possesses, moreover, the advantage that the workman can experiment on his blade of steel with a view to determine the temperature best suited for hardening.

Grain No. 1 corresponds to a white-red heat for hardening.

Grain No. 2 corresponds to an orange-red heat for hardening.

Grain No. 3 corresponds to some shade of cherry-red heat for hardening.

Grain No. 4 corresponds to a dull red heat for hardening.

As there is some difficulty in remembering the exact points at which these several temperatures are reached we will complete this account of the mode of testing by the following:

=70.= On a thick plate of metal, maintained at an orange-red heat, place three fragments of the steel under examination, previously marking them, so as to observe the order in which they are immersed in water; and have three vessels of water standing near. As soon as one of the pieces reaches a dull cherry-red heat, allow it to slide into one of the vessels; heat the second to a medium cherry, and the third to a bright cherry-red, introducing them in succession into the water-vessels. If these pieces be examined as to the resistance they offer to breaking, and the fracture of each be compared with the fracture at different points of the razor-blade, the file being used to test hardness, we shall have sufficient evidence as to the most suitable temperature for the hardening of this particular variety of steel.

=71.= =Body.= A steel that possesses _body_ is not brittle. This quality may be tested in the following manner: Several bars of different kinds of steel, of equal dimensions and hardened as uniformly as possible, are bent until the breaking point is reached. If all the conditions of the trial are identical, those bars that stand the greatest angular deflection without breaking have the most body.

Steel that possesses body does not break as easily as that which is wanting in body. Its fracture will be, as it were, bevelled off like the mouth-piece of a whistle. If soft and fibrous, it will be characterized by parts being torn asunder.

=72.= =Elasticity.= The elasticity may be tested in a similar manner. It is proportional to the curvature or to the weight that a rod or blade of the metal under examination can support without failing to return to its initial position as soon as the weight or obstacle is removed. A sample of steel that is distorted by a weight that another specimen resists, is evidently inferior in elasticity.

=73.= =Malleability, tenacity, ductility.= A cold hammering, if carefully managed, will suffice to indicate the limits between which steel will support frequently repeated percussion, without breaking, cracking or flying.

Forge a piece, introducing it a number of times into the fire in order to ascertain whether it loses its distinctive characteristics rapidly, and whether it can be successfully forged.

It is more difficult to forge, according as it is harder and more “steely.”

The degree of malleability is indicated by the manner in which it supports hammering and rolling, and by the smallness of the dimensions to which it can be brought by such operations.

Passing the metal through a draw-plate with smooth holes, or tapping it in a screw-plate will give useful indications as to degree of ductility and tenacity.

A metal is said to be _malleable_ when it can be easily spread out under the hammer or in the laminating rolls. It is called _ductile_ when it can be reduced to very thin wire by passing through the draw-plate.

It would seem that these two properties, ductility and malleability, should always exist together, to the same degree, in any given metal, but such is not the case. Iron can be drawn into very fine wire, but cannot be reduced to sheets of relatively equal thinness; tin and lead give leaves of extreme thinness, but cannot be drawn out into very fine wires; gold and silver are both very malleable and ductile, and they rank highest as regards the possession of these properties.

Steel is more fusible and malleable than iron, but less ductile.

=74.= _Observations._ Formerly the makers of cylinder escapements preferred forged steel, and their cylinders often cracked after the hardening: modern makers employ drawn steel, and it is much preferable. At the same time they do not appear to recognize the principal reason for the difference in the two varieties of steel. It seems to us to be as follows: forged steel is malleable; drawn steel, which has passed well through the draw-plate, is ductile, and, therefore, tenacious. But tenacity in a metal is nothing else than an exceptional resistance, opposed by its particles to a fracture or separation; it follows, then that drawn steel will crack with less facility than the other.

PREPARATIONS OF STEEL.

=75.= When a variety of steel has been selected that possesses the requisite properties: that is to say, fibre and elasticity for springs; body and tenacity for circular cutters, gravers, etc., it must be prepared; in other words, it must be made so that it can be worked with ease, for steel that is badly prepared will resist both the file, the graver and the drill. It can never be turned perfectly round, and will harden unevenly.

=76.= =To anneal steel.= The commonest, and at the same time best, method consists in heating the metal to a dull, red heat, burying it in hot ashes and allowing it to cool slowly.

Steel raised to a red heat in contact with air loses a portion of its carbon, so that it is better to place the metal in a vessel of burnt clay; this is introduced into a fire which must not be too bright at first, and when the vessel has attained a red heat the fire is checked and left until the whole is quite cold.

In order to soften steel by annealing with a view to work it, engineers entirely cover the metal with dry powdered wood charcoal or dry iron filings or turnings, in a cast iron box or pot, or in a crucible, shutting up all the openings so as to protect it from the direct action of the fire and from the air. The vessel is then put in a dull fire, the heat being gradually raised until the whole has acquired the requisite temperature, which is known by observing the color (see the following table); this degree of heat is maintained for about ten minutes and the fire quenched, after which it must be allowed to gradually die out. Frequently the cooling is not complete for a day or two, and even more when the crucible is of large dimensions.

The metal will become softer, according as the cooling is more slowly effected. It is generally heated to 800° or 900° C. (1500° or 1600° F.), a cherry-red heat. When the steel is associated with brass, as in the case of a compensation balance, it is not safe to exceed 600° C. (1000° F.)

=77.= It will be useful here to give the following table, compiled by Pouillet, of the temperature, as indicated by the air-thermometer, corresponding to various colors of a heated body:

Incipient red heat corresponds to 525° C. (980° F.) Dull red " " " 700° C. (1280° F.) Incipient cherry-red " " 800° C. (1470° F.) Cherry-red " " 900° C. (1650° F.) Clear cherry-red " " 1000° C. (1830° F.) Deep orange " " 1100° C. (2010° F.) Clear orange " " 1200° C. (2190° F.) White " " 1300° C. (2370° F.) Bright white " " 1400° C. (2550° F.) Dazzling white " 1500-1600° C. (2730-2910° F.)

=78.= _Annealing or softening in water._ Instead of allowing a piece of steel to cool slowly, it may be thrown into water when heated to a temperature just below that at which it would harden. In this case the metal will not harden, but, on the contrary, become very soft. A single operation suffices for certain varieties of steel, but with others it must be repeated.

The only difficulty consists in fixing upon the precise moment at which the metal has the requisite tint (a purplish yellow or dull red), and this is more especially felt when dealing with small pieces; experience can alone guide the workman in this matter.

A skilful workman recommends the employment of water containing one-fifth of its weight of gum arabic. He also recommends that the metal be wiped over with an oiled rag, then held in the fire, and, as soon as the oil is converted into a thick smoke, and is on the point of igniting, to immerse in water.

=79.= =Hammering steel.= Watchmakers who are called upon to manipulate exceedingly small pieces of steel, can somewhat increase the body and homogeneity of the metal by a cold hammering. After annealing, the object is hammered with light, uniform blows, again annealed, and the same operation is repeated one or more times, according to the degree of malleability already acquired by the metal. Steel thus prepared has more body; the particles composing it are more closely pressed together; it files and turns well, can be heated more evenly, and is not distorted or only very slightly in hardening, providing the requisite precautions are taken.

=80.= _The hammer and anvil._ It is important that in these operations the surfaces of the hammer and anvil employed be perfectly smooth and even polished. If they are rough or cracked, if they are uneven or have a grained surface, a flaw will be produced in the body of the steel or a crack on its surface.

=81.= =To clean rough steel.= The black coating known as “scale,” which covers the surface of the metal after it has been in the fire, will rapidly spoil gravers and files, and, in addition to this, it leaves behind in them excessively hard particles that will become imbedded in the steel itself after a clean surface has been exposed. It is then essential, in order to ensure good and rapid workmanship, to previously remove this crust from the surface.

This can be done in two ways: by using a rapidly-revolving grindstone, which instantaneously removes the oxide, at the same time smoothing the surface of the steel; or by leaving it for a sufficient length of time in dilute acid, by which the superficial oxide is dissolved.

Sulphuric acid is usually preferred; in addition to the cleaning, it is said to produce an effect somewhat similar to annealing. On withdrawal from the acid, the steel must be thoroughly washed with water and wiped dry with care.

=82.= =Ordinary mode of preparing steel.= When the metal has been annealed by one of the methods indicated above, its preparation is completed by “pickling” in acid, after which it is hammered cold between an anvil and hammer (=79=, =80=). When the metal has been worked, it is heated to a bluish tint, and after cooling slowly is ready for the hardening.

=83.= _M. Covillot’s mode._ This author adopts a method whereby he obtains steel that is very soft to work and perfectly free from hard grains or “pins” of cast iron, which are so often to be met with in steel, causing it to crack in consequence of their inability to spread under the hammer.

Take some garlic, the younger the better, mix it with sufficient good walnut-oil to cover the garlic and form into a paste; then place it in an earthenware pot on the fire. When beginning to boil, heat the steel to dull redness and plunge it into the boiling paste. Withdraw it with a quantity of oil and garlic adhering; again heat to redness and plunge into the paste. This operation may be repeated two or three times. Then heat the steel, while inclosed in an iron tube or box placed on the fire, and allow the whole to cool. Finally, the steel may be finished by setting it to _cook_ (if we may use such an expression) for ten or twelve hours in the composition of garlic and nut-oil.

The last operation may be performed by setting the boiling solution over an oil-lamp, after depressing the wick in such a manner that the paste may be kept just simmering.

M. Covillot employed the same mixture for hardening the objects; but then, of course, it must be cold.

HARDENING.

=84.= It is well known that by the operation of hardening, which consists in heating a piece of steel to a red heat and immediately chilling it, the hardness is very materially increased.

Hardening increases the dimensions of the object. A steel collar adjusted to fit a cylinder will slide on more easily after hardening.

Rolled steel is more liable to be distorted in the hardening than metal which has been forged or hammer-hardened. As a general rule, when steel—especially cast steel—has been carefully annealed, cold-hammered and, after working, heated to a blue temper

and slowly cooled, it will not be distorted in the hardening, providing the heating is skillfully conducted, and if, at the moment of introducing the object vertically into the bath, the heat is evenly distributed throughout. Some practical men affirm that the mere presence of an oily layer on the surface of the water will check the tendency to distortion.

A workman frequently pretends that he has some exceptionally good solution for hardening, of which a great mystery is often made; but it is very generally admitted by those who are well-informed that these so-called secrets are a delusion and in no sense superior to pure water. There is a certain amount of truth on both sides, and the former class are somewhat justified by experiments with the various solutions enumerated below. We may, however, lay down the three following conditions as essential to the successful conduct of the operation of hardening: (1) _The steel must previously be carefully prepared and worked_; metal that has been skillfully hammered cold or below a red heat, for instance, will harden better than when not so treated; but if hammered too much or carelessly, it will crack; (2) _The method of heating_ should be such that the heat is evenly distributed throughout the object; if, on immersion, its temperature is not uniform, the degree of hardness will vary; (3) _The skill of the workman_ must enable him to detect the exact degree of heat the variety of steel can withstand, and this must on no account be exceeded, for in that case the steel will lose tenacity, will be more or less _burnt_, &c. In the case of irregular shaped articles, considerable skill is often needed to ensure that the several parts of the mass shall be cooled at, approximately, the same rate.

=85.= =Methods of hardening.= The baths used for hardening may be classed under three heads: _Tough_, _Hard_, and _Glass-hard_. It must be understood, however, that these classes may be made to merge more or less into one another, by varying the degree of temper.

=85a.= The following receipts are drawn from various sources, and the reader is recommended to select the one which he finds on trial to be best adapted to his requirements, for, as Prof. Akerman has pointed out, there are very many conditions exceedingly difficult of calculation that influence hardening, and hence it follows that a workman accustomed to hardening often considers that only one method, which he has been in the habit of employing, can be used for a certain purpose, while another equally skillful workman can only attain the same result by a method essentially different.

I. _Tough._ Tallow; tepid water; oil; resin; sealing-wax; lead; beeswax; a solution of 3 to 4 parts (by weight) of gum arabic in 100 parts of water; 1 part of soft soap in 100 parts of water; cold water with a layer of oil over it, the thickness of which varies with the degree of hardness required; 10 parts mutton suet, 5 parts resin, 2 parts sal-ammoniac, and 35 parts olive oil.

II. _Hard._ Cold water; water containing various salts, such as sal-ammoniac and sea-salt; a solution of 5 parts sea-salt and 1 part sal-ammoniac in 20 parts of water; 4 parts sulphuric acid, 50 parts sea-salt, 10 parts alcohol, and 1,000 parts water (all by weight); 4 parts sulphuric acid, 1 part nitric acid, 1 part pyroligneous acid in 1,000 parts water (to be used very cold).

III. _Glass-hard._—Mercury; nitric acid; opium; any cyanide.

=86.= As a rule it is well to employ tallow for the hardening of small objects in which hardness without brittleness is needed. Oil renders the surface harder than the interior, and soapy water has the same effect. Saline solutions generally give great hardness. Very minute drills may be hardened by simply whisking them about in the air after heating the blade to redness, and small objects may be hardened by pressing between two cold surfaces, as those of the hammer and anvil.

If hardened in nitric acid, opium, or mercury, the hardness of steel is so great that it will easily cut glass. But such steel is brittle and all the more delicate according as the precise temperature necessary (which is not very high) has been exceeded. For it must always be borne in mind that steel which has been heated too highly has deteriorated in quality and will remain brittle.

=87.= =Precautions to be observed in hardening.= In the case of delicate pieces it is necessary to avoid the use of the blow-pipe, as the current of air causes the surface to scale, and, as is well known, the metal being unevenly heated will be distorted in the hardening, and will not be uniformly hardened.

It is better to enclose the article between two pieces of ignited charcoal, or in a metal tube, or to bring it in contact with a sufficiently hot piece of metal, etc. An excellent plan is to heat the article in a bath of hot lead, or of lead and tin in proportions dependent on the temperature required. The heating is thus exceedingly uniform, and, if operating in a dark room, the temperature can be accurately judged.

When it is required to harden an object without discoloring the surface or destroying the polish, it may be placed in a tube, and completely surrounded with powdered wood charcoal, or, preferably, animal charcoal. The whole after being heated is plunged in water without the steel being in any way exposed to the air. The powder must be heaped up as a precaution against access of air. On being taken from the water, the steel is at once placed in alcohol, and if at all dull it will generally be only necessary to rub the surface with a little rouge.

It is essential that the animal charcoal be previously heated in order to expel moisture, as otherwise it would adhere to the surface and produce marks and even irregularity in the hardness.

As a rule the object must be immersed in the cooling liquid vertically in the direction of its greatest length, and if of unequal thickness, the stout portion should touch the surface first, so that the metal may cool more uniformly. In hardening large masses of steel, various devices are resorted to in order to insure uniformity in the cooling, but space prevents us from entering more fully into this interesting question.

The vessel must be of such a depth that the object will not reach the bottom until quite cold. It is liable to distortion if introduced sideways, or if the vessel is too shallow.

The method described above for protecting the surface from the action of the fire should be adopted when hardening delicate or complicated articles; but in the case of drills, for instance, a simple coating of one of the following preparations is sufficient.

When an object is hardened in a saline solution, it is well to cover it with a paste composed of water, salt and flour (some use yeast and salt for this purpose), or a thin clay. This precaution prevents any blistering or oxidation of the surface. If it be desired to avoid oxidation, and, at the same time, to restore to the steel the carbon it has lost owing to the action of the fire, it must be rolled, while still wet, in another paste, containing powdered horn or leather, or some such calcined animal matter. Delicate parts can also be protected by a layer of beeswax and olive oil made hot.

In hardening small drills, very good results are obtained by enclosing the blade in a pellet formed of prussiate of potash, lard and Castile soap, and cooling in beeswax, or the surface may be protected by a layer of soft soap.

Steel as forged, that is with the thin scale on, is less liable to break in hardening than if previously brightened, for the scale causes it to cook, and, therefore, contract more slowly. At the same time it should be borne in mind that when the surface is bright the hardness will be somewhat greater.

It will be well to warn the beginner that, if an object is not entirely immersed in the cooling liquid, it should never be held still, but rapidly moved up and down, as otherwise there is a liability to crack at that part which was level with the surface.

As a watchmaker only uses steels of the best quality, he should, in hardening never exceed a cherry-red heat, and cherry-red comprises three distinct tints (=77=); incipient cherry-red, cherry-red, and clear cherry-red. The second of these should not be exceeded in hardening cast steel, and the third should be taken as an extreme limit in the case of shear steel.

Ice-cold water should never be employed, but the extreme chill should be first taken off. Indeed, it is found that frosty weather interferes materially with the operation of hardening.

Some workmen maintain that the hardening is done better if the water has been long used for the purpose without renewal.

TEMPERING.

=88.= Hardened steel is extremely fragile, but its tenacity may be restored by _tempering_, that is to say, by heating it to a degree dependent on the amount by which its original softness has to be restored. The color of the metallic surface will gradually change as the temperature rises, each tint corresponding approximately to the degree of heat given in the following table (Stodart):

1. Very pale straw yellow 220° C. (430° F.) } 2. A shade darker yellow 235° C. (450° F.) } Tools for metal. 3. Darker straw yellow 245° C. (470° F.) } Tools for wood and 4. Still darker straw yellow 255° C. (490° F.) } screws, taps, etc. 5. Brown yellow 260° C. (500° C. 500° F.) } Hatchets, chipping 6. Yellow, tinged slightly } chisels and other with purple 270° C. (520° F.) } percussive tools, 7. Light purple 275° C. (530° F.) } saws, etc. 8. Dark purple 290° C. (550° F.) } 9. Dark blue 300° C. (570° F.) } Springs. 10. Paler blue 310° C. (590° F.) } 11. Still paler blue 320° C. (610° F.) } Too soft for the 12. Still paler blue, with tinge } above purposes. of green 335° C. (630° F.) }

=89.= It will facilitate the precise determination of these points if it be remembered that

An alloy of 1 part lead and 1 part tin (by weight) melts at 196° C. (385° F.) Metallic tin " " " 230° C. (446° F.) An alloy of 2 parts lead and 1 part tin " 240° C. (465° F.) Metallic bismuth " " " 270° C. (520° F.) An alloy of 5 parts lead and 1 part tin " 290° c. (550° F.) Metallic cadmium " " " 310° C. (590° F.) Metallic lead " " " 320° C. (608° F.)

=90.= Before proceeding to temper an object, at least one of its faces must be smoothed with pumice-stone, oilstone dust, or emery paper, and the surface must be left perfectly clean, care being taken to avoid contact with the fingers, as otherwise it will be difficult to ensure the requisite tint being obtained.

Tempered to any shade between Nos. 1 and 6 the steel will, if previously well hardened, be left too hard to be worked by a file or graver; heated beyond No. 10, it can no longer be much bent without distortion.

When the quality and the degree of hardness of steel differ, the temper corresponding to a given tint will also vary. As a rule, hardened cast steel, tempered to No. 8, will be found as soft as natural steel which has been let down to No. 9, or even to No. 10.

A piece of steel can be let down to the same tint several times in succession without altering its properties.

If a good and uniform color is desired, the steel must be highly polished, as the oxidation of rough parts will render the tint irregular. The rouge employed must not be too dry, and, if the burnisher is used, care should be taken that it acts on the entire surface. Metal of a bad quality, which will not take an even polish, can rarely be nicely blued.

When the object is finely _smoothed_ with a uniform white surface, very good results may be obtained; but in such cases the cleaning must be carefully conducted, as the presence of minute greasy particles will always render the color irregular, and may even entirely prevent its appearance.

A uniform color can only be obtained by heating the object in such a manner that its temperature is raised evenly throughout.

The tempering may be performed by placing an object on the _bluing tray_, a thin metallic plate, often covered with a thick layer of fine brass filings, which should be renewed for each operation; or on a thick piece of metal previously heated to a sufficient degree; on ignited charcoal covered with a layer of white ash; in a bath of molten metal, the temperature of which corresponds to the requisite degree of heat, or the object may be laid on the surface of such a bath, etc. Some watchmakers when letting down a piece of steel immerse it in water to check the action; but by so doing they produce an exactly contrary effect. If a piece of steel be cooled suddenly in water as soon as it assumes any given color it will be _softer_ than if left to cool in the open air (=78=).

At one of the blue tints, steel possesses its _maximum elasticity_. The exact shade varies with the different qualities of steel.

If a hardened and tempered spring has lost its initial elasticity, this may be restored or even improved upon by gently hammer-hardening, and after whitening with emery, again tempering to the proper blue tint.

=91.= A very convenient way of tempering a large number of small articles at a time, heating them with absolute uniformity, is to place them in a small vessel with sufficient tallow or cold oil to cover them; the whole is then heated to the requisite degree, which may be determined by a thermometer or by observing the smoke. When smoke is first seen to rise, the temper corresponds to No. 2 in the table (article =88=). Smoke more abundant and darker corresponds to No. 5. Black smoke still thicker, No. 7. Oil or tallow takes fire with lighted paper presented to it, No. 9. After this the oil takes fire of itself and continues to burn. If the whole of the oil is allowed to burn away, the lowest temper in the table is reached.

It is often convenient to simply smear an article with oil or tallow, and hold it over a flame or piece of hot iron. The temper can then be judged in the manner just explained.

With a view to combine the two operations of hardening and tempering, M. Caron suggested that the temperature of the water used for hardening be heated to a pre-determined degree. Thus the requisite temper may be given to gun-lock springs by heating the water in which they are hardened to 55° C. (130° F.).

TO WHITEN AND BLUE STEEL.

=92.= Some makers of watch-hands and balance-springs, when they are not satisfied with the color assumed by an object in tempering, immerse it in an acid bath, which whitens it, after which the bluing operation is repeated.

We have seen watchmakers whiten small pieces of steel with a piece of pith moistened with dilute sulphuric acid, but the method cannot be recommended.

Others fix fine steel work, a watch-hand for example, with wax on a plate, and whiten it by means of pith and polishing rouge, or a small stiff brush charged with the same material. It is then detached, by heating, and cleaned in hot alcohol.

These methods, if judiciously employed, are of great service, but it is important to remember always to thoroughly wash after the use of acid, and then to allow the object to remain for a few minutes in alcohol.

Sulphuric acid does not whiten well. It often leaves dark shades on the surface. Hydrochloric acid gives better results.

=93.= =To blue steel uniformly.= In order to secure a uniform color in tempering or bluing, it is essential that the smoothing and polishing should have been very evenly done. The surface must be perfectly clean; for otherwise parts that are greasy, or on which the rouge has remained too long, or has been too dry, will not exhibit the same tint as the rest. The heat must be uniformly distributed. This is why, when bluing screws in a perforated bluing pan, it is customary to lightly strike the handle, for the vibration and the perpetual change in the contacts ensures their receiving the heat more evenly. A similar purpose is served by placing the pieces in brass filings. Steel must not be tempered while only in contact with bodies that are bad conductors of heat, stone, either in powder or block, for example; because, as we have already observed, the distribution of heat would occur unevenly throughout the metal.

Watchmakers secure a uniform tint more easily by using an iron or copper polisher than one of any other metal.

=94.= _To blue small pieces of steel evenly._ If the foregoing precautions are carefully observed, the following methods will give satisfactory results:

First blue the object without any special regard to uniformity of color. If it proves to be imperfect, take a piece of dead wood that does not crumble too easily, or of clean pith, and whiten the surface with rouge without letting it be too dry. Small pieces thus prepared, if cleaned and blued with care, will assume a very uniform tint.

A clever mechanic assures us that he easily obtains a similar result by rubbing the surface, after it has been well smoothed, with the end of a stick that has been partly burnt in the fire.

=95.= _To blue a clock hand or a spring._ To blue a piece of steel that is of some length, a clock hand for example; clockmakers place it either on ignited charcoal, with a hole in the center for the socket, and whitened over its surface, as this indicates a degree of heat that is approximately uniform, or on a curved bluing tray perforated with holes large enough to admit the socket. The center will become violet or blue sooner than the rest, and as soon as it assumes the requisite tint, the hand must be removed, holding it with tweezers by the socket, or by the aid of a larged-sized arbor passed through it; the lower side of the hand is then placed on the edge of the charcoal or bluing tray, and removed by gradually sliding it off towards the point, more or less slowly according to the progress made with the coloring; with a little practice, the workman will soon be enabled to secure a uniform blue throughout the length, and even, if necessary, to retouch parts that have not assumed a sufficiently deep tint.

Instead of a bluing tray, a small mass of iron, with a slightly rounded surface and heated to a suitable temperature, can be employed; but the color must not form too rapidly, and this is liable to occur if the temperature of the mass is excessive. Nor should this temperature be unevenly distributed.

A spring after being whitened can be blued in the same way. Having fixed one end, it is stretched by a weight attached to the other end, and the hot iron is then passed along it at such a speed that a uniform color is secured. Of course the hot iron might be fixed and the spring passed over it. A lamp may be used, but its employment involves more attention and dexterity.

=96.= =Bluing as an indication of temper.= This subject has already been very fully considered in article =88= to =90=. When the color assumed by a piece of steel does not require to be preserved, and it is only necessary to temper the object at a certain temperature, the means best adapted to expedite the operation will naturally be sought. Thus, in factories, large numbers are tempered at once in a bath of tallow, oil, etc. The workman, in judging temper by color (=88=), must have enough experience to

enable him to determine, for a given sample of steel, what are the successive colors as well as the temperature of the bath, etc. His success is certain; but it depends on the experience, and, therefore, on the sense of sight of the operator, and, we should again add, on the knowledge he possesses of the qualities of the steel he is using.

CASE-HARDENING.

=97.= This process is often resorted to when a hard surface is required on objects of wrought iron, for example the face of an anvil. It is the exact converse of the method already described in article =59= for obtaining malleable castings, and consists in heating the object to a red heat in contact with charcoal, or some substance containing carbon; this enters into the surface iron, converting it into steel. Or after heating to a bright redness the object may be sprinkled over with prussiate of potash, returned to the fire, and after a few minutes cooled by immersion in water. When a greater thickness of steel is needed, or when dealing with large articles, they must be enclosed in wrought-iron boxes, and bedded in such substances as fragments of horn, bones, leather cuttings, etc; the box is then luted up and the whole maintained at a red heat for twelve hours, after which the fire is allowed to die out. Articles may sometimes be case-hardened by coating with a paste of arsenious acid, powdered leather, horn, or other nitrogenous body and hydrochloric acid, and then heating them to bright redness in a muffle or other suitable furnace.

INFLUENCE OF FOREIGN METALS AND METALLOIDS ON THE QUALITIES OF IRON AND STEEL.

=98.= It would be impossible to give a full account of this subject in the space at our disposal, and the reader must be referred to works on the metallurgy of iron and steel for details in regard to the remarkable influence of minute traces of phosphorus, tungsten, silicon, manganese, arsenic, etc., on the mechanical and chemical properties of those metals.

COPPER.

=99.= Copper is an elementary body of a reddish-brown color, which must not be confounded with brass, occasionally termed yellow copper. In tenacity it comes next below iron, breaking with a strain of 34 kilo. per sq. mm. of section (or 48,000 lbs. per sq. inch).

In horology, the only use made of the pure metal is for the construction of compensation pendulums on the gridiron principle, and as wire in electric clocks. It is also employed, when rolled into thin sheets, for a base to receive the enamel of watch dials, in consequence of its expansion being about the same as that of the enamel, which does not therefore crack in the cooling.

The copper of commerce is seldom pure, and this gives rise to many of the imperfections met with in ordinary brass.

ZINC.

=100.= This is an elementary metallic body of a bluish white color. It is used in the form of rods, for compensation pendulums.

It must be obtained of great purity, whether it is employed by itself or to alloy with another metal. The presence of foreign bodies in zinc, even in very small quantities, has a marked influence on the physical properties of an alloy into which it enters.

The purer the metal the more easily will it roll, and this fact can be taken advantage of as a test of quality.

Although very brittle at 0° C. (32° F.) and 200°C. (400° F.), it has a maximum malleability at about 100° C. (212° F.), the boiling point of water; it should, then, be heated to this degree before bending, rolling, hammering, etc.

It may be annealed in boiling water, or by heating to such a temperature that water hisses when allowed to drop on to it.

It melts at 420° C. (790° F.) and volatilizes if raised to a red heat.

A sudden cooling, or the presence of arsenic or antimony, will render zinc brittle. It must not be melted in cast iron vessels, as the quality of zinc is deteriorated by the small quantity of iron it takes up under such circumstances.

This metal possesses a great affinity for oxygen, and therefore oxidizes very readily when fused.

It is usual, before pouring zinc that is intended for rolling, to throw some pieces of the solid metal into the molten mass, the object being to somewhat reduce the temperature, and thus prevent a too rapid cooling, as, in that case, zinc is very brittle.

BRASS.

=101.= Pure copper is difficult to work with the graver or file, but such is not the case when this metal is alloyed with zinc; we then obtain brass, or, as it is sometimes termed, yellow copper.

Alloys containing copper, zinc, and tin are termed bronzes.

If a small quantity of lead, about 1 per cent. of its weight, be added to brass, it renders the metal less fibrous, imparting to it a certain degree of brittleness so that it is more easily worked with the graver, file, drill, or the saw.

When the brass is required to be hammered, a portion of the lead is replaced by tin; by this means the metal becomes more malleable, or, in terms of the workshop, soft.

The color, tenacity, ductility, malleability, etc., vary with the percentage composition of the alloy. It is, then, of the utmost importance that a watchmaker be able to test and select the brass before employing it in his work; metal that is excellent for wire-drawing, for example, would be utterly useless for making an escape wheel, since it would become distorted in the cutting in consequence of its ductility. It belongs, in fact, to the class of metals that will extend under the hammer without hardening (very soft brasses).

The following is given as an analysis of brass very frequently employed in horology: copper, 66 per cent., zinc, 33 per cent.; and lead, 1 per cent. But it must not be forgotten that this is only to be taken as a mean. Both the proportions and the qualities vary with different makers, doubtless also according to the degree of purity of the metals employed in their manufacture.

=102.= =To select brass.= By following the directions given below any watchmaker should be able to select the brass best suited to his special requirements.

When the copper is in excess, zinc being proportionately reduced, the brass is usually soft and of a beautiful golden color. On the other hand, as the proportion of zinc is increased, the brass becomes more and more brittle, and at the same time, more fusible; the color changes to a light yellow, ultimately becoming greyish-white, and brass of this nature is said to be "hard."

Very soft brass chokes the file, and spreads without hardening under the hammer; very hard brass, on the other hand, is fragile, liable to crack when hammered cold, and breaks in passing through the draw-plate.

Metal of a good yellow shade, intermediate between the golden and the pale yellow color, passes well through the draw-plate, spreads out slowly under the hammer, but without cracking, until of about half the initial thickness, and then resists the further action of the hammer, which rebounds from it; such brass is usually found to be of good quality for watchwork.

A sheet of brass is rarely homogeneous. If, after pouring, the metal has been allowed to cool slowly, the interior will be crystalline, and there will be an uneven fracture. This will cause the tenacity, etc., to vary throughout the mass. Similar differences are occasionally to be observed between the two faces of the same plate, due to the phenomenon of _liquation_; that is to say, to a tendency that characterizes certain metals when melted together to separate from one another when the cooling is not affected under proper conditions.

If the two surfaces of a plate be scraped clean at several points, and drops, as nearly equal as possible, of very pure watch oil, be placed on these clean surfaces, it may be taken as a rough indication that the metals are uniformly distributed if the successive shades of color of the oil as time goes on are the same at all the points experimented upon.

Some watchmakers heat the brass to a red heat (which must never be exceeded), and plunge it into nitric acid (equal parts acid and water). By this means the entire surface is cleaned, and the above examination is facilitated.

HAMMER HARDENING OF BRASS.

=103.= =Plates.= The selection of the metal will depend on the purpose for which it is intended, and the thickness must be such that, when hammered till of sufficient hardness, it will approximately equal one dimension of the required object; for it is advisable to remove as little of the surface metal as possible, a plate always hardening much more at the surface than in the interior.

There is considerable difficulty in indicating clearly in a book the exact mode of conducting the operation of hammer-hardening, and the assistance of a competent master is essential, at any rate for the first few trials. It must suffice to point out that the anvil, with a slightly convex surface, and the hammer, of sufficient weight, must be in very good condition and, if possible, polished on their

faces; the head of the latter should be rather convex, and the pene or chisel end somewhat broad and gently rounded off in all directions, for it will be needed as a means of bending the metal upwards; the curvature being such that there is not a danger of starting a crack, etc., by its means. We have already spoken of these two tools (=79=, =80=); it is only necessary to add that a thick straw pad should be placed under the anvil or block.

When one is compelled to use brass that is too thick, so that there is much work to be done with the hammer to reduce the thickness to what is required, it is a good plan to commence by elongating the metal in one direction, striking with the pene of the hammer a series of parallel blows in the direction of the required elongation; when the thickness is two or three times that ultimately needed, the surface is smoothed with the hammer-head and annealed; then it is brought to the right thickness by another hammering in the manner explained below, but it should be again pointed out that, when possible, metal of a suitable thickness ought to be taken in the first instance, since too much hammering has a detrimental effect.

Before hammer-hardening a plate, it must be dressed, an operation which consists in rounding off the edges very carefully in order to prevent their cracking, and in rounding the bottom and sides of internal angles which, without such a precaution would occasion a rupture. After this is completed, proceed to the hardening, using a rather heavy hammer, and giving sharp blows along lines parallel to the sides of the plate; commence from one of the corners in the case of a square plate; and with a round plate let the blows be in circles. In the latter case, work from the circumference towards the center, at the same time gradually increasing the force of the blows, since the metal opposes a greater resistance towards the center. If the work is done evenly and without hurrying, the surface will remain fairly flat, a fact which should be verified from time to time by the aid of a metal rule.

Round plates are sometimes hardened by commencing to hammer in the center and working towards the circumference along two radii in opposite directions; that is along a diameter. This first diameter is then crossed by another at right angles; the intervals are filled in with other diameters that must not touch until the entire surface is covered, always taking care to work from the center towards the circumference.

When the metal is thin only the hammer-head is used, but beyond a certain thickness the pene of the hammer must be employed until about half the required thickness is reached; the surface is planished and the hardening finished with the face.

Blows that are irregular, too hard or roughly given, will cause the metal to crack. Hurried working will disturb the molecular grouping of the alloy; it will at the same time be heated and therefore softened, thus losing all the good qualities that are anticipated from hammer-hardening, namely increased body and elasticity. It was in order to avoid this heating that the old watchmakers used to hammer the brass in cold water, an excellent precaution which is too much neglected at the present day.

Brass that is badly hammered, the blows being violent or irregular, will spring out of shape on being cut and occasionally crack when gilding.

If during the process of hammering, a crack is observed to be commencing at the edge, it must be removed with a rat-tail file, all sharp angles being rounded off; and when cracks immediately reappear on continuing the operation, it is an indication that the metal cannot support any further hammering cold.

If brass is compact or well forged it may be relied upon to preserve the oil at pivots, etc., better, as oil is decomposed more rapidly in presence of a finely divided metal.

=104.= =Brass rods.= Rods having a square section must only be hammered on two opposite faces.

A rod of square section can be hammered on all four faces but it must be first filed perfectly square; the hammering must not be pushed too far, and the four angles must be maintained right angles. If some are made obtuse and others acute, a flaw will be produced in the direction of a diagonal.

The three following methods are employed in the case of round rods:

The first consists in hammering over the entire surface, the rod being at the same time rotated on the anvil by hand; but this operation must not be much prolonged, as the metal is liable to crack lengthwise.

The second method consists in reducing the diameter of an annealed brass rod to about one-half or two-thirds its initial amount by causing it to pass in succession through a number of holes of the draw-plate.

When the third method, which is due to Brocot, is adopted, one extremity of the brass rod is gripped in the bench vise and the other end in a hand vise, which is then caused to rotate round the rod as an axis. If the torsion be continued until the metal is on the point of breaking, it will be found to be very effectually hardened. This method is resorted to with advantage for hardening pin-wire and the metal for making pillars.

TO ANNEAL BRASS.

=105.= When it is necessary to considerably reduce the dimensions of a piece of brass, either with the hammer, rolls or draw-plate, it must be annealed from time to time.

The metal should not be heated to redness; it is supposed, rightly or wrongly, that such a proceedings especially if repeated, separates a portion of the zinc, or at least changes the mode in which it is associated with the copper. Brass should be heated slowly and uniformly, in a moderate fire, until the temperature is such that drops of water thrown onto the surface are rapidly converted into vapour, or paper turns yellow and begins to smoke. It is then withdrawn from the fire and allowed to cool.

Brass is brittle when hot, so that it can only be worked cold.

When brass is annealed, just as when steel is tempered, the metal should not be allowed to rest on a bad conductor of heat, such as wood or stone, because there will be a tendency to uneven distribution of the heat throughout the metal.

CAST BRASS.

=106.= This is usually brittle, owing to the fact that the copper employed in its manufacture consists, as a rule, of all sorts of scrap, from good or bad metal; moreover, from motives of economy, the proportion of zinc is generally increased and, in pouring, the precautions essential to avoid the effects of liquation (=102=), etc., are frequently neglected. Such an alloy must never be used for small objects, it must be entirely excluded from a watch, and in a clock only such pivots as are called upon to perform an insignificant amount of work should be allowed to run in it.

In order to avoid injuring the file, or embedding in the metal any particles of the hard coating of oxide that always covers rough castings, it is usual to dip the object in dilute nitric or sulphuric acid (=155=), by which the oxide is dissolved.

TIN.

=107.= This is an elementary body, almost as white as silver and having a breaking strain of only 8 kilo. per sq. mm. of section (or 11,300 lbs. per sq. inch.)

Watchmakers use it in making solder. It is also sometimes used in the form of plates or rods for polishing with rouge, and it is said to be much more efficient when very pure.

If a strip of pure tin is bent, a crackling noise, termed the “crying” of tin, is heard. After frequent bending, the metal loses this property.

The degree of purity may be judged:

(1) By the loudness of the “cry,” which is found to be greater as the tin is purer;

(2) By the relative lightness of two balls of equal size, one of which is formed of very pure tin and used as a standard;

(3) By pouring the metal, when just melted, in a mould 1 or 2 centimetres (about ¾ inch) in diameter. If tin is pure, when cast into plates or ingots, the surface will be perfectly smooth, without exhibiting any sign of crystallization at the moment of solidification, whereas the presence of small quantities of foreign metals causes it to be covered with a network of needle-formed crystals, which are the more numerous according as the metal is less pure.

The Banca tin is almost chemically pure; English tin is also very pure; but others contain a small percentage of copper, lead, iron, or arsenic.

BRONZE.

=108.= Bronze is an alloy, in very variable proportions, of copper and tin, to which may be added, according to circumstances, a small percentage of lead or zinc, or even iron, when it is desired to increase the hardness or tenacity.

As a rule, this alloy is tough and hard to work; it is especially used for parts of large machines that are subjected to considerable pressure.

The fusion and casting of bronze require special precautions, for the proportion between the metals is liable to vary through oxidation of the tin, which then goes to form a dross, and the composition may vary throughout the mass. It sometimes results from this that the bronze bearings for the pivots in large clocks are not even as good as ordinary brass, and wear away more rapidly than the pivots.

Bronze is also used by watchmakers for making plates or small rods for polishers, and for the bells of clocks. Bell-metal contains about 78 per cent. of copper and 22 per cent. of tin; it has a beautiful fracture, and is very fusible and sonorous. The addition of any other metal is rather prejudicial than otherwise; this explains why so many clock bells are wanting in sonorousness.

An impediment to the use of bronze is its want of malleability; but Dronier has recently pointed out that such alloys may be rendered perfectly ductile and malleable by adding from ½ to 2 per cent. of mercury. These alloys are said to be less oxidizable than ordinary bronzes, and at the same time more hard, elastic, resisting and sonorous.

STERRO.

=109.= This is an alloy containing 56 per cent copper, 41 zinc, 2 tin and 1 iron. It resembles a reddish-colored brass, and has been much used in Vienna, where it is considered superior to brass from the point of view of ductility, tenacity and malleability.

An experienced horologist, M. Grossmann, made satisfactory lever escape-wheels of it, and he considers it to be superior to the best brass in regard to both density and elasticity. At the same time he points out that it clogs the cutter, and the color is inferior to that of good hard brass.

LEAD.

=110.= A metal with a brilliant bluish grey lustre, which rapidly becomes dull when exposed to the air. It is very malleable and ductile. It breaks with a strain of 2.9 kilo. per sq. mm. section (4,000 lbs. per sq. inch), but possesses extreme flexibility.

Lead is not used in horology, except as a constituent of solders; in these, however, it plays a very important part. It is occasionally used in the pure state as a lap for applying polishing materials, but more frequently alloyed with tin, by which hardness is imparted to the metal, the alloy being known as “pewter.”

NICKEL.

=111.= An elementary metallic body of a greyish-white color, resembling that of platinum. With care it can be forged when hot and formed into plates; its structure in that case is fibrous. Its hardness is the same as that of iron, and nickel will take a high polish. Next to iron, it is the most powerfully magnetic of all metals.

It can be caused to alloy with many other metals—notably iron, cobalt, copper, zinc, tin, and antimony. According to Stodart and Faraday, an alloy of 33 parts iron and 1 part nickel is as malleable as the former metal, but less liable to rust. Fleitmann has recently shown that by the addition of about 1-10th per cent of magnesium, nickel is rendered perfectly malleable and ductile, capable of being drawn into wires or rolled into sheets, and Garnier finds that 3-10ths per cent of phosphorus has a similar effect.

Nickel is useful as a coating for objects that are not subjected to friction, for preserving them from the action of the air. It takes a beautiful polish, and is not tarnished by being touched.

GERMAN SILVER.

=112.= Although the proportion of copper in this alloy is considerably greater than that of nickel, watchmakers frequently apply the latter name to it, doubtless on account of the beautiful polish of which the metal is capable and the comparative inoxidizability which it derives from the presence of nickel.

German silver is an alloy of copper, nickel and zinc, with the occasional admixture of a small proportion of iron or tin. When used in the construction of objects that require soldering, 2 per cent. of lead is added.

The alloy usually employed in horology is very malleable; it has a mean composition: copper, 60 per cent; nickel, 20 per cent; and zinc, 20 per cent. That containing 58 per cent copper, 14 nickel, 25 zinc, and 3 iron, is said to be highly elastic.

The following useful details with regard to the employment of German silver for watchwork are due to M. C. E. Jacot.

Watch movements have been made of this alloy for the past thirty years; it was long thought that the taste would die out, but, on the other hand, the demand for "nickel" movements increases each year.

The alloy is better prepared at the present day; it has a beautiful grayish-white colour, it is more malleable, and better to work than formerly, but still not so easy as brass. The latter alloy is less detrimental to the file, and can be turned and drilled more rapidly.

German silver is only used for the plates, cocks and bars. The barrels and wheels are of brass, and surfaces exposed to friction, such as the center pivot-hole (all other holes being jewelled) are bushed with the same metal, for it is observed that in presence of nickel oil is rapidly blackened and the pivots wear sooner than when working in good brass.

The color remains unaltered for a long time if the surface has been carefully smoothed in the first instance; and if cleansed with soap and water, its original freshness can be to a great extent restored. Some watchmakers prefer to employ chemical preparations for cleaning the metal.

The following is recommended as very effective for this purpose: Mix 50 parts alcohol, 1 part sulphuric, and one part nitric acid. Allow the pieces to remain in this liquid for 10 or 15 seconds, wash with cold water, and subsequently with alcohol, dry with a soft rag or in boxwood saw dust.

GOLD.

=113.= An elementary body, the most beautiful and the most valuable of all the ordinary metals. In the unalloyed state it has a pure yellow color, and when reduced to extremely thin leaves, appears green by transmitted light. It is the most malleable and ductile of all the metals, but its tenacity is low.

Gold resembles platinum, silver, iron, etc., in being capable of welding, that is to say, two pieces of the metal can be united without previous fusion. Indeed, by the application of great pressure it can be made to weld when cold.

It is insoluble except in aqua regia (a mixture of 1 part nitric acid and 4 parts hydrochloric acid), alkaline persulphides and selenic acid. Chlorine, phosphorus, and a few other substances can be made to combine with it by the acid of heat.

It is as a preservative, that is applied in layers termed "gilding," that gold is principally used in watchwork, and some details will be found on this subject under "Gilding," (articles =142=-=153=). Owing to its softness the metal is not used in a pure state, but usually alloyed with copper. The principal alloys in use in this country are:

22 parts (carats) gold, 2 parts (carats) copper, for coin and wedding rings.

18 parts gold, 6 parts copper, for high-class jewelry and watch-cases.

15 parts gold, 9 parts copper, for ordinary jewelry.

12 parts gold, 12 parts copper; and 9 parts gold, 15 parts copper, for common jewelry.

The alloys used for soldering gold will be described under "Solders" (=126=).

Alloys of gold with silver and copper have been employed for making watch wheels; they wear well, and will take a beautiful polish, which is maintained for a longer time than in the case of brass wheels.

Chronometer balance-springs and the suspension-springs for astronomical clocks have also been made of gold-copper or gold-silver alloys rolled and hardened (=591=.) If carefully prepared, they maintain their elasticity unimpaired for a long period, and there is no liability to rust.

The dilatation for a given change of temperature is, however, greater than that of steel, so that a greater compensating effect becomes necessary, but this inconvenience is partially compensated for by its inoxidizability and the fact that it is not liable to become magnetic.

SILVER.

=114.= This metal in an unalloyed state is too soft for use in horology; its principal use is for cases, and as a constituent of solders.

Houriet made watch wheels of an alloy containing 2 parts silver to 1 part 18-carat gold, and he affirmed that this alloy became polished at the acting surfaces of the teeth. Jurgensen states that chronometer escape-wheels made of this alloy, carefully hammered, do not require oil at the points of their teeth.

Dumesnil proposed an alloy of 2 parts copper, 1 part silver, and 1 part zinc, all perfectly pure. Lecocq made chronometer balances in which the brass was replaced by pure silver deposited on the surface of the steel by electrolysis, thus avoiding the use of a fire. The compensation is said to have been very efficient.

ALUMINIUM AND ALUMINIUM BRONZE.

=115.= Aluminium is an extremely light elementary body, having a density of only 2.56; with equal bulks, therefore, it will weigh only about as quarter as much as silver. As its capacity for heat is very great, this metal is observed to heat or cool more slowly than other metals.

Pure, or in a slightly alloyed state, it has not been used in horology, except for pendulum rods and large hands in regulator clocks; in short, it can be employed where lightness is the principal quality in view.

It is extremely ductile. The presence of 1-100th part of bismuth, however, renders the metal somewhat brittle, and it develops cracks under the hammer. Traces of iron also decrease its malleability.

An alloy of 5 parts silver and 95 aluminium can be as easily worked as the pure metal, but is harder and takes a better polish.

We would add a curious observation of M. Redier: After passing a piece of aluminium several times through the draw-plate, he observed that the elongation had only occurred at the surface; for on cutting the wire at different points, he noticed that, throughout a portion of the length, the metal was hollow, a very fine capillary tube being thus formed.

=116.= _Aluminium Bronze_ is an alloy of aluminium with copper. A alloy of 5 parts of the former to 95 of the latter has a beautiful golden color, but if the proportion is changed to 10 and 90 parts respectively, we obtain the most serviceable and the most easily worked alloy.

This bronze can be forged at a cherry-red heat, and even near its melting point; and its thickness can be reduced to a very small amount under the hammer. It is easily filed and turned, but does not possess any special advantage over brass, which is less detrimental to the file; the density is 7.7, very little below that of brass, 8.4.

It appears from a considerable number of experiments that it might be used with advantage for the bearings of axes that rotate with high velocities. It resists wear better than any other metal. In the experiments made by Foucault to demonstrate the rotation of the earth by means of the pendulum, he found that an aluminum bronze wire lasted for the longest period. Its tenacity is equal to that of iron. It has been shown that slide-bars of locomotives made of this bronze resist wear twice as long as those formed of the ordinary bronze. There would then be an advantage in using it for the bearings of foot-lathes, etc.

Grossman asserts that lever escape-wheels of this metal have proved satisfactory, and he makes the following observation on the subject. If aluminium bronze be reduced to three-fourths of its original thickness by hammering, it will begin to crack. This can be prevented by heating to a red heat and plunging into water; it can then be again reduced by one-fourth of its thickness, and again annealed, and so on. He reduced the thickness from 2.5 millimeter to 0.2 millimeter, and the metal resisted for a long period repeated flexures backwards and forwards; and he observes that no other metal, after being so much compressed, would possess the same marvellous degree of tenacity.

In order to obtain aluminium bronze of the best quality, the copper should be absolutely pure, and, in the manufacture, the alloy must be melted and forged two or three times in succession, as by this means the strength and tenacity are increased, and the

metal can be more easily worked.

The beautiful golden color possessed by certain of these bronzes when polished, has caused them to be used for cheap watch-cases, but they always tarnish at those parts that are not subject to daily wear.

MERCURY.

=117.= This is the only metal liquid at the ordinary temperature; it solidifies at -40° C. (-40° F.). It possesses a high metallic lustre, resembling silver, but with a slightly bluish tint, and does not oxidize at ordinary temperatures.

Mercury alloys with many other metals, forming amalgams, and as small a quantity as 1-40th per cent of lead suffices to entirely alter its character. The presence of such traces can be easily detected by the liquid wetting glass or china, and therefore forming a tail when a vessel containing it is tilted.

The commercial metal is rarely pure, but the greater portion of the lead, tin, bismuth or copper, by which it is contaminated, can be removed by distillation. The most convenient method consists, however, in agitating the metal with either dilute nitric acid, a solution of mercurous nitrate, strong sulphuric acid, a solution of corrosive sublimate or of perchloride of iron, and subsequent washing with distilled water. When mercury is only contaminated with mechanical impurities, they can be very effectually removed by agitating with powdered loaf sugar.

This metal has many uses in the arts, for the construction of thermometers, barometers; for plating, etc.; in horology it is used for compensation pendulums, and has also been occasionally used for compensation balances.

PLATINUM.

=118.= This elementary body is almost as white as silver, takes a brilliant polish, and is highly ductile and malleable. It is the heaviest of the ordinary metals, the least expansive when heated, and has a breaking strain of 40 kilo. per sq. mm. section (56,500 lbs. per sq. inch.).

Platinum is infusible, except at the high temperatures attainable with the oxy-hydrogen blow-pipe. At a white heat, however, it softens, and can be forged and welded. It is unacted upon by the air at any temperature, and is insoluble in acids, except aqua regia (=155=), although acted on by certain alkalies.

This metal is used in the construction of scientific instruments, and for objects that are exposed to the air, as, for example, sun dials. Alloyed with irridium, (a rare metal of the same group) it possesses an excellent and unalterable surface for fine engraving, as the scales of astronomical instruments, etc. This alloy has also been adopted for the construction of international standards of length and weight.

Platinum is much employed for chemical apparatus, in consequence of its being unacted on by acids, and its non-liability to melt in ordinary furnaces. Both the pure metal and its alloys with silver have been employed in the form of wire for bushing the pivot-holes of watches, and in sheets for cutting out cocks and wheels, but the results obtained were not as good as with good brass. As a rule, such wheels are found to occasion a rapid wear of pinion leaves.

Attempts have also been made to construct balance-springs of this metal, but we are informed that they were not found to possess any sufficient advantages.

It is advisable to heat platinum in a spirit lamp or Bunsen burner; the naked flame is objectionable, because, being charged with a certain amount of carbon, it deteriorates the metal.

PALLADIUM.

=119.= This metal resembles silver rather than platinum, and is almost as infusible as the latter metal. It has a density of 12.5. When heated in contact with air it becomes blue, owing to the formation of an oxide. It possesses the remarkable power of absorbing (or _occluding_) about 900 times its own volume of hydrogen, if attached to the negative pole of a battery in acidulated water; its bulk is increased slightly by this charge, and, on expelling the gas by the aid of heat, the metal shrinks to less than its initial dimensions. Palladium is useful for the graduated scales of scientific instruments, since it is not discolored by sulphurous acid. It forms alloys with most of the metals and some of these can be hardened like steel. If 100 parts of steel be alloyed with 1

part of this metal, the resulting alloy is said to be excellent for making scientific instruments, and an alloy of 24 parts palladium, 44 silver, 72 gold, and 92 copper has been recommended for use in horology.

M. Paillard, of Geneva, has introduced balance-springs made of an alloy, whose composition is not given, possessing the following advantages: they are non-magnetic, their tenacity is considerable, are not tarnished by the air, sulphurous acid, or sea water; nor are they distorted by heating, and, on cooling, they recover their original elasticity, which is equal to that of steel hardened and tempered to a blue color. The co-efficient of expansion of this alloy is rather less than that of steel.

CHARACTERISTIC PROPERTIES OF ALLOYS.

=120.= _Density._ This is sometimes rather greater and sometimes less than that deduced from the densities of the constituent metals,[4] but no exact law has been discovered in regard to this question.

Hardness, Ductility, Tenacity. Alloys are usually harder, more brittle, and less ductile and tenacious than the most ductile and tenacious constituent metal.

Elasticity. The co-efficient of elasticity of an alloy generally approximates closely to the mean of the co-efficients of its constituent metals.

Expansion. The co-efficient of linear expansion of an alloy, that is to say, the number representing the proportional part of its length by which it increases for each degree rise of temperature, may be approximately estimated as follows: multiply the linear co-efficient of each constituent metal by the percentage of it present in the alloy, and divide by its density. Add together the several numbers thus obtained. Multiply this sum by the density of the alloy (which must be experimentally determined) and divide by 100. The resulting figure is the required linear co-efficient (=122=).

Fusibility. Alloys are always more fusible than the least fusible of their component metals, and often more so than any one of them.

Oxidation. As a rule, the air acts with less energy on alloys than on their constituent metals. There are, however, cases in which the converse is the case.

Action of acids. This is generally similar to the action on the predominating metal.

Observations. Alloys formed of metals that differ materially in density are rarely homogeneous, especially if they have been allowed to cool slowly. It is, then, essential that they be thoroughly stirred and cooled rapidly. It is for this reason that alloys are frequently poured out on to a flagstone to cool, or that they are compressed after pouring, whereby the formation of crystals is prevented.

=121.= =Metals and alloys.= The following table gives the more important physical properties of the metals and alloys generally met with, and will be found useful for reference. The precise meaning of each number may be gathered from the notes in paragraph =122=.

+------------------+------------+----------+-----------------------+ | | Specific | Degree | Linear Expansion | | METALS. | Gravity. | of | per | | | (Water=1) | Hardness | 1° Fahr. 1° Cent. | +------------------+------------+----------+-----------+-----------+ |Aluminium (115) | 2.56 | -- | 0.0000123 | 0.0000222 | | " Bronze (116)| 7.7 | -- | -- | -- | |Brass, Drawn (101) | 8.54 | -- | 0.0000107 | 0.0000193 | | " Cast (106) | 8.10 | -- | 0.0000104 | 0.0000187 | |Bronze (108) | 8.40 | -- | 0.0000100 | 0.0000180 | |Copper (99) | 8.94 | 2.5-3 | 0.0000102 | 0.0000183 | |German Silver (112)| -- | -- | -- | -- | |Gold (113) | 19.26 | 2.5-3 | 0.0000077 | 0.0000138 | |Iron, Wrought (54) | 7.84 | 4.5 | 0.0000066 | 0.0000119 | | " Cast (58) | 6.9 to 7.5 | -- | 0.0000062 | 0.0000112 | |Lead (110) | 11.33 | 1.5 | 0.0000167 | 0.0000301 | |Mercury (117) | 15.60 | -- | 0.000101 | 0.000182 | |Nickel (111) | 8.82 | 5 | [cubical | [cubical | |Palladium (119) | 11.80 | 4.5-5 | -- | -- | |Platinum (118) | 21.50 | 4-4.5 | 0.000005 | 0.000009 | |Silver (114) | 10.57 | 2.5-3 | 0.0000111 | 0.0000190 | |Steel (60) | 7.72 | 6-7(hard)| 0.0000057 | 0.0000103 | |Sterro (109) | -- | -- | -- | -- | |Tin (107) | 7.30 | 2.5-3 | 0.0000152 | 0.0000273 | |Zinc (100) | 7.13 | 2 | 0.0000122 | 0.0000220 | +------------------+------------+----------+-----------+-----------+

+------------------+---------------+---------+---------------------+ | | Specific Heat | Melting | Conductivity | | METALS. | per Degree | Point. | for | | | Cent. | | Heat. Electricity. | +------------------+---------------+---------+--------+------------+ |Aluminium (115) | 0.2143 | 1500° F.| -- | 56.1 | | " Bronze (116)| -- | [about| -- | -- | |Brass, Drawn (101) | } 0.0939 | { -- | -- | -- | | " Cast (106) | } | { 1870° | -- | -- | |Bronze (108) | -- | 1692° | -- | -- | |Copper (99) | 0.0951 | 2000° | 73.5 | 99.8 | |German Silver (112)| -- | -- | -- | 7.67 | |Gold (113) | 0.0324 | 2610° |

53.2 | 78.4 | |Iron, Wrought (54) | 0.1138 | 2900° | 11.9 | 16.8 | | " Cast (58) | 0.1298 | 1920° | -- | -- | |Lead (110) | 0.0314 | 608° | 8.5 | 8.3 | |Mercury (117) | 0.0333 | 39° | -- | -- | |Nickel (111) | 0.1086 | -- | -- | 13.1 | |Palladium (119) | 0.0593 | -- | 6.3 | 18.4 | |Platinum (118) | 0.0324 | -- | 8.4 | 18.0 | |Silver (114) | 0.0570 | 1832° | 100.0 | 100.0 | |Steel (60) | 0.1175 | 2400° | -- | -- | |Sterro (109) | -- | -- | -- | -- | |Tin (107) | 0.0569 | 446° | -- | 12.4 | |Zinc (100) | 0.0955 | 680° | -- | 29.0 |
+------------------+--------------+---------+--------+------------+

=122.= =Notes on the foregoing table.= For a complete explanation of the several properties of metals and alloys that are enumerated in the above table, the reader must be referred to works on mechanics and physics, but the following explanatory notes are necessary.

The number in brackets after the name of each metal, etc., refers to the article in which it is considered.

The _specific gravity_ of a substance is the ratio of the weight of a given bulk of that substance to the weight of the same bulk of water at a definite temperature. The numbers here given can only be regarded as approximations, as the specific gravity varies greatly with the state in which a body exists, the hammering it may have been subjected to, etc.

Degree of hardness is ascertained by means of the following standard series, observing which of them scratches the body under examination and which it is capable of scratching.

1, Talc; 2, Gypsum; 3, Calc-spar; 4, Fluor-spar; 5, Apatite; 6, Felspar; 7, Quartz; 8, Topaz; 9, Sapphire; 10, Diamond.

Linear expansion. These co-efficients represent the extension in length that the several substances undergo when heated: the first column for each degree Fahrenheit and the second for each degree Centigrade. The extension is given per unit of length; thus, 1 inch of copper at 32° F. will become 1 + 0.0000102, or 1.0000102 inch at 33° F.; and 1 + 30 × .0000102, or 1.000306 at 32 + 30 or 62° F.

Superficial expansion may be obtained by multiplying the linear co-efficient by 2, and cubical expansion by multiplying the same number by 3.

As in the case of specific gravity, these data, as well as those in succeeding columns, can only be regarded as approximations, depending on the condition of the metal etc.

Specific heat is the amount of heat required to raise the temperature of a substance one degree (the Centigrade scale being here adopted), that required for the same weight of water being taken as unity. The corresponding numbers on the Fahrenheit scale can be deduced from those here given by multiplying by 5 and dividing by 9.

The _melting points_ are given on Fahrenheit's scale and can only be regarded as approximate on account of the difficulty experienced in determining these high temperatures. Different observers often vary by two or three hundred degrees in their estimates.

Conductivity for heat and electricity are given in reference to that of silver, which is called 100. It surpasses all other known metals in both these properties when chemically pure, but a trace of impurity has a very prejudicial influence on them.

It will be observed that in many cases the conductivities have not been determined, a remark that applies to other columns of the table.

SOLDERING.

=123.= It is well known that a _solder_ is an alloy employed to unite, by the aid of heat, two metallic bodies that are placed in contact. A solder, then, must be much more fusible than the metals it unites, otherwise these latter would be damaged by the degree of heat applied. Solder is all the less tenacious, and melts the more easily according as the proportion of the most fusible metal present is increased.

This fact is taken advantage of when several solderings have to be performed on the same object. The alloy last employed will require to be considerably more fusible than the first, as otherwise the heat would be so great that the earlier joints would melt. In an ordinary lead-tin solder, the fusibility is increased by increasing the proportion of the latter metal till the lead is to tin, as 6 is to 1. This alloy melts at 194° C. (380° F.), and the melting point may be still further reduced by adding a gradually increasing proportion of bismuth.

As the melting point of the solder approximates to that of the metals to be united, the risk of damaging these latter is of course increased, but, at the same time, the joint will be all the stronger, as the metal will be almost as strong there as at any other point, and it can be forged, etc.

Solders are distinguished as _hard_ or _soft_; the former requires the application of a red heat, and can therefore only be used for such metals as gold, silver, brass; whereas the latter melt at very low temperature, and can be employed for metals that have low melting points, or when it is important not to exceed a moderate degree of heat. The joint is, however, the more solid according as the heat employed approximates to that at which the metal will melt.

=124.= =Composition of solders.= The solders ordinarily employed can be obtained from material dealers, but it is advisable to give here the composition of some of the more important, specifying the metal to which they are applicable.

=125.= _Aluminium solders._ I. Zinc, 70 parts; copper, 15; aluminium, 15.

II. M. Mourey employes a series of aluminium-zinc alloys, commencing with two per cent aluminium to 98 per cent zinc, and progressing to 20 per cent of the former to 80 per cent of the latter metal.

=126.= _Gold solders._ I. Gold, 6 parts; copper, 1 part; silver, 2 parts.

II. Gold, 15 parts; silver, 2 parts; copper, 1 part.

III. Gold, 11.94 parts; silver, 54.74 parts; copper, 28.17 parts; zinc, 5.81 parts. The three first metals are melted together in a crucible, and when they have somewhat cooled, a rather greater proportion of zinc than is here indicated (to allow for loss by volatilization) is added, and the alloy constantly stirred.

=127.= _Silver solders._ I. Silver, 2 parts; brass (for pin-wire), 1 part.

II. Silver, 5 parts; pin-wire brass, 1 part.

III. Silver, 10 parts; pin-wire brass, 5 parts; pure zinc, 1 part.

=128.= _Tin solders._ I. (ordinary soft solder.) Tin, 2 parts; lead, 1 part.

II. (Harder, and known as “Plumbers’ Sealed” solder.) Tin, 1 part; lead, 2 parts.

III. Many other proportions of tin and lead are occasionally used, ranging from tin, 1 part; lead, 25 parts, to tin, 6 parts; lead, 1 part.

IV. (Very fusible solder, melting in boiling water.) Lead, 3 parts; tin, 5 parts; bismuth, 8 parts. The fusibility is still further increased by adding mercury or cadmium.

=129.= _Spelter solders._ (Used for brazing.) Copper and zinc in varying proportions. It becomes more fusible as the amount of zinc present is increased.

METHODS OF SOLDERING.

=130.= A thorough cleansing of the surfaces to be united is always needful, but more especially so in the case of soft soldering. It may be effected by means of acids, or with a graver or scraper, etc.; the cleansed surfaces must not be touched with the fingers, and the soldering should be done at once. If acids are employed, the objects should be thoroughly washed after soldering, in order to avoid rust; and, after drying, they should be rinsed with alcohol.

The parts to be soldered are held in position with clamps, tweezers, pins, or iron wire. This latter, known as _binding wire_, is used for delicate objects and should be very pliable. When a high degree of heat is to be applied, all risk of the iron uniting with gold may be avoided by mixing a little sandiver with the borax employed. (See article =153=).

Before heating, if there are already parts united with solder, they should be covered with borax to prevent softening.

Only a moderate heat should at first be applied, so as to melt the borax, or sal-ammoniac without displacing it. The violent frothing up, which is very liable to displace the parts or the fragments of solder, can thus in a great part be avoided. If a naked lamp-flame is

used, or if it is directed on to the object with a blow-pipe, it should be, so to speak, large and soft, and the jet should not be directed to the point of juncture until the solder is observed to have fused. In soldering brass to steel, it is sometimes necessary to direct the flame against the brass only, in order, as far as possible, to avoid softening the steel. The hard solders for gold, silver, etc., require a considerable degree of heat, so that the objects must be heated to redness.

=131.= =To solder gold and platinum= to each other or to themselves. On a hard wetted surface, marble, for example, rub a piece of borax until a white liquid paste is obtained (or the powdered borax sold by chemists can be made into paste direct). Having prepared the borax, the surfaces to be united are cleansed either by scraping or with dilute nitric acid (=155=); the acid may be previously heated to boiling, as it will then act more rapidly; and the surfaces are subsequently scraped. They are now covered with the borax with a paint brush, set in position, and small pieces of solder placed on the junction. As already observed, the heating must at first be gentle to avoid displacing the solder by the frothing of the borax.

=132.= =To solder silver.= Also for uniting gold to silver, or silver, brass, steel to each other or to themselves. Proceed in the manner already explained for gold and platinum, except that the borax paste must be sensibly thicker.

=133.= =To solder tin.= Also for uniting gold, silver, brass to each other, or to other metals, such as steel, iron, etc. Clean the surface with a graver or scraper; sulphuric or hydrochloric acid may be used, but in this case the cleansing afterwards must not be forgotten.

The heating is effected as in soldering gold, unless a soldering iron is used, when the directions subsequently given should be followed.

=134.= =To solder aluminium.= M. Mourey recommends the following method.

One of the series of aluminium solders, No. II. (art. =125=), is employed and, as a flux, two-thirds of balsam of copaiba, one-third very pure Venice turpentine, and a few drops of the juice of a citron; these constituents are pounded together in order to secure a perfect admixture.

The surfaces to be united are covered with solder (employing a soldering iron of aluminium) just as in the case of tinning (=137=), the flux just mentioned being used. The two surfaces, thus prepared, are placed in contact and maintained in the required position, and, after laying on the joint particles of solder that are richer in aluminium than the one used for preparing the surfaces, the whole is placed over a charcoal fire or heated before the blow-pipe, pressing gently on the pieces of solder, which will soon melt and should be distributed by means of a little tool of aluminium.

During this second stage of the process, it is necessary to be very cautious in the application of the flux; the pieces of solder should only be dipped in it before being placed in position, for the flux is mainly for use in preparing the surfaces; as soon as the solder has run well, the temperature should be lowered in order not to dry up and burn the solder, which would be apt to become brittle.

In preparing the solders, the aluminium is first fused and stirred with a small iron rod; then add the zinc and stir again; add a little tallow and cast the solder into rods.

The zinc must not be too much heated, as it will volatilize, leaving the alloy rich in aluminium and therefore brittle.

=135.= =Fluxes for soldering.= Various substances can be employed as fluxes for cleansing the surfaces to be united:

Sal-ammoniac reduced to powder and made into a paste with sweet oil, or merely dissolved in water. A paste formed of _sal-ammoniac_ and _resin_, reduced to powder, with water or oil. _Resin_ alone will suffice for the soft soldering of copper or brass. _Venice turpentine_, which has the advantage of not causing steel to rust, although it makes the objects sticky so that they require to be afterwards rinsed in alcohol or turpentine.

Various acid solutions are sold for the purpose and experience will enable the watchmaker to select that which is best adapted to his requirements.

Lastly, saturated _chloride of zinc_ can be recommended. It is prepared as follows:

Some dilute hydrochloric acid (which also goes by the name of spirits of salts, or muriatic acid) is placed in a glass flask and strips of zinc are added one by one; the flask must be left uncorked and the zinc added a little at a time, lest the effervescence that occurs

should break the vessel. When the zinc added is not acted on by the fluid it may be concluded that the acid is saturated or "killed," and the fluid may then be transferred to a stoppered or corked bottle for use. In using it, a small quantity is spread over the surfaces that are to be united and the solder will be found to run with great freedom. Some authorities recommend the addition of sal-ammoniac to the extent of one-fourth the weight of acid taken. It is well again to warn the reader that the pieces must be thoroughly washed after employing these liquids, for, otherwise, they will cause tools with which they are brought in contact to rust and will rust themselves if they consist wholly or in part of iron or steel. The vessel containing the fluid must be kept well away from the work-bench.

The liquid can be used immediately after being prepared as above explained; but all acid reaction may be prevented by evaporating at a moderate temperature until of the consistency of oil; it is then allowed to cool and kept in a bottle.

=136.= =The soldering iron= with a head of copper, such as is used by tin-plate workers, is well known; if made on a small scale it may occasionally be of service to the watchmaker. The tool may be =T=-shaped, one end of the horizontal portion, the copper head, terminating in a rather thin blade, and the other enlarged, so that, when held in the flame of a lamp, it will store up a sufficient amount of heat. The upright part of the =T= corresponds, of course, to the handle. After the iron has been heated just short of redness in the dark, the end of the blade is moistened with soldering fluid and a small piece of solder attached to it. The object to be united is gently heated and also moistened with the fluid; the iron charged with solder is presented to it, often with the enlarged extremity of the head maintained in the flame of a lamp, and the solder will, as a rule, run without again heating the object, although this might be done while the iron is still in contact. It may be found convenient to fix the iron in a suitable position with the lamp below the large end of the head; the object will then be brought against the iron after being moistened with the fluid.

=137.= It is often advisable to tin the surfaces to be united previous to soldering them; in order to do this they are moistened with soldering fluid, small pieces of solder are then spread over, and these are fused by passing the hot iron over the surface; or the solder can be spread after fusion by means of a metallic rod charged with the liquid.

=138.= =Brazing.= This operation consists in soldering iron, steel, brass, or copper, with an easily fusible brass, which is specially prepared in the form of coarse dust, termed spelter solder, or cut in thin strips of convenient shape (=129=). The method resembles, in all essential particulars, the application of hard solders previously referred to (=131=, etc.)

Heat is usually applied direct by the blow-pipe, borax being used as a flux, and the precautions taken that are mentioned in article =130=: it is necessary to avoid a greater degree of heat than would melt the brass, since the object might in that case be fused. For fine work, it is better to employ silver solder.

On an emergency, two pieces of steel can be united by brazing and subsequently hardened, and we have successfully practiced this method in such a case as the following: A small portion having been broken off from the quarter-piece of a repeater, we dovetailed into it another piece of steel of the required form, but a trifle too large at the upper side. When the brass had run well into the joint, and the piece was still at a full cherry-red heat, it was hardened, and afterwards cleaned and tempered to a blue color. The upper surface was then brought to shape with a good file, resting it on a wooden block against a projection, and, after making sure that it would act correctly, the whole was smoothed and polished. It has since worked well and does not show signs of wear.

BRONZING.

=139.= =To bronze copper.= The following are two methods recommended for bronzing objects of this metal, for example, a medal.

Dissolve two parts of verdigris (acetate of copper) and one part of sal-ammoniac in vinegar. Boil the solution, skim it, and dilute with water until it no longer possesses a feebly metallic smell, nor produces a whitish precipitate on the addition of water. Then let it boil again in an earthenware or porcelain vessel and transfer it, while boiling, into another vessel containing the perfectly clean medals, etc., and place the whole on the fire. As soon as the medals assume the required color, remove them, and wash carefully in clean water.

The objects must not be left too long in the acid bath over the fire, because the layer of oxide would become too thick, and would easily scale off the surface; whereas, if the operation is properly conducted, the coating adheres so firmly that it cannot be separated even by scraping. Of course, it is only after a certain number of trials, and with experience, that the exact moment can be ascertained for removing the objects from the bath. It is very necessary that the bath be not too concentrated, as the superficial oxide becomes proportionately less adherent: moreover, a whitish powder is deposited on the medal, which turns green on

exposure to the air and spoils the appearance of the bronzing.

=140.= =Chinese bronzing.= The Chinese employ the following mixture for bronzing copper, the several constituents being powdered before being incorporated together: 2 parts of verdigris, 2 parts of cinnabar, 5 of sal-ammoniac, 5 of alum, and 2 parts of the beak and of the liver of a duck. A paste having been made, with vinegar, it is spread over the perfectly clean surface of the copper, and the whole exposed for an instant to the fire, then allowed to cool, washed, and the operation repeated as often as may be needed in order to obtain the desired tint.

By adding sulphate of copper to the mixture a browner shade will be obtained, and it may be made yellower by adding borax. Copper thus treated is said to present a beautiful appearance, and to be so permanent that neither air nor water has any influence against it.

=141.= =To bronze brass.= Dissolve copper turnings in nitric acid until it is completely saturated. Immerse the brass objects to be bronzed in this solution after they have been cleaned, smoothed with water of Ayr stone, and heated to such a temperature as the hand can just support; on being placed over a charcoal fire they will assume a green color; rub them over with rags, repeat the immersion and heating over charcoal until the required tint is obtained. The shade may be improved by oiling the finished surfaces.

It is asserted that by immersing copper articles in molten sulphur containing lampblack in suspension, they assume the appearance of bronze; and that they may even be polished without losing their color.

GILDING.

=142.= =Gold gilding without the aid of mercury.= Prepare the gold in fine powder, as explained in the following paragraph, or procure it from the dealers in chemical products, who manufacture it of various tints. Make a mixture of this powder with pure rock salt and cream of tartar (bitartrate of potash), pulverized in the same manner as described in speaking of silver-plating and take the same precautions in its application.

The gold surface will present a dull appearance; acid cannot be used to improve its color when operating, for example, on a wheel with attached pinion, but the same result may be attained by a very simple method. Rub the object after plating with cream of tartar, mixed with a large proportion of water; then immediately wash in an abundance of warm water at not less than 40° C. (104° F.); soap it thoroughly, so as to neutralize any acid that may remain, and finally pass through alcohol to dissolve any remaining soap.

The surface will be still further improved by rubbing with a very hard piece of pith, such as is occasionally met with.

M. Robert, in describing the above method, adds: “In this manner I have gilded cocks, domes, compensation balance weights, and even their brass rims. When, skilfully and expeditiously performed, the pinion need not be discolored; but, if it is at any time slightly marked, it may be restored by at once rubbing the surface with a soft stick and fine rouge.”

=143.= =Preparation of the gold powder.= As already observed this can be obtained of any desired color from the dealers in chemical products, but the following method is given for the benefit of any one who desires to prepare it for himself:

Place some gold in thin leaves in a dish, and add a little honey, thoroughly intermixing the two by the aid of a glass rod flattened at one end; then place the paste so obtained in a glass of water containing a little alcohol, washing it and allowing the powder to settle. Decant the liquid and again wash the residue, repeating the operation until a fine brilliant powder is obtained. This powder is mixed as required with rock salt and powdered cream of tartar in the manner already described.

=144.= _Second method._ Dissolve one part by weight (say about ten grains) of pure gold, rolled very thin, in aqua regia (=155=) contained in a porcelain dish, which may be gently heated on a sand-bath, and evaporate the acid until it assumes a blood-red color. Add about 30 parts, by weight, of warm distilled water, in which 4 parts of crystallized cyanide of potassium have been previously dissolved; thoroughly stir the mixture with a glass rod, and filter it through a glass funnel.

=145.= _Third Method._ Roseleur recommends the following solution for gilding by simple immersion. Distilled water, 17 pints; pyrophosphate of soda (in crystals) 28 ounces; hydrocyanic acid, 1-3 ounce; crystallized perchloride of gold, 2-3 ounce. The pyrophosphate is added, in small quantities at a time, to 16 pints of water, in a porcelain vessel, stirring with a glass rod and applying gentle heat; then filter and cool. The gold salt is dissolved in a small amount of water; filter and add to the cold solution of pyrophosphate; lastly, add the hydrocyanic acid and the solution, heated to the boiling point, is ready for use.

The articles to be dipped must be thoroughly cleansed and passed through a very dilute solution of nitrate of binoxide of mercury; they must be constantly agitated while in the bath and the best coating is obtained by dipping the articles in a nearly exhausted solution of the same kind immediately after the mercury solution.

=146.= =Electro Gilding.= But the method most usually adopted is that in which a battery is employed. It is, however, impossible, within the limits of this work, to explain the precautions that are necessary in conducting the process, managing the battery, etc., and the reader must be referred to works on electro-metallurgy for these details.

=147.= =To prepare the pieces to be plated.= After the surface has been stoned, boil the object a few minutes in a solution of soda or potash, and rinse in clean water.

Roseleur, in the articles already referred to, gives very full instructions, of which the following is an outline. The reader who desires to obtain more complete information can consult his works.

Attach the pieces to a cork and brush with a clean brush charged with water and pumice-stone powder and thoroughly rinse. Place them in a solution consisting of: water, 2¼ gal.; nitrate of binoxide of mercury, 1-14 oz.; sulphuric acid 1-7 oz. Then rinse again.

=148.= =Graining.= Mix thoroughly with the application of moderate heat, silver powder, 1 ounce; pure common salt, finely powdered, 13 ounces; cream of tartar 4 to 5 ounces. Make a thin paste of this mixture with water and spread with a spatula on the pieces; having mounted them on a cork to which a rotary motion is given, rub them in all directions with a brush with close bristles, adding fresh paste from time to time. When the desired grain is obtained, wash and scratch-brush with revolving wire brushes. Three of these are often used of varying degrees of hardness and a decoction of liqorice, weak size or stale beer is liberally applied to the surface.

=149.= =Resist.= This is a composition for covering steel parts in order to protect them from the action of the acids, etc., in the various processes of cleaning, graining and gilding. It consists of yellow wax, 2 ounces; clear resin, 3■ ounces; very fine red sealing-wax, 1½ ounces; finest rouge, 1 ounce; Melt the resin and sealing-wax in a porcelain dish, then add the yellow wax, and when the whole is thoroughly liquid, gradually add the rouge, stirring with a glass rod. The parts to be coated are slightly heated and covered with the mixture.

To remove the resist after the gilding process is completed, place the pieces in warm oil or turpentine, then in a very hot soapy or alkaline solution and lastly in fresh water.

=150.= When prepared as above explained, the object may be gilt by one of the preceding methods; of course a hot solution cannot be resorted to when the resist has been applied.

=151.= =To clean objects that are of gold or gilt.= The following method is equally applicable to pieces that are gilt, such as cocks, domes, etc., the frames and parts of timepieces and to either gold or gilt jewelry.

To about a tumbler of water add 20 drops of strong ammonia. Immerse the object several times in this mixture and brush it with a soft brush; as soon as the operation appears to be completed (which experience will soon enable the workman to ascertain), wash in pure water, then in alcohol, and dry with a fine linen rag. The original brilliancy of the gilding will then be restored.

When the coating is thin and has been galvanically deposited, only very soft brushes must be used.

Gilders, instead of dipping in alcohol and drying with a linen rag, usually immerse the pieces in boxwood sawdust, leaving them long enough to become thoroughly dry; after this treatment they merely require to be shaken and lightly rubbed with a fine brush.

The sawdust must be perfectly dry; indeed it is a good plan to slightly warm it by placing the wooden box containing it for a few minutes on a hot oven or stove in the winter and exposing it to a hot sun in summer.

Instead of ammonia, alum (=156=) is sometimes boiled in water and the objects dipped two or three times in this solution, subsequently brushing as in the previous case.

=152.= _To restore the dead surface of gold or gilt objects._ Place them for two or three minutes in chlorine water, rinse them in clean water, soap them and finally dry in sawdust. It is advisable that parts that are polished be prevented from actual contact with

the liquid as it would produce a somewhat deadened surface.

=153.= _To clean gold jewelry after soldering._ Particles of binding wire are often left adhering to the surface of jewelry after soldering, and, on dipping the object into the dipping liquid, a layer of oxide may be formed. This can be removed without detriment to the polished surface by plunging the object for a few seconds in nitric acid (=155=).

ACIDS AND SALTS.

=154.= The watchmaker has occasion to employ a few acids and salts. He should never forget the advice already given to keep them away from his work-bench and always to well wash a piece of metal that has been in contact with them.

=155.= =Acids.= _Nitric Acid_, either in a concentrated or dilute form, will dissolve iron, steel, copper, lead, silver, zinc, brass, nickel, mercury, German silver. It does not dissolve tin, but reduces it to a white powder, known as metastannic acid. Hence, if an attempt be made to dissolve bronze which contains tin, this metal is deposited, and the copper and zinc pass into solution.

Sulphuric acid will dissolve iron, steel, copper, tin, silver, zinc, brass, nickel, mercury, German silver.

Hydrochloric acid will dissolve iron, steel, zinc and nickel and has a slow action on copper, tin, brass and German silver.

Aqua regia, a mixture of about 2 parts hydrochloric and 1 part nitric acid, will dissolve all the above-named metals, and in addition, gold and platinum, although separately neither acid will attack these metals.

Hydrofluoric acid attacks and dissolves all metals, except platinum, lead and silver with violent effervescence. It is also used for etching on glass or enamel. It is usually preserved in gutta-percha bottles, and is of such a dangerous nature that no use should be made of it without a good knowledge of its properties.

Acids are rarely employed pure by watchmakers; they are diluted with water. Nitric acid of commerce has a density of about 1.4 (38° on Baume's hydrometer). If this density is reduced by the addition of water to 1.16 (20° Baume), we obtain the acid most commonly employed. For cleaning metallic surfaces prior to soldering etc.; for giving a grained surface to brass, and for whitening blue steel, special proportions are found most convenient, which the reader can best determine experimentally for himself, remembering that the action of the acid should neither be too quick nor too slow. When once he has ascertained the best proportion, he can always recover it by the aid of the hydrometer.

=156.= =Salts.= _Borax_ serves as a flux in soldering gold, silver, platinum, etc., (=131=); also for the same purpose in brazing (=138=); it is met with in crystals or as a powder.

Sal-Ammoniac (also called _Chloride of ammonium_), is used for soldering tin, either as a powder or made into a paste, with sweet oil or with water, or mixed with resin.

Alum dissolved in water may occasionally be used in place of nitric acid for cleaning surfaces that have been soldered; it attacks iron or steel more energetically than copper, zinc, or brass. This fact is often taken advantage of for removing broken screws, etc., from brass plates. All other steel parts are removed and the plate placed in a solution of alum, when the steel screw is gradually eaten away by being converted into rust.

In 100 parts of cold water, only 9 parts of alum will dissolve, but if the water be boiled, it will take up 75 parts. Its action will then be proportionately more energetic when boiling.

OIL.

=157.= The oil intended for use as a lubricant for watchwork, etc., should be kept away from the light, as otherwise it would be discolored; it is on this account that the bottles containing such oil are frequently covered with black paper. Only the quantity wanted for immediate use should be placed in the oil-cup.

Two preliminary tests will afford some indication as to the quality of an oil. A thick layer is placed on a small portion of the surface of a glass plate, and side by side, a similar layer of another oil used for comparison, and they are exposed to the air for some time without being touched. The one that is found to be sticky under the finger when the other has dried up will, in all probability, be preferable. The second preliminary test is made on a whetstone; it is usually found that the oil that takes the longest time to thicken

is of better quality. Of course these tests will only suffice to afford a rough approximation, and cannot be accepted as conclusive.

The mode adopted for testing either the acidity or the purity of oil will afford no evidence as to how long it will maintain its fluidity; and very good results have at times been secured by the use of oils that were slightly acid, or from mixtures of oils of two or more qualities.

Many of the methods recommended for purifying oils are to a great extent illusory, for they cannot impart to the fluid characteristics that are wanting from the beginning. Success depends largely on the skill of the manipulator; and if he is not endowed with the power of judging, mainly by the taste, whether oil satisfies certain prescribed conditions, he can never be certain of the result. Crops differ as regards degree of maturity, etc., from year to year; and the animals from which oils are procured are rarely in the same condition as regards health, age, nourishment, etc.

Tests made on a whetstone, and on a window-pane, as well as observations made on drops of oil placed in jewel holes, or in oil-cups in a metal plate kept for the purpose—some of the drops being exposed to the air, while others are in closed boxes—will afford valuable indications; and according to the observations of M. H. Robert, it is safe to consider an oil bad if, at the end of six or eight days after being placed on a plate of good brass, it shows a marked green tinge—especially so if a clearly defined fringe forms round the drop, or else if the brass itself is discolored.

After all, the only evidence on which the watchmaker can rely is that which he obtains by experimenting on watches which he keeps to lend to his customers while their own are undergoing repair, and these trials should last for at least a year.

And there is great variety among the wearers of watches. Some live in constantly varying temperatures, often dusty; many ladies use perfumes; some persons perspire more than others; all these causes influence the oil, and make it alter or evaporate more rapidly in one watch than in another.

=158.= =To secure the maximum permanency in oil.= In the case of very many watchmakers who complain bitterly of the oils they employ, the fault is their own and not that of the oil; for they neglect the most simple precautions, both in purchasing and in using it.

The following are a few points to which attention should be given:

Do not buy, from motives of economy, bottles that have lain for years in the shop.

Keep the oil away from the light, and only take in the oil cup the amount required for immediate use, as stated above.

Ascertain that the watch-cases close well. If they do not, there will be air currents generated, and the oil will suffer.

The oil in a cylinder escapement will always deteriorate very rapidly; some watchmakers coat over the inside of the dome-joint and recommend the owner not to open it. By doing so, the oil can be maintained in good condition at the escapement for a long time.

Lastly, when cleaning a watch, the work should be conscientiously done. This point is very important.

When the parts are carelessly cleaned with soap, or with impure benzine, they will, after a few months, assume a dull colour, in consequence of a thin layer of the materials used in cleaning having been left on the surface. It has at times been noticed that steel work was preserved from rust through the perspiration of the wearer, after being cleaned by certain fluids. Evidently this was due to a thin coating having been left on the surface of the metal. The conclusion to be drawn is obvious: clean carefully; push the pivots into rather hard pith; finish with a soft brush in proper condition, and clear out all pivot-holes with pegwood.

=159.= =Mixed oils: camphorated oils.= Good results are frequently obtained by mixing together two different kinds of oil. Thus, American watch oil, which is very fluid and apt to evaporate at the temperature of the pocket, is improved by the addition of a somewhat thicker oil. A mixture of real American oil with the Rodanet oil has been recommended as excellent.

There are some who advocate the addition of a small quantity of camphor to an oil that is known to be satisfactory, but we cannot answer for it from personal experience.

=160.= =Sinks.= In cleaning, it is important to avoid removing the gilding in the oil sinks of watches, or the superficial oxide in the sinks of clocks that have been going for a considerable time. For if it be removed, there will be a fresh coating formed in time, and this, too, at the expense of the oil.

In new timepieces that are not gilt, it is well worth while polishing the sinks over their entire surface. If not applied too liberally, the oil will then be more likely to remain in contact with the end of the pivot. Moreover, as the surface is smoothed and hardened, and its pores are, as it were, closed by the action of the polisher, the oil will oxidize more slowly. This fact was first pointed out by Robin.

=161.= _Caution to be observed in applying oil._ The precautions to be observed in applying oil will be better considered in Part V. of this work, where we shall describe the method of cleaning and putting a watch together.

=162.= =Retention of oil on acting surfaces.= Since oil is essential in order to diminish friction, and the movement of the bodies to which it is applied tends to drive it from the surfaces of contact, it is important, with a view to its being constantly brought back and maintained in proximity to these surfaces, that they be formed in accordance with certain rules based on the laws of hydrostatics.

ALCOHOL.

=163.= Only what is known as rectified alcohol should be used in cleaning parts of watch work. The copper pan in which it is made to boil should not be too thin. The handle should be so arranged that it can be fixed in the vise, and the lamp held under the pan.

When, in heating, the alcohol ignites, it is best not to attempt its extinction by blowing; if the pan is held against the under side of the bench, the flame will at once be put out, or this can be effected by merely laying a piece of sheet metal over the pan. A good plan for preventing ignition is to make a lid of wire gauze, which is placed over the pan during the application of heat.

The substance known as "methylated spirit" is a cheap preparation of alcohol, and of use for burning in a spirit lamp, and for other purposes where the alcohol is not required to be pure.

BENZINE, ETC.

=164.= This and other preparations of a similar nature, such as Essence Lemoine, Essence Genevoise, etc., are much used for dissolving clogged oil and other substances of a greasy nature from parts of watches in cleaning.

POLISHING MATERIALS.

=165.= The following account of the materials used for polishing, is, for the most part, extracted from Holtzapffel's _Turning and Mechanical Manipulation_, to which the reader is referred for fuller information in regard to them, and to their mode of application:

=Buff Leather= glued to a flat surface, or to the edge of a revolving disc, is used with emery, crocus, rottenstone and other powders.

=Charcoal= is much used by steel and copper-plate engravers. That made by burning elder without access of air is considered the best, but willow and elm have also been recommended.

=Diamond=, in the form of powder, is used by lapidaries, seal engravers, and watch jewel makers. The latter obtain the diamond _bort_ that is rubbed off stones in faceting, and they separate it into various degrees of fineness, by decantation (=168=). The mode of applying it is described in articles =207=, =216=.

=Diamantine=, Sapphirine, Rubitine, etc., are names given to various chemical preparations for polishing, to be obtained at the tool shops; they must not be assumed to consist in any way of the jewels from which their names are derived.

=Emery.= At the present day, oilstone dust is very frequently replaced by emery with oil or water, especially in clockwork. Any required degree of fineness can be obtained by decantation. Emery dust is sometimes used in place of rouge for polishing.

The solid emery wheels and sticks, that are now common in the trade, work rapidly, but they have the disadvantage of heating steel, and many of them soon become pasty. The heating renders them less suitable for grinding gravers, but they are very convenient for roughly shaping steel work, or removing the hard surface caused by the application of heat.

To make emery paper. If occasion requires it, this can be done as follows: Fix a sheet of stout rope manila paper on a board, glueing it round the edge. Having put emery powder into a sifter, the mesh of which has the requisite degree of fineness, and rapidly covered the surface of the paper with thin hot glue, shake the sifter lightly over the paper until it is evenly covered, and leave to cool. When dry, detach the paper and shake it vigorously to detach loose grains. Cloth may be used instead of paper, if desired.

=Hone slates.= Under this heading are included a great variety of stones used for smoothing and polishing.

Ayr stone, or water of Ayr stone, is much used for smoothing brass work prior to gilding (=142=), etc. It should be kept wet in order to prevent it from becoming hard.

Blue polishing stone is much used by jewelers, clockmakers, and others; it is recommended for use in spotting (=174=) and for polishing wheels (=176=.)

Oilstone. This forms the quickest cutting whetstone known. Oilstone slips are used by watchmakers after the manner of files. Oilstone powder, or dust, is much used in the earlier stages of polishing, and is preferable to emery in that it does not leave particles embedded in the surface of the metal. On pewter laps it may also be employed for polishing steel work.

Oxides of iron. Under this head are included the several materials known as crocus, rouge, red-stuff, colcothar of vitriol, etc. It is advisable to remove gritty particles from these materials by decantation (=168=) before using.

Pumice-Stone is extensively used for polishing cut glass, and is applicable to brass and other metal work.

Putty Powder is oxide of tin, or, more commonly, of tin and lead in varying proportions. The whitest kind, provided it be heavy, is considered the best.

Rottenstone. This variety of tripoli is of the greatest value for polishing brass work, as well as for silver, glass, and even the hardest stones.

Tripoli is of a greyish yellow or red color, and consists mainly of silica. Its principal use is in the polishing of hard woods.

Whiting is common chalk, ground, washed to remove sand, etc., and dried in lumps.

=166.= =Polishing Stones.= The following method is described by M. Cadot for preparing these stones, which are very useful for polishing a wheel that is not riveted to its pinion (see article =185=).

Carefully select a blue stone; after dressing its surface, smooth it with emery paper of gradually increasing fineness. Saturate the surface with oil, and rub it with a common piece of rough sapphire, one face of which is flat and partly smoothed, until the surface of the stone is hardened.

Such a stone is used dry. The wheels must previously have been carefully smoothed, since the stone does not abrade the metal. If care is taken to avoid scratches, the surface will last for a long time, although, of course, it is only serviceable for gold, brass, nickel or metals of a similar degree of hardness.

=167.= The several materials used for polishing must be kept carefully packed (glass stoppered bottles are preferable), as a few grains of dust, or of foreign bodies, will suffice to prevent the operation of polishing from being successful. Polishers should be filed very smooth, with a perfectly clean file that is not quite new. Files that are dirty or new will deposit small hard particles of dirt, or cause pieces off the points of their teeth to become embedded in the surface of the polisher.

PREPARATION OF POLISHING MATERIALS.

=168.= =Decantation.= This consists in causing a material in a fine state of sub-division to fall slowly through a liquid with the view to separate coarse particles, or various degrees of fineness, by taking advantage of their different rates of descent.

The watchmaker should prepare all his smoothing and polishing materials, etc., by decantation. He will by this means obtain them in grains that are much more uniform in size, of any required degree of fineness and free from hard or large particles.

[Illustration: _Fig. 40._]

The operation is exceedingly simple. The material having been pounded under the hammer or otherwise, is thrown into a vessel more or less filled with a liquid, water, oil, etc. After being thoroughly stirred, it is allowed to partially settle, and the liquid is carefully poured into another vessel. All the coarse heavy grains will be found as a residue in the first vessel; they are collected and used for coarse work. After again stirring and leaving to settle for a longer period, the liquid is again poured off, and the powder thus separated will be the second degree of fineness, so that it may be termed No. 2. By successive operations, in which a gradually increasing interval of time is allowed, Nos. 3, 4, etc., can be obtained; that is to say, a series of powders of the same material but presenting a greater degree of uniformity in the size of grains and of gradually increasing fineness. It may be observed that when

the powder of the requisite degree of fineness is nearly attained the mass should be left to settle until the following day, or, rather, until the fluid is clear; then decant carefully so as not to lose any of the deposit.

When treating a material that is soft and friable, it should be crushed between the fingers, as by using a hammer hard grains of foreign matter might be accidentally intermixed. Oil may be used for decanting diamond powder or oilstone dust for smoothing; water for rottenstone or tripoli; alcohol for hartshorn, etc.

=169.= =To prepare diamond powder.= Select rough diamonds of a blackish tint, of such a size that there are four or five to a caret. These are crushed in a hard steel mortar of the form indicated in fig. 40, the pestle being provided with a small stuffing box that can be brought down on to the mortar to prevent the escape of diamond-dust; but it is well to first crush one stone, with a single blow of the hammer on the pestle; remove all the fragments and examine the end of the pestle; it will be found that a number of particles have bedded themselves in it; these should be examined to select pieces to serve as drills and gravers. The larger fragments serve for gravers, and particles should be sought that are as nearly as possibly triangular prisms about ½■■ inch long for making drills. The other stones may be treated in similar manner till enough fragments are found. Now place all other pieces in the mortar, and continue for two or three hours striking the pestle with the hammer, turning it partly round after each few blows to prevent the powder from imbedding itself in the steel. When no "bite" is perceived in rotating the pestle, the diamond is sufficiently reduced; it is shaken out of the mortar into a watch-glass containing the most limpid oil attainable, and if necessary the fragments are released by a steel spatula, at the same time striking the external surface of the mortar with the hammer. Thoroughly mix the oil and the powder, subdividing the latter as much as possible by rubbing against the glass with a spatula; allow the mixture to rest for an hour and pour off the liquid into a second glass, leaving the larger particles behind. Leave the oil in the second glass for four hours; then decant, into a third glass with the same precautions; this is left for eight hours; the next glass sixteen hours. When all the powder has settled pour off the oil, and the several degrees are ready for use.

Some jewelers prefer to leave the powder for two or three days in a mixture of equal nitric and sulphuric acid in order to dissolve particles of steel. The acids are then much diluted with water, left for some days and decanted. Then wash the powder in two fluid ounces of pure alcohol, leave for two days, decant and dry, and afterwards treat with oil. The operation is long and hardly necessary.

SMOOTHING.

=170.= If a surface is smoothed well, the labor of polishing will be diminished by at least one-half, and it is an essential preliminary if a good gilding on brass is required.

The materials most frequently used are emery and oilstone dust for steel, pumice and water of Ayr stone for brass. The stones should not be traversed by veins, nor exhibit hard grains. Powders should be freed from large or hard grains by decantation, and it is advisable to repeat this operation several times in order to have several degrees of fineness.

SMOOTHING OF BRASS.

=171.= Every watchmaker knows that after finishing the object with a smooth file, it is smoothed, first with a blue stone or rather coarse water of Ayr stone, and then with one of finer grain. If the brass is to be gilt, the operation is concluded with a series of circular strokes, so as not to leave any striæ or bright spots; if the surface is to be _spotted_ or watered the final strokes should all be parallel.

A soft piece of charcoal applied with water may also be used on objects intended for gilding; in other cases it is used with oil.

=172.= =Wavy or watered smoothing.= This is done with water of Ayr stone and oil carefully prepared, or with a piece of wood charged with oilstone dust, etc. The oiled corner of an emery buffstick can occasionally be used.

To obtain wavy undulations on a smooth piece of metal, the finger should first be placed at the point of commencement of the undulations. Resting the wood or stone against the finger, it is moved a little in a straight line, and then in a series of semicircular waved lines, from right to left or left to right. The finger is advanced through a definite distance and the operation repeated, and so on.

A very good watered surface can be produced with soft charcoal. With a view to increasing the regularity in the marks, a rule may be laid on the object, against which the charcoal is brought.

[Illustration: _Fig. 41._]

Parallel watering is usually done mechanically, but any watchmaker can secure regularity by the following simple device.

Fix a graduated rule _t g_ across the cork (fig. 41) and two pins A A, to form stops for preventing the stick or stone from traveling too far. A division of the rule is made to correspond with the line _v v_; and, when the first line has been traced, advance the object by one, two or three graduations of _t g_, according to the interval that is to be left between successive undulations. Then trace the second wave, and so on.

=173.= =Wavy and curvilinear smoothing.= These are of two kinds; some are entire circles, which we shall proceed to consider; others radiate in curves from the circumference to some other point of the circle as, for example, many of those that are met with on keyless ratchet wheels. The latter will be discussed farther on, when discussing the smoothing of steel, for the process is identical for both steel and brass, except that with the latter named metal and nickel the stick may be replaced by a strip of zinc or tin, and coarse rouge is used.

=174.= =Circular snailing or spotting.= This is produced on a special tool by which several motions can be given to the object, but watchmakers, as a rule, so seldom have occasion to trace this class of ornament, that it will suffice to explain how it can be produced by the appliances that everyone has at hand.

The universal mandrel may be employed for the purpose, but, in that case, the operation is a very slow one, whereas, with the ordinary lathe, it can be done both rapidly and well.

[Illustration: _Fig. 42._]

Adjust a rest of the form shown at s (fig. 42), taking care that the height of the center is sufficient; the small rectangular bed _a a_ has a projecting edge, divided by equidistant graduations. To the headstock of the lathe is attached, at _b_, a piece of bluestone or wood. Having set the rest at a convenient height, and holding the object to be spotted, P, on the rest, bring in it contact with _b_ when in rotation. When the mark is made, lean the object from _b_, slide it along _a a_ so that its edge coincides with the next division and make another mark, and so on until an entire row is completed. Then raise or lower the rest and repeat the process for a second row, and so on.

Instead of applying oil to the acting face of _b_, which would have to be renewed at each operation, it is usual to cover the object P with oil, if _b_ is a stone, or with oil mixed with the substance used for smoothing, if _b_ is of wood. If this precaution is taken, the work will progress much more rapidly.

When the object operated upon is of irregular shape it must first be attached to a rectangular plate and then proceed as already stated.

A still more simple method, but one that is, in certain cases quite sufficient, consists in passing through the poppet-head a center of the form _f d_ (H, fig. 42) which is caused to rotate by the fingers or any other means.

[Illustration: _Fig. 43._]

To make spottings that, instead of being parallel, radiate from the center to the circumference, the rest _a a_ must carry a disc that can rotate on a clamping screw, and is maintained in position by a finger, with an even number of equidistant divisions on the circumference of the disc. The object to be operated upon is then fixed to the disc, and a stick used, the diameter of which is equal to the distance between two radii that pass through a pair of graduations on the disc; for example, the small circle _s_ (fig. 43). A series of circular spots is then made by gradually rotating the disc. Now replace the rod _s_ by one of the diameter _n_; advance the support until it corresponds with the position _n_, and make the second range of circular spots, and so on. The figure renders any further explanation unnecessary.

The watchmaker who has clearly followed what precedes will be able, should occasion require it, to construct a special tool acting with certainty; but it will be well to remember that there is a great advantage in driving the spotting stick by the foot, and bringing it down on the object by a small hand lever, after the manner of the drilling machines used in factories.

SMOOTHING OF STEEL.

=175.= The smoothing of a steel object is commonly done on a piece of cork, with a large iron polisher charged with oilstone dust and oil. If a flat surface, it can be finished with a copper polisher or on a sheet of glass. In the case of staffs, arbors, etc., that are not intended to be polished subsequently, a certain degree of brilliancy is given to the surface by rubbing with wood, usually pegwood, or with a stick covered with the finest emery paper and oil.

A surface that will not be subjected to friction—as, for example, the head of a screw—can be smoothed rapidly and well with a dry emery buffstick if little metal has to be removed, and the polishing can then be at once proceeded with. Only one cleaning is in this case necessary, for after the emery it will suffice to rub with pith and pass a brush over the surface.

For ordinary work, smoothing a staff or head of a screw with dry, fine emery and finishing by the friction of rather hard pith backwards and forwards, will give a fairly satisfactory surface.

=176.= =White and dead smoothing.= To produce a graining, the piece of steel must be previously smoothed in the ordinary way, perfectly flat and free from scratches. The graining is produced by rubbing the object on a sheet of ground glass with the finger, taking very small circular strokes, especially towards the end of the operation. The degree of success depends on the quality of the oilstone dust employed. It must be very fine, and it will be a prudent precaution to decant the powder in water, or preferably in oil, and not to use the earlier deposits (=168=).

When the oilstone dust is not very good, it may be washed in hydrochloric acid, which dissolves most of the hard grains, but it will require to be thoroughly washed in water afterwards, on account of the difficulty there is in removing the last traces of the acid. Of course such a method is only to be resorted to on an emergency.

Perhaps the most difficult piece to grain is a keyless barrel ratchet, because if the operation is at all prolonged the edge of the ratchet may become white before the center and it may even polish. If this happens, the ratchet should be held in the hand and rubbed with a piece of pith cut to a blunt point with a flat end. By this means it is easy to act on the center, avoiding the edges.

=177.= =Dead white or frosted surface.= After having grained the steel in the manner above indicated, if it is required to obtain a dead white frosted surface, employ a mud formed of Arkansas stone dust, or the sticky deposit on a whetstone, which is more easily obtained. It should not be too yellow, as the result is all the better according as a greater number of steel particles are mixed with the oil; at least, so we are informed by some very good workmen. A large piece of elder-pith having been divided into two equal parts lengthwise, is smoothed with a new, clean file; the mud is spread upon it, and the piece of steel is moved over it with circular strokes as in producing the graining. In this case the movement can be rapid. If the operation be well done, and if the oilstone dust used be of good quality, the object will, after being cleaned, present a beautiful uniform white surface in which the graining is still visible. Experience and knack are everything in the proper conduct of such an operation, especially in its concluding stage.

The surface may be cleaned in pure benzine mixed with a little sulphuric acid, followed by a very clean buffstick, which will impart a brilliancy to the metal.

M. Bean recommends fine Turkey oilstone powder mixed with turpentine as the best preparation for rapidly producing a dead smooth surface on steel work.

Workmen that are constantly engaged in graining employ a foot-wheel for the purpose. The ground glass is fixed so that, although not rotating, a small circular motion is communicated to it. The steel is then simply held against it; indeed, several pieces can be grained in this manner at once.

To the methods above described we would add the following, which is successfully practiced by several English workmen:

They lightly fix the ratchet, for example, by its edge, and finish the smoothing with a piece of pith, more or less charged with pure charcoal powder and fine oilstone dust. Here also knack is mainly instrumental in insuring success.

=178.= =Snailing.= To produce the snailing on a fusee or on keyless wheel-work, the device shown in fig. 44 can be used. The ratchet or fusee is mounted between one pair of centers and driven by a cord from a foot or hand-wheel. The copper or iron lap, having a diameter equal to about three times that of the surface to be snailed, is charged with fine emery powder and oil, or oilstone dust, etc., and set in contact with the face of the steel, which thus causes it also to rotate. The direction of the snailing will be the

same, whether the rotation is to the right or left. If it be required to change the direction, the relative positions of the two pieces must be reversed.

It has been already observed that brass and nickel can be snailed in the same way, employing a zinc or tin lap and coarse rouge (=173=). In some cases, hard wood laps can be used for these softer metals.

In keyless steel wheels a beautiful snailing can be obtained with Arkansas stone mud (or, in its absence, the greasy mass from an oilstone) mixed with polishing rouge.

[Illustration: _Fig. 44._]

With reference to the little tool shown in fig. 44, it may be observed that, if the axes of both the steel piece and lap were driven by bow or otherwise, the surface would be polished and not snailed.

In the absence of the tool here referred to, any one can easily construct one for the purpose which will adapt to the mandril or a foot-lathe: in order to help him in doing so we will describe one designed by M. Cadot, of Paris.

=179.= _Tool for snailing._ This is shown in fig. 45, and we would at the outset observe that it can be used equally well for polishing. To a shoulder at the extremity, A, of a piece of steel rod, B (which takes the place of the slide-rest cutter) is riveted an L-shaped piece _c c d_, and to the point _d_ is firmly fixed by a screw or rivet, the upright piece _d h_ parallel to _c c_; this piece is enlarged at _h_ so as to give a bearing to a hardened steel screw, with a hollow point, in the axis of B: the lap is supported between this screw and a hole in the center of A. The figure will suffice to indicate the form of this lap which is dished internally as shown by the dotted line. It is made of iron or copper if intended for use with hardened steel.

[Illustration: _Fig. 45._]

The piece to be snailed is fixed to a chuck of the foot-lathe, and, having fixed the rod B in place of the cutter, the lap is brought, by means of the slide-rest screws, in contact with the steel, taking care not to set it up to the center, as snailing that starts from the center is not so good. Having charged the lap with fine emery and oil, the object is rotated and it sets the lap also in motion.

It was mentioned above that this tool can be employed for polishing: for such a purpose use fine rouge, replace the lap by one of bronze or bell-metal, fix a ferrule at _i_, and, while the object turns in the lathe, rotate the lap with a bow.

By fixing a rod at L instead of at B, the tool is at once adapted to be used in an ordinary pair of turns, as it can be fixed in place of the T-rest; but it is not so easy to secure parallelism of the two surfaces.

=180.= =To restore the watered surface in nickel movements, etc.= Although the following is employed for nickel (or rather German silver) it may be well to observe that it is equally applicable to all other metals.

As these nickel movements are not gilt subsequent to being repaired, it frequently happens that the water marks on the surfaces do not correspond. By the aid of the following device watchmakers can correct this fault, but we must warn them that, as in all operations involving dexterity, they must first make experiments in order to acquire the requisite manual skill.

[Illustration: _Fig. 46._]

On a small open frame C C, fig. 46, fix several parallel bars _f l_, _e d_, etc., and on two of these adjust a slide _p o n m_, with two strips glued underneath so that it can travel up and down between _a_ and _b_. On _p o n m_, fix a guide of convenient form, as G; and, after cementing the piece, say A, that is to be watered on a board resting on the bench, place the frame C C above it and trace the figure of the guide with a pegwood stick charged with polishing material. The same figure can be reproduced in parallel rows as the guide can be moved up or down.

By varying the shape and position of the guides, the water lines can take the form of waves, festoons, circles or ovals. In the two latter cases the guide has apertures of the requisite form, and the board that carries A, not being more than half the size of the aperture, can be moved about by hand or by a tool.

If preferred, one of the bars, as _e d_, can be graduated and arrangements can be made for clamping the slide by screws in any position.

These explanations will suffice to enable any intelligent watchmaker, after a few trials, to imitate successfully any of the beautiful watered surfaces that are, on a manufacturing scale, produced by machinery.

As regards the material to be used, first mix medium rouge and putty powder in equal proportions. It will be possible to decide from the shade obtained whether more putty powder should be added, because when there is too much rouge, the surface does not acquire a good white color.

POLISHING.

=181.= =To polish brass.= When it is required that a surface be maintained perfectly flat, first dress with somewhat coarse water of Ayr with blue stone and then go over with a softer stone. Next work with fine rottenstone and oil on a felt or buffstick for objects of large dimensions and on a piece of pegwood for smaller articles. They are then soaped, washed and dried in sawdust (=151=).

The work can be accomplished more rapidly, but without maintaining a perfectly flat surface, by first employing pumice-stone and oil spread over a large piece of soft wood or felt. It is then cleaned and polished with rottenstone.

When the form permits of it, a tin disc charged with tripoli and rotating in a lathe can be employed.

Observations. Pumice-stone is powdered fine and then sifted. In using rottenstone a piece an inch or two cube is crushed between the fingers into a cup of water, and this is decanted so as to give several degrees of fineness (=168=). The polishing can best be effected by using old wood from which the sap has dried up: French chalk has but little action if the polisher with which it is applied is from the animal kingdom, horn for example, etc.

=182.= =To polish watch wheels.= Although the operation of polishing is extremely simple, it is very important that a certain degree of manual skill be acquired by practice, as otherwise the work is never of the best.

We will here enumerate several methods of procedure, in order that, after trial, each can select the method with which he finds himself most successful.

Smoothing. The smoothing should be done carefully with very soft water of Ayr stone, free from veins and hard grains and perfectly flat. The wheel must then be well cleaned.

Polishing. In polishing, rods of walnut or boxwood, of tin, bronze or zinc are used. A buffstick and burnisher are also employed.

The materials applicable are rottenstone (with oil or alcohol, being made very thin in the latter case) tripoli, prepared chalk, polishing rouge, crocus, etc. These materials have been sufficiently described in articles =165-7.= Workmen sometimes prefer to make mixtures of two or more substances, but it is more usual to employ them separately.

=183.= _First Method._ After smoothing and cleaning the wheel, it is polished while resting on a piece of cork, where it is held between the fingers which cause it to rotate; the best rottenstone is used and is applied by smooth pieces of boxwood, about 8 inches long, which are filed to a bevel edge. It is best to have the grain of the wood crosswise and the polishers should be of sufficient thickness to prevent their bending when in use.

The rottenstone can be replaced by tripoli and the boxwood by walnut. Some wheel polishers prefer a triangular stick of pure tin or zinc which is often planed to ensure perfect flatness; rouge, rottenstone or tripoli can be used with it.

The wheel, after being well washed in soap and hot water, is thoroughly dried and finished with a fine buffstick in good condition, while it rests on a cork covered with smooth felt; this operation is with a view to prepare the surface prior to using the burnisher.

Some polishers, instead of the dry buffstick, prefer one charged with a little rouge, tripoli or rottenstone moistened. But such preparations must be applied very sparingly as they involve a risk of rounding the edges.

The burnisher is next rapidly passed over the surface of the wheel, which rests on cork, covered with a linen rag, or on a piece of wood, covered with smooth paper. Some give long backward and forward strokes with the tool; others give semicircular movements. It will be found sufficient to give short strokes from half an inch to an inch in length. A slight motion of the wrist is all that is required and after a few trials the necessary skill will be attained. We cannot say more. Practice must also be relied on for determining the most suitable pressure.

The burnisher, about half an inch wide and four inches long, is curved in the direction of its length. A straight burnisher might be used, but it is less safe; the angle of the burnisher set against the pinion should be rounded off.

The burnisher is cleaned and restored by drawing across a large flat piece of walnut charged with rouge of very good quality and very pure. After being washed, a little white wax is passed over it, and then it is again rubbed vigorously with a piece of cloth or a buffstick; finally with a soft linen rag. When a tendency to stick shows itself this operation must be repeated.

=184.= _Second process._ By this method the surfaces are somewhat rounded off at the edges. But, although not so pleasing to the eye, this circumstance involves no inconvenience except that, when burnishing, the burnisher would not at once come in contact with the entire surface; we need not, however, employ the burnisher.

Laying the wheel on a cork, some workmen smooth the wheel by covering it with oil and fine tripoli and rubbing with a walnut-wood stick. Others spread a layer of such a mixture first on the stick and then rub the wheel. When no more lines are observable across the surface of the wheel it is cleaned, placed on a fresh cork that is covered with a soft linen rag, and polished with a fresh buff stick (or one that has already been used for a similar purpose) and an abundant supply of rouge or even fine rottenstone and oil may be used. The buffstick receives a semicircular movement in all directions in order not to needlessly round the corners, the edges of the teeth and the crossings.

It is then washed in warm water, bathed in alcohol and dried with a fine linen rag.

=185.= _Third process._ After smoothing with a very soft stone, rub it with a piece of the root of boxwood cut across the fibre, on which is a layer of the following composition:

Two-thirds rottenstone mixed with one-third castile soap, worked into a paste with a few drops of water so that, although not a liquid, it can be spread out at will.

Make the wheel move backwards and forwards between the fingers while resting on a smooth, good cork, without a linen rag, and, as the operation nears its completion, a semicircular motion should be given to the wood. Wash with soap, boil in alcohol and dry.

The wheel can be burnished on a cork without any linen rag and the (curved) burnisher should be moved with short circular strokes from the center towards the circumference, gradually working up towards to the extremity of the burnisher; the same portion of the burnisher should not pass twice over the wheel (see also article =166=). For common work, fairly satisfactory results may be obtained by using French chalk and a piece of hard wood.

Clock wheels are polished with a piece of felt and rottenstone. They are subsequently soaped, washed and dried in sawdust. (=151=)

=186.= =To polish lever escape-wheel teeth.= The Lancashire escape-wheel makers employ a triangular frame carrying at its corners, (1) a cutter to slit the teeth, (2) a cutter to shape them, and (3) a revolving piece of hard leather of a section corresponding to the form of the space. This latter is charged with the finest glossing stuff, used dry, and the sides of the teeth of six wheels at a time are polished by revolving the disc in each of the spaces in turn. It is hardly necessary to observe that the operation is completed before the wheels are removed from the cutting engine.

=187.= =To polish sinks or oil-cups.= A piece of pegwood, rounded at the end, is used for this purpose, rotating it in a lathe; the watch plate or cock should be inclined in varying directions to the stick in order to remove scratches. If a very high polish is required it may be given by following with a stick, the end of which is covered with wash-leather charged with rouge.

TO POLISH STEEL.

=188.= The polishing must always be preceded by a very thorough smoothing, either with oilstone dust, fine emery, or coarse rouge. If any lines are left to be erased by means of fine rouge, the operation becomes tedious and is rarely successful. The oilstone dust is applied on an iron or copper polisher. When it is desired to preserve the angles sharp, at a shoulder for example, the polisher should be of steel.

When using diamantine an iron polisher, drawn out and flattened with a hammer, answers very well.

With fine rouge, a bronze or bell-metal polisher is preferable for shoulders; and, for flat surfaces, discs or large zinc or tin polishers, although glass is preferable to either of these.

After each operation with oilstone dust, coarse rouge, etc., the polisher, cork, etc., must be changed, and the object should be well cleaned—preferably by soaping; perfect cleanliness is essential to success.

Fine rouge or diamantine should be made into a thick paste with oil; a little is then taken on the polisher or glass and worked until quite dry. As the object is thus not smeared over, a black polish is more readily obtained, and the process gets on better if the surface is cleaned from time to time.

=189.= =To get a good black polish.= As just pointed out, this is mainly secured by using very little polishing material at once, in a very little liquid on either, the polisher or glass plate and drying up quickly. If the surface does not prove satisfactory at first, it will often be found that a final rapid and light application of dry diamantine or rouge on a piece of glass or pith will produce a brilliant black polish.

If operating on an axis or staff, polish as well as possible, first erasing the marks of the graver or file, and then, hold the ferrule between the fingers, rotate it with one hand and with the other rub the axis lengthwise with a pegwood stick charged with rouge or diamantine.

A rod will show a black polish if it be rubbed lengthwise with emery paper of gradually increasing fineness, oil being applied with the finest quality.

To polish flat surfaces. Place the object on a sound piece of cork covered with a clean rag and rub with, a long strip of ground glass.

To polish a square shoulder. Fix a rod in place of the T-rest of the turns, and set it in such a position that the polisher rests on this vertical rod when lying flat against the shoulder. Another and better method consists in cementing or otherwise fixing in the plane of the shoulder a brass disc of such dimensions that the polisher is constrained to remain flat.

Observations. The corner of the polisher that is used for polishing a shoulder should be neither right-angled nor too acute. In the first case it would round off the shoulder, and in the second it would become soon distorted and leave dull radial marks on the surface.

Diamantine should not be used for polishing the acting surfaces of pivots, the pallets of escapements, etc., since this material, as well as emery, is liable to leave particles embedded in the steel which occasion rapid wear.

CEMENT, WAX, RESIN, ETC.

=190.= The principal uses to which the watchmaker applies cement is for fixing objects in the lathe, pallet-stones in position, as well as locking and unlocking pallets, ruby-pins, etc.

The selection of a cement or wax is not a matter of indifference; fine sealing-wax causes objects to adhere firmly together, but many of the best workmen prefer refined shellac. Certain kinds of wax are too dry, the consequence being that a false stroke of the graver will often detach the piece; others are thick and soft, and are apt to heat rapidly under the action of the burnisher or polisher, so that the object is displaced. It is only by making a series of trials that the efficiency of the material can be ascertained. Some workers claim that a mixture of sealing-wax and shellac gives good results.

=191.= =Mode of applying cements.= When employing wax, resin, cement, etc., for uniting two objects, it is important to note that the mode in which it is applied has an important influence on its efficiency. The following observations on this point are due to M. Sibon, and the reader will be able to select those portions that have reference to his work.

When two objects are united by a cement, this will lose much of its value if unskillfully applied, and, in order to use it to the best advantage, the following practical rules should be observed.

1. The surfaces to be united must be quite clean.

2. The less cement, wax, etc., that is interposed between them, the better they will adhere. This is owing to the fact that with a thick layer the object has, at the junction, no more rigidity than that of the cement itself; as a rule this more fragile than the material it is

employed to unite.

3. There should be perfect contact between the cement and the surfaces. With a view to securing this, the object must be first heated to a point such that the wax or cement cannot solidify without having first had time to effect a perfect union.

This remark is especially applicable when using sealing-wax, mixtures of resin, shellac, and similar materials. They will not adhere firmly unless the surfaces have been heated very nearly to the point of fusion of the cement. The sealing of letters offers an example in proof of this assertion. When the seal has been used several times in succession or been left too long on the wax so as to become hot, it will adhere and cause some inconvenience if further employed.

With hot melted glue, adhesion is best secured by friction or a moderate pressure.

Sealing-wax is excellent for uniting metal to glass or stone, providing they are sufficiently heated to melt it; for, if applied to cool surfaces, it will not adhere at all. By heating two pieces of glass or stoneware sufficiently to melt shellac, a small quantity will suffice to make them adhere firmly together; notwithstanding that every one has seen such joints, very few succeed in making them, for the simple reason that they do not recognize the necessity of heating a delicate piece of glass or china to the point which is essential for securing a good result.

In conclusion, the principal obstacles to adhesion are air and dirt. The first is always present; the second is due to accident or carelessness. All surfaces are covered with a thin layer of air that is very difficult to remove; its influence prevents highly polished metal from being moistened when immersed in water. So long as this layer of air is not displaced, the cement cannot adhere to the surface to which it is applied, because it cannot come into direct contact. The most effective agent for displacing this air is heat. Metals heated to about 75° C. (170° F.) are immediately moistened on being plunged into water, hence it follows that, as regards cements that are applied in a fused state, heat is the best means of bringing them into intimate contact with the surface.

We would add that, in addition to possessing this advantage, the application of heat also renders the surfaces more penetrable to the layer of cement, after the manner of soldering, and makes the interlocking of the molecules more perfect; this explains the greater degree of tenacity of a well made joint with only a thin layer of cement.

=192.= =To set in wax in the lathe.= Trace a series of concentric circles on the face of the chuck with a graver point, after turning it true: this will increase the adhesion of the cement. Then the flame of the spirit lamp is held under the rotating chuck and, when this is hot enough, its surface is covered with a layer of shellac or sealing-wax, and the object is held against it. Holding it in position with a piece of pegwood supported on the T-rest, the lamp is removed and the lathe kept rotating until the cement sets. The cooling can be hastened by applying a small moist sponge, but it should not set too suddenly.

If the object requires to be very exactly centered, its position must be insured while the cement is still soft by means of a long pegwood stick in its central hole. This stick is held in position until the cement sets, steadying it between two fingers close up to the chuck. The slightest eccentricity will be indicated by a motion of the free end of the stick.

If the object is round, and has no central hole, it must be centered by its circumference, holding the pegwood in front, or resting against a corner of a circular elevation or depression, as, for example, the collet of a wheel, or of a cylinder riveted to its balance, etc.

The beginner should make a number of trials; they will enable him both to acquire lightness of touch, and to recognize the proper degree of softness of the cement for centering, as well as its tenacity.

When it is essential that the two faces of the object be strictly parallel, a precaution is necessary; this consists in leaving on the face of the chuck a slightly projecting circular rim with a fine smooth edge, and of a diameter rather less than that of the object. By moving this latter backwards and forwards after applying it to the wax, and pressing it into close contact while cooling, the requisite parallelism will be secured.

=193.= =To fix a pallet-stone, etc., in position.= To fix a pallet-stone or an end-stone by means of shellac it is usual to place a small piece of the latter round the stone when in position and apply heat. But very often the lac spreads unevenly or swells up; and this, in addition to being unsightly, is apt to displace the stone. The inconvenience can be avoided as follows: The pallets are held in long sliding tongs, and, taking a piece of shellac, heat it and roll it into a cylinder between the fingers; again heat the extremity and draw it out into a fine thread. This thread will break off, leaving a point at the end of the lac. Now heat the tongs at a little distance from

the pallets, testing the degree of heat by touching the tongs with the shellac. When it melts easily, lightly touch the two sides of the notch with it; a very thin layer can thus be spread over them, and the pallet-stone can then be placed in position and held until cold enough. The tongs will not lose the heat suddenly, so that the stone can easily be raised or lowered as required. The projecting particles of cement can be removed by a brass wire, filed to an angle and forming a scraper.

To fix an end-stone, the cap must be held by its edge in the sliding tongs, and shellac carefully applied around the edge of the hollow. It is advisable to hold the cap in a small tool formed of two parallel blades, as when reversed so as to press the stone on a flat surface, the shellac will spread over the end-stone, from which it will be removed with difficulty.

ENAMEL.

=194.= This name is applied to an opaque glass, with which various metallic compounds, such as oxide of tin, phosphate of lime, borax, etc., have been incorporated by fusion. The color, of course, varies with the substance so added.

Willis recommends the following as a good white enamel for dials: silver sand, 14 parts; borax, 10 parts; red lead, 18 parts; niter, 2 parts; oxide of tin, 12 parts; flint glass, four parts; and binoxide of manganese, 1-50th of a part. But a good deal of care is requisite, both in selecting the materials and preparing the enamel, in order to insure a pure color of any desired shade; it is, therefore, often desirable to purchase the enamel ready prepared.

In applying enamel, regard must be had to the relative dilatation of the metal to which it is applied, the two being so combined as to expand and contract together; otherwise there is danger of the enamel cracking, either at once or shortly after it has set.

Enamel may be applied to gold or copper. Associated with the latter, it forms the ordinary dials of watches and timepieces, and, with the former, it serves for making enameled gold dials or cases. The gold should be of 22 carat, the 2 carats of alloy consisting of equal parts of silver and copper. If the gold is of a higher standard, it will not adhere so well, and, if lower, there will be a further danger of melting the metal before the enamel is fused.

Silver is apt to cockle on the application of heat, and enamel applied to it presents a bubbly appearance.

=195.= =Application of enamel in the cold.= We are indebted for the following particulars to M. Fournier, of Dieppe, a well-known enamel maker:

There are two kinds of false enamel for application, when cold, to damaged dials.

The first, a mixture of white resin and white lead, melts like sealing-wax, which it closely resembles. It is advisable, when about to apply it, to gently heat the dial and the blade of a knife, and, with this, to cut a piece of enamel of the requisite size and lay it on the dial. The new enamel must project somewhat above the old. When cold, the surface is levelled by scraping, and a shining surface is at once produced by holding at a little distance from the flame of a spirit lamp. It is necessary to be very careful in conducting this operation, as the least excess of heat will burn the enamel and turn it yellow; it is, however, preferable to the following, although more difficult to apply, as it is harder and does not become dirty so soon.

The second false enamel contains white lead mixed with melted white wax. It is applied like a cement, neatly filling up the space, and afterwards rubbing with tissue paper to produce a shining surface; if rubbed with a knife blade or other steel implement its surface will be discolored.

PRECIOUS STONES.

=196.= The principal precious stones used in watches, chronometers and regulator clocks, in their order of hardness, are: diamond, ruby, sapphire, chrysolite.

A watchmaker, although he may not have had any previous experience of jewels, can easily ascertain their relative hardness by rubbing one against the other. The softer will be scratched by those that are harder, and the stone that can be marked by a file may be thrown aside as useless.

=197.= =Diamond.= We shall make a very brief reference to this stone, as it is not used except for the end-stones for balances for chronometers and high-class watches.

Splinters of diamond are employed for drilling materials of a less degree of hardness, and fragments fixed at the end of a rod are used for turning very hard steel; diamond dust is the principal material used for working precious stones, polishing, etc. (see articles =165= and =169=).

=198.= =Ruby.= This jewel, of a rich, velvetty, red color, exists in three principal varieties: oriental, spinel and balas rubies, which differ as regards their chemical composition.

From a jeweler's point of view, the value of a ruby is enhanced by its rich color and transparency; but this is not the case in regard to its application in horology, for which hardness and capability of taking a high polish are mainly necessary.

The specific gravity of the three varieties is: oriental, 4.2; spinel, 3.7; balas, 3.6.

The first of these is the best, since it is the hardest, both taking a better polish in the first instance and retaining it for a longer period.

In comparison with the other varieties, its specific gravity is greater and it possesses a brighter color, but will often be found to be less transparent.

Spinel and balas rubies are frequently met with that are very beautiful to the eye, but their hardness is inferior to that of the sapphire and even of the chrysolite. They must be carefully excluded from all good work, for, either in consequence of the inferior hardness or the mode in which the oxide of iron, magnesia, etc., is combined, or of other causes, oil rapidly deteriorates in contact with them, and the moving parts, especially if they are of steel, soon show signs of wear. The rubies themselves also suffer, and it is by no means uncommon, especially in the case of the duplex escapement, to meet with such jewels quite rough and even pitted on their acting surfaces.

=199.= _False ruby._ In a certain class of watches, a variety of stones pass for rubies that are known to jewelers as rubicelle, rubace, rock ruby, Brazil, Siberian or Bohemian ruby, rose ruby, etc., the hardness of which is even less than that of rock crystal. Pivot-holes made of these imitations of the real ruby are worth less than plain brass settings.

=200.= =Sapphire.= The color of this stone, sometimes even milky, passes through all the shades of blue. Like the ruby, there are several varieties that differ appreciably in regard to hardness. The hardness of oriental sapphire is equal to that of oriental ruby; both consist of nearly pure alumina, colored by a little oxide of iron; their chemical composition thus being the same, they only differ in regard to color. It is, then, a great mistake on the part of watchmakers to prefer spinel or balas rubies in place of oriental sapphires.

The sapphire is more brittle than the ruby.

The other kinds of sapphire, such as water sapphires, are not true sapphires; they are soft and should never be used in horology. The density of the oriental sapphire is about 4.01, whereas that of other kinds is only 2.58.

=201.= =Chrysolite.= Under this name lapidaries include a variety of stones of yellow-green, apple-green with shades of yellow, and other colors.

That known as oriental chrysolite, which is the same as the oriental topaz, has a beautiful pale yellow color with shades of apple-green; it is the most highly esteemed. This stone has a sufficiently high degree of hardness for use in watchmaking, as it will scratch rock crystal. Its density varies from 3.73 to 3.00.

The other varieties, ordinary chrysolites, come very low in the scale of hardness. They can be scratched by quartz, rock crystal and even by the file, and are thus of no use for watches.

=202.= =Agate, Carnelian, Topaz.= Only the varieties of the stones already considered that are termed oriental can be used for the pivot-holes or the pallets of astronomical regulators, but for the escapements of the ordinary timepieces of commerce, such, for example, as the pallets of Brocot escapements, the topaz, agate or carnelian may be used. When of the hardest kind, and capable of receiving a high polish, they will very efficiently resist the friction of brass teeth. As to the softer kinds, they are inferior to hardened polished steel for pallets.

WORKING IN PRECIOUS STONES.

=203.= The methods adopted for working in the precious stones are in great parts kept secret by those who practise them; it is, however, well known to watchmakers that jewels are usually worked and polished with powdered diamond, and the following details will afford all the information necessary to enable the reader to make a jewel of any required form. Where not otherwise stated, the information is taken from a work published by N. Dumontier.[5]

=204.= =Tools for working jewels.= These are all of simple construction, and can be made by any watchmaker if, indeed, he has not them already to hand.

[Illustration: _Fig. 47._]

(1.) A small lathe arranged to receive chucks, fixed to the bench or in a vise, and driven by a foot-wheel. Its form resembles that shown in fig. 47.

(2.) Two circular laps of copper and one of tin about 2 inches in diameter and ■th inch thick; these present a flat face for grinding, smoothing and polishing the stones, and are adapted to the nose of the lathe.

(3.) A small barrel (that also screws into the nose of the lathe) with six brass covers, perforated at the center, on which to cement the jewel-holes, when enlarging, smoothing and polishing their holes.

(4.) A flat steel circular cutter half an inch in diameter, for slitting stones. Also two similar discs, one of copper and the other of tin, of the same size, and having sharp edges, are occasionally useful.

(5.) Two small laps, one of copper and one of tin, to smooth and polish cylindrical stones. These laps are mounted in place of the T-rest, or in the slide-rest, in such a manner that they can be rotated in a horizontal plane by a bow, in a manner sufficiently indicated by fig. 48.

[Illustration: _Fig. 48._]

(6.) Two chucks adapted to the lathe, on which to cement the jewels for drilling, turning and polishing.

(7.) A number of small broaches, spindles with concave and convex ends, etc., for smoothing and polishing jewel-holes, convex and concave surfaces.

There may also be added a small steel plug mortar for powdering the diamond (=169=), and a flat steel plate with a block for working up the powder.

=205.= =Selection of Stones.= This is of the first importance. By the aid of a powerful lens, or a microscope, ascertain that they contain no cracks, air cavities or black specks; avoid stones that are milky, preferring such as are marbled, and in which the directions of crystalization seem to cross one another, as they are the hardest. The hardness may be tested by trying them one against the other (=122=), but an experienced workman needs only to note the amount of resistance it offers to the operation of cutting on the lap. The density also affords a valuable means of determining the nature of stones. (See above notes on the several kinds.)

=206.= =To find the axis of crystallization of a stone.= It is well known that jewels differ from glass, in that they form crystals of certain definite forms; they are therefore termed “crystalline,” whereas glass is “vitreous.” If a jewel-hole is drilled in any direction other than the axis round which the crystal may be assumed to have been formed, there will be difficulty experienced in the drilling and polishing; the edges of the hole will become rough during the act of rounding them off, and the hardness will appear to be irregular. This point seems, however, to be ignored by the majority of jewel-hole makers, although the determination of the most suitable direction presents no difficulty.

Obtain, from any optician, two tourmaline plates cut parallel to their axis of crystallization and with their faces polished. Mount them in a light frame, parallel to each other, so that each can rotate independently of the other round the axis through their centers; it is convenient if a light spring tends to bring the plates together so that a stone can be held when placed between them. Or such an arrangement can be bought ready made at most opticians: it is known as a tourmaline polariscope. If this instrument be held up between the eye and a light, and one plate be rotated while the other remains stationary, it will be seen that the light becomes gradually greater or less according to the direction of rotation; and further, if the plates be good ones, a point will exist at which there is nearly total darkness.

To examine a stone, cut and polish on it two parallel faces approximately at right angles to the axis of crystallization; this can generally be roughly guessed at by inspection. Place it between the plates (when set at their darkest position), and not only will the light be in part restored but beautiful colored rings will be formed. If they are circular, the faces of the stone are at right angles to its axis; if not, incline it till the rings become so, and the axis will then coincide with that of the instrument. In case the rings are not observed at all, the stone must again be cut at right angles to the original direction, and the experiment repeated. If they still do not appear, the stone is unsuitable for drilling, but may be used for pallets, locking-stones, ruby-pins, etc.

The stones to be examined in this manner must be larger than those commonly met with, and if cylindrical rubies can be obtained they are to be preferred, as it is then only necessary to slice them across their axis.

It should perhaps be observed that these precautions can only be taken in making jewel-holes for the higher class of clocks, chronometers and watches. The cheaper class must of necessity be cut in such a manner as their figure may suggest.

=207.= =Making jewel-holes.= Having selected 20 or 30 stones of about the same height, cement them to a smooth brass or copper-plate, heated to melt the cement. Hold this plate in contact with a revolving copper lap in which the coarser quality of diamond powder (=169=) has been embedded by means of a hard steel block; the lap is moistened with water.

When one side of the stones is true, soften the cement and, after washing, place them in a vessel containing spirits of wine heated by a lamp. After doing the same to the plate, again cement the stones to it with the trued sides downwards, and grind the other faces until the desired thickness is arrived at. Clean the stones and smooth them on the brass lap charged in a similar manner with a finer quality of powder.

The stones are now ready for drilling. This may be done with diamond powder, or with the diamond drill, both of which methods will be explained.

=208.= _To drill with powder._ In drilling with powder, the stone is fixed with sealing-wax or shellac on a carrier that is adapted to the tool-holder of the slide-rest, this carrier being provided with a vertical slide, so that by the screws in three directions the stone can be accurately centered; it is, moreover, so arranged that the stone can be advanced to or from the drill by pressing with the finger axially. Drill a small hole in the center of the chuck and, after fixing a piece of steel in it that has been hardened and tempered to a greyish color, turn a point on it about twice the length of a pivot, to serve as a drill. This point must be slightly thinned backwards to prevent it from choking in the hole and its end should be flat, so as to retain the powder.

When the stone is exactly centered, place No. 2 diamond powder on the end of the drill, and press the stone gently against it, constantly releasing it from the drill for an instant at a time. The hole will be perforated in from 8 to 15 minutes, according to its depth, during which interval the powder should be renewed two or three times. Remove the stone and fix it on the barrel-chuck cover so as to turn true in the lathe; then turn out the oil-cup with a diamond graver of suitable form. See again that the stone is central, and re-center it if this be found necessary. This is done with the smooth conical end of a soft round broach, or a pegwood, a lamp being held under the chuck at the same time.

=209.= _To use the diamond drill._ Having centered the stone on the chuck, as explained in the preceding paragraph, set it in rotation and bring a sharp-pointed diamond graver against its center, pressing lightly and resting the handle on the =T=-rest; a minute central mark is thus made in the stone for maintaining the drill axial. Selecting a diamond drill of convenient diameter, moisten it in the mouth and present it to the mark, applying a gentle pressure, the amount of which can only be ascertained by practice. It is to be observed that a number of stones should, if possible, be drilled at the same time, for the hand is apt to lose the requisite knack, if only one or two are perforated at a time.

=210.= =Smoothing and Polishing.= When the hole is made through, remove the stone and invert it on the chuck. The diameter being less than that ultimately required, pass a brass broach charged with No. 3 powder through the hole, giving it a gentle axial motion while the stone revolves, and taking care to avoid pushing it so far forward as to lock in the stone, and holding it very lightly between finger and thumb. When sufficiently smooth, clean with rotten wood or soft bread, and treat it in a similar manner with a copper broach and No. 4 powder. Then again clean and use a tin broach and powder No. 5. Next, taking a small bone cone, smooth the angles of the holes; then use a copper wire with rounded end for smoothing the oil-cup (with powder No. 3); follow as explained for the hole with the finer degrees. Using a finely pointed pegwood that passes through the hole, _marry_ or round off the internal angle between the hole and oil-cup (the powder that remains in the hole being sufficient for this purpose) and do the same

to the outer circumference of the cup with a copper spindle of somewhat larger diameter.

Round off external angles with a diamond graver followed by a copper polisher, the end of which is cup-shaped. The flat face of the stone is polished with a small copper disc and No. 4 powder, pressing it lightly with the finger at the same time that a circular movement is given to it; finish with No. 5 powder. Or the stone may be detached and the flat face polished by working on a ground glass plate, a pegwood point being passed into the hole to form a handle.

Re-set the stone, inverting it, on the chuck, centering it. The other side is then polished in the same manner, using such tools as its form may require.

Having thus completed the stone, examine it carefully with a powerful glass to ascertain that the hole is highly polished and the angles rounded off, etc. It is then ready for setting.

=211.= =Setting Jewel-holes.= Whether it be a plate, cock or bushing in which the stone is to be set, the piece must always be cemented to a chuck and the hole accurately centered. Turn it out to a depth corresponding to the thickness of stone, and make a circular groove round the hole thus made with a round-pointed graver, only leaving a very thin fillet of metal on the inside. The stone should fit easily in the hole, but without play, and should pass in to such a depth that its surface is slightly below that of the plate, etc., when there is an end-stone; in other cases it must, of course, often depend on the end-shake to be obtained. At the same time it appears desirable that it always should be slightly below.

Clean out the setting and place a small quantity of oil in it to prevent the stone from flying out when made to rotate; or it may be rendered still more safe by a pointed pegwood held in the hand. The stone is fixed in position with a small conical burnisher (as, for example, the point of a round broach) very carefully polished, so as to avoid all abrading action; if an excess of metal is forced over the surface of the stone, it is removed with a graver. The surface of the brass is finally smoothed with pith or pegwood, and tripoli in oil, followed with polishing rouge in spirits of wine.

English jewel-setters often do not turn the groove, but leave a projecting edge round the hole, which is pressed on to the stone with a burnisher.

=212.= =To Make End-stones.= The details already given will enable any intelligent workman to make end-stones. If one of diamond in a brass or steel setting is required, take a small rose-cut stone, turn out a hole in the chuck to receive it, and, after cementing in position, turn off the corners with a diamond graver so as to be able to set it.

For making end-stones of ruby, sapphire or chrysolite, flatten a face, using the laps Nos. 1, 2, and 3 in succession, or a plate of ground glass. Then cement with the flat face towards the chuck, and turn to the requisite form with a diamond graver. Polish with the cup-ended brass and copper spindles, and set, if requisite, in the same manner as a jewel-hole.

=213.= =To make pallets, unlocking pallets, etc.= This may be done on the lap, or by using files of soft steel, copper and tin. In the first case the stones are roughed out while held by the hand, and the required form is given them while holding them in a small carrier that fits into the T-rest support, but the forms of such stones are so various that no special details can be here given. The diamond powder of different degrees of fineness is used, as in making jewel-holes.

=214.= =To make semi-cylindrical locking stones, ruby-pins, etc.= The stone must first be made approximately cylindrical on the lap No. 1, so that it may be turned with the diamond graver. Drill a hole in the chuck, cement the stone in it and turn it in this manner. When true and of the requisite length and diameter, round off the outer end and smooth with a cup-ended spindle, then polish with powders 3 and 4 successively. Round off the sharp corner with a cup of rather greater curvature. The cylindrical surface is polished by means of a small lap carried on a vertical spindle in a frame fixed in the T-rest support, and caused to rotate rapidly with a bow, the lathe-head also revolving at the same time (=179=). The lap-carriage should have a vertical screw adjustment so that it may be brought just into contact with the stone; it is supplied with the several degrees of powder in turn. Now drill a hole in another chuck of the diameter of this cylinder, fix it in position and finish off the opposite end.

To form the flat face along the axis of the stone it is cemented to a support in place of the =T=-rest and brought against the revolving lap in the lathe; or the same result may be attained by using a brass file.

=215.= =To make a duplex roller.= At the present day this operation so rarely has to be done that only a few words can be devoted to its consideration.

Very pure rubies must be selected, and the hole drilled as explained in =209=; if the drill is too short it must be introduced at opposite ends, and the two holes made to meet. After smoothing the surface, the notch is cut with the thin steel cutter referred to in article =204=, the roller being cemented to a support that replaces the T-rest. When the steel disc charged with powder No. 4 is revolving very rapidly, advance the roller under it by a screw. The notch is polished by a small copper file of suitable form, and its corners rounded off by a tin one of square section, one edge of which enters the notch.

=216.= =To mount diamond drills and gravers.= Drill a hole or file a notch in the end of a piece of brass wire to correspond with the fragment of diamond; heat the end in a spirit lamp and lay on it a piece of good sealing-wax or shellac. When this commences to melt, set the diamond in position and leave the whole to cool. Diamond drills are very commonly mounted at the end of a pin that has had its point filed off; mark a point on the end with a graver and drill the hole, which should be very shallow. Holding the pin in a pin-vise with its point projecting about 1-10th inch, heat the vise in a lamp, and proceed as above explained.

FOOTNOTES:

[4] The theoretical density of an alloy, on the assumption that in alloying the metals do not contract or expand, is obtained by dividing the percentage proportion of each constituent metal by its density, adding the products so obtained together, and dividing their sum into 100.

[5] _L'art de travailler les Pierres precieuses a l'usage de l'Horlogerie et de l'Optique._ Paris. 1843.

PART III.

HEALTH AND MANIPULATION.

PRESERVATION OF HEALTH.

=217.= Some of the following directions may perhaps be considered to be over-minute and too restrictive; but they are not so. Good habits contracted in youth are easily maintained, and, when the watchmaker has tried them long enough to convince him of their influence on his health, he will experience no difficulty in keeping them up.

THE SIGHT.

=218.= When working at any small mechanism, such as a watch, it is necessary to use the glass, but this practice is apt to produce inflammation of the conjunctiva or cornea and a weakening of the eyesight; a too frequent and prolonged use of the glass will have the same effect as using spectacles that are too strong.

In order to preserve his eyesight, the watchmaker should take the following precautions:

He should not retain the glass at his eye by a contraction of the muscles for more than a brief interval of time. The glass holder, which can be at once set in any desired position, has therefore much to recommend it.

Drill a few holes in the frame of the glass to avoid or at least diminish the inconvenience that arises from the heating of the enclosed air, as well as from the deposition of moisture on the surface of the glass.

Do not use glasses of too great magnifying power; they needlessly fatigue the eye.

Only use glasses that are truly achromatic. If compelled to use the ordinary simple glass, place a ring of dead black paper inside the frame and against the lens, which, by diminishing the field of view, will reduce the inconvenience due to spherical aberration.

It is hardly necessary to advocate the use of a green cardboard shade to the lamp, as they are so generally used by watchmakers. It should be so arranged as to protect the head and eyes from radiation, and cardboard is preferable to metal as it radiates less heat.

Working at night and by artificial light, more especially by the dazzling light of gas, fatigues the eyes much more than with ordinary daylight, and the workman will find it a relief, if obliged to work by artificial light on very minute objects, to rest his eyes frequently on large stationary bodies. If he can do so, it is a great comfort to bathe the eyes in cold water.

It is good practice to habituate oneself to the use of either eye with the glass.

By adopting these simple precautions, how many of our fellow-workers who are now only able to see objects indistinctly and suffer from incipient blindness would have preserved their sight uninjured. And there is yet another precaution that has been pointed out by Dr. Haltenhoff, of Geneva. He has shown that by avoiding an excessive indulgence in alcoholic drinks or tobacco, many old watchmakers in that town have succeeded in preserving their sight unimpaired, and it is impossible to doubt the truth or over-estimate the importance of this fact.

The same authority draws attention to the necessity of taking care that, before adopting watchmaking as a trade, youths should ascertain that they do not suffer from progressive nearsightedness, which is often hereditary, as in such a case they would most certainly be compelled to abandon it in after life. Boys should not be set to work on such small objects as the details of a watch too early in life, before the membranes of the eye have assumed a certain degree of rigidity.

Mr. Brudenell Carter, a well-known ophthalmist, is of opinion that the habitual use of the glass by watchmakers has the effect of actually developing and preserving the power of the eye.

THE BODY IN GENERAL.

=219.= It is often found that an old, or even middle-aged watchmaker is irritable, often tired and soured. This arises, not so often from an over-excited uneasiness in regard to his trade, an explanation that is usually urged, as from a derangement of his digestive organs brought about by the habit of life he is compelled to adopt. Prolonged working at minute horological mechanism is perhaps more wearying to the mind and body than any other trade or occupation.

To avoid its ill effects the watchmaker should adopt the following precautions as far as possible:

Do not use a stool with a stuffed seat, but prefer one of cane or wood.

Take care that the relative heights of the board and stool are such that an excessive compression of the muscles of the chest, etc., is avoided during any long operation that renders it necessary to maintain the body in a constrained position.

A stool with adjusting screw similar to a music stool is convenient from this point of view.

Change the position as much and as often as possible, especially when working with the file or graver. With this object in view many workmen have a second board of such a height that they can work standing.

When using the lamp let it always be provided with a cardboard shade as already recommended.

A screen to protect the head from the direct heat of the flame is often found advantageous; in fact, the watchmaker should adopt the advice of Boerhaave: “Keep the head cool and the feet warm.”

Let him always remember that nothing does more harm than sitting to the bench immediately after a meal. He should allow an interval of half an hour to elapse and with some temperaments, even this is not enough; during this period he should only do work at which it is possible to stand. A little exercise, such as a walk that is not hurried, will be still better; it will stimulate the circulation and stretch the muscles that have been maintained in a constrained position for a long time through the prolonged attention and slight motion that his labors involve.

USE OF THE FILE AND GRAVER.

=220.= The first operations that a watchmaker ought to learn are to file flat and square, to turn round, to forge, to hammer-harden a piece of metal without deteriorating it. These accomplishments are but too much neglected in the modern training of an apprentice, an omission that is partly owing to the want of good instructors and partly to the shortness of the time he can afford to devote to learning his trade.

TO FILE FLAT AND SQUARE WITH BOTH HANDS AT ONCE.

=221.= It is a very common practice to place an old file in the hands of an apprentice, to fix in the jaws of a vise a piece of metal, either brass, iron or steel, and to set him to work rubbing and filing the surfaces with great labor, the only result being that they are utterly mis-shapen and covered with brilliant spots.

This method is bad. The action of the file is mechanical and the problem that has to be solved is the following: To produce good work in the shortest possible time, and with the least expenditure of force. It is therefore only by very slow degrees that an apprentice can hope to acquire the requisite ability, if he is set to work trying to shape an object in some hard metal before he knows how to maintain lines straight and surfaces flat. Not knowing how to proportion his effort to the resistance to be overcome, and allowing the file to travel irregularly over the surface, he gets confirmed in the tendency to give a rocking motion to the file, whereby the surface is left round, and he will find it all the more difficult to throw this habit aside.

It is far better to let him commence on round pieces of common wood, filing with a rasp or coarse-cut file, without removing too much at once. By this means he may rely on learning to file flat and square by the eye alone without the aid of a straight-edge.

When he works well in common wood, he can be set to file harder woods, box for an example, roughing with a rasp and finishing with a new bastard file. He should not be allowed to have hard wood until able to file a surface so well that, on placing a metal rule across it in any direction, it is found to be flat.

=222.= Let him then advance to brass, which, if cast, should be previously dipped in acid to remove the hard surface, as this should not be filed off. The resistance it offers would cause a jerky motion of the file that would be apt to disturb the slight amount of decision the hand has already acquired.

As brass opposes a considerable resistance, the pupil should be carefully watched with a view to preventing too rapid movement and an excessive pressure, involving waste of power, while he fancies the work is being proportionately advanced; the manner in which the file is applied to the surface should also be observed, taking care that little or no pressure is applied during the backward stroke. The teacher should both explain and demonstrate that the main secret of success consists in a perfect equilibrium between the actions of the two hands; one should increase as the other decreases with the horizontal motion of the file, since the two levers in use, namely the portions on either side of the point of contact, are continually the one increasing and the other decreasing.

By filing steadily and attentively, the hands will gradually acquire the requisite sensitiveness, or tact, that enables each to adjust the pressure in proportion to the other, as well as the knack that enables them to maintain the surface flat. It is important to avoid short and jerky movements.

Practical instruction from a competent teacher must be relied on to complete the directions here given; no written instructions can replace it.

It is advisable to use new, or nearly new files in the above lessons; the wear will have brought them into good condition for working iron or steel.

Proceed with these metals as already explained in regard to brass, and special attention must still be given in order to prevent hurry on the part of the pupil. The files remove less metal at a time and a greater pressure is necessary, so that he does not make such rapid progress as with brass, and this gives rise to a tendency either to use new files, which are soon spoilt, or to give the stroke too suddenly, while applying considerable pressure, especially during the return stroke. He thus heats his file, breaks off the crests of the teeth, which become embedded in the metal and do much to further damage the file. Moreover, he will lose some of the sensitiveness of touch that his hand has already acquired.

=223.= It would perhaps be well to subdivide the day into three parts for as long as appears necessary; the first to be devoted to filing, the second to turning, and the third to forging and cold hammering.

By this means he will be quicker in acquiring the requisite skill of hand and eye, and, when he has attained to this ability, it will be time to practice himself in the management of various tools. Feeling certain of himself he will soon become quick in his work.

It is prejudicial to the true instruction of a pupil and a false economy of both time and money, to let him commence either a clock or watch before arriving at this point. He will experience difficulty in making even the simplest pieces, which, besides being very badly made, will take up a long time; he will keep forgetting as he goes on, because, owing to the slowness with which he works, the construction of a machine occupies months, or even years, whereas it would only have occupied a few weeks, or months, if he had possessed sufficient manual skill to enable him to handle properly the file and graver.

We insist specially on the need of this preliminary training of the young horologist, because, with very rare exceptions, if a pupil is set to delicate details before he is master of his tools, he works with a want of decision, and, therefore, with difficulty. He will, as a

rule, make a workman of but moderate ability, and will soon become disgusted with his trade, from the mere fact that he cannot work with ease and rapidity.

Time is an element of success; hence gratuitous apprenticeships for short terms, that become a tax on the master if he does not soon make use of his pupil's services, will very seldom produce good watchmakers.

TO FILE FLAT WITH ONE HAND.

=224.= When an object is to be held on a cork or wood block fixed in the vise, with one hand, and filed with the other hand, special care must be taken to lay the file flat without any hesitation after each return stroke, and the hand should be able to feel if the file is wrong in this respect, and to at once bring it flat. After the pupil has learned this, he will very soon be able to adjust the pressure and the force exerted in moving the file horizontally, so that it shall remove an equal amount from the entire surface operated upon. It often happens that the object can conveniently be rested upon a finger of the left-hand while the right-hand holds the file. The maintenance of the file flat is in that case much easier.

=225.= _Mechanical device for filing flat._ This (the _pradel_) consists in placing behind the workman a horizontal bar, on which rests one end of the file handle, prolonged for the purpose to about a yard in length; thus the file has two points of support: the bar, adjusted at a convenient height, behind the workman, and the object to be filed flat fixed in the vise in front.

This method, while convenient for amateurs, may be utilized in teaching an apprentice, letting the supports be hinged at one and press at the other end on a rather strong spring index, which must be prolonged so as to be brought under the eye of the pupil.

The displacement of the index will show him every false movement of his hands, and will guide him in adjusting them. It would be best if the prolongation of the handle were as light as possible, but rigid and arranged so that the file can be held naturally.

TO TURN CYLINDRICAL PIVOTS, ETC., AND SQUARE SHOULDERS.

=226.= Just as in working with the file, advice and demonstration by a good master are here indispensable.

The materials should be worked in the same order as is explained in parts =221-4=; that is: wood, brass, iron, steel, hardened and tempered steel; no one sample being set aside until the student can turn it perfectly round, flat on shoulders, etc., and smooth throughout.

He should turn for a long time, whether it be by the lathe or bow, exclusively with the point of a square, or lozenge-shaped graver, the end of which is ground off on a slope; this is the only possible method of learning to turn true, and it enables the workman to acquire great delicacy of touch.

Owing to carelessness, or to the fact that, when first beginning, they were set to work on metal that was too hard or rough, most learners turn with gravers that are ground to very blunt points; as the graver bites less, they are obliged to apply a proportionately increased pressure, and only succeed in tearing the metal away, subjecting it to a kind of rolling action, and rendering the hand heavy. If a pupil will not practice turning with the graver point, so as to preserve it intact for some time, dependent on the nature of the metal, he will never be able to turn perfectly true.

The bow should be used through its entire length, and with a motion that is progressive, not jerky. The knack of the turner with the bow consists mainly in keeping the simultaneous actions of the two hands quite distinct; one drawing the bow downwards, while the other depresses the point of the graver supported on the =T=-rest, and these two movements of the hands must be performed at the same time, but quite independently.

Irregular and sudden depressing of the graver point, or engaging it too deeply, causes its frequent rupture. This also sometimes arises from the fact that the point is not removed with sufficient rapidity, so that on raising the bow the metal catches it while traveling in the reverse direction; the graver is thus drawn slightly towards the work, and its point will be found too close in when the bow again descends.

As has been already observed, the bow, which must not be too short, should be used to its full length with a regular, but not rapid motion. Afterwards, when the hand has learnt how to manage the graver, the speed can be gradually augmented. There is always a danger of losing time, teaching, and, therefore, money, if pupils are too much hurried in their lessons. Before trying to work quickly, they should, at any rate, know how to work fairly well.

Short and sudden movements of the bow will make the object turned jerk; it will be heated, and the sharp angles of the graver will jamb in the metal; thus there is less work done, although there is more noise, and this is done badly.

=227.= When sufficient experience has been gained in turning with the graver point, and a trial is made with the cutting edge, do not attempt to remove much at a time by pressing heavily, but take the metal sideways so as to remove a continuous thread, using all the points of the edge in succession and the entire length of the bow. The metal will thus be removed as a thin ribbon or shaving. When the hand has had some experience, it will be found easy to remove long strips, and the work can be done quickly, although there be no hurrying in the movement of the bow. These remarks are equally applicable to turning with a lathe.

=228.= Hardened steel that has been let down to a blue temper requires certain precautions. If the graver is found not to cut cleanly, it must at once be sharpened, and no attempt should be made to remove more metal by increasing the pressure of the hand, because the steel will burnish and become hard under a point or edge that is blunt, and the portions thus burnished are sometimes so hard as to resist the best gravers. The only way of attacking them is to begin at one side with a fine graver point which must be sharpened for each stroke; at times it becomes necessary to temper the metal afresh before it will yield. It is asserted that by moistening the point of the graver with petroleum it becomes more able to attack hard substances, and that a mixture of two parts petroleum and one part turpentine enables it to turn very hard steel with comparative ease. Indeed, for all turning it is a common practice to moisten the graver with oil, water, turpentine, or simply by introduction into the mouth.

We have frequently seen apprentices, and even watchmakers, themselves, careless as to the proper sharpening of their gravers and thinking that they could hasten their work by the application of considerable pressure; they thus produced bright spots that required several hours of work before they could be removed.

There is one essential condition for ensuring good work with the lathe, and this consists in the perfect roundness of the points or holes of the runners or centers, and of the holes or points that are supported in them; this perfect truth is nevertheless very rarely met with, for it is noticeable that barely one watchmaker in ten knows at the present day how to roll such a point. We shall subsequently indicate the precautions to be observed in order to secure this accuracy.

The diameter of ferrule is also to be considered; if it is too small, the bow will slip and the object will only rotate by jerks; if too large, it loads the object unnecessarily and the velocity of rotation is reduced, since for the same stroke of the bow the ferrule must make a less number of turns. Moreover, if it is of large diameter, only a light bow must be used, because otherwise the force applied would be excessive.

Swiss workmen—at least the great majority of them—turn with the right or left-hand indifferently. This is a very useful accomplishment easily acquired when young.

The working of various tools, such as the English or Geneva mandrel, and any lathe driven by a treadle, will be a great help in developing the sense of touch and in making it more certain.

But it must not be forgotten that, in order to turn well, the lathe must be well made and planned; without this, no accurate work can be done. The lathe is the first and most important of tools, and a great number of very serviceable accessories can be added to it, which, unfortunately, but few watchmakers know how to make properly. As a rule they content themselves with a simple pair of finishing turns on which but a comparatively small amount of work can be done.

Without committing the mistake of having a too great multiplicity of tools, let the pupil rest certain that a well-planned set of tools in good condition both facilitates and abridges his work and renders it more perfect.

PART IV.

TOOLS AND APPLIANCES.

WORKSHOP FITTINGS.

=229.= Before proceeding to describe the various forms of lathes and the several small tools that the watchmaker should make for himself as occasion offers, either during his apprenticeship or immediately after, with a view to increase his manual skill or to extend his experience, it will be well that he take note of the principal conditions that should be satisfied by the ordinary tools that he will have to buy, as well as the precautions to be observed in their use and some improvements of which they are capable.

=230.= =The bench or board.= This should be fixed in front of a large window that affords a good light. The various hooks, recesses, etc., for holding files, hammers, etc., as well as the drawers, should be well in sight, not only in order that the hand can at once take hold of whatever tool is required, but also to enable the workman to restore them to their place immediately after use. By doing so he will have no occasion to retain on the bench any but those tools that are very frequently or continuously used.

It is an excellent habit, conducive both to well-planned and rapid work, and which can be easily acquired by a little attention during an apprenticeship, to always place the same tools in the same places, as the bench will then never be encumbered. By this means loss of time in turning over a number of objects in order to find one that may be small is frequently avoided.

This observation is of minor importance to specialists who require but a small number of tools; but it is of the first importance to a workman that is engaged in the repair of watches.

=231.= =The stool.= Those with cane seats are to be preferred. The height of the bench and stool should be so related that the muscles of the chest are not too much cramped, especially if the workman is engaged on an operation that occupies a long time and obliges him to maintain a stooping position. The stool with a screw is advantageous in this respect.

=232.= =The lamp.= Certain precautions in regard to artificial light have already been indicated in article =218=.

=233.= =Oilstones.= It is impossible to maintain the points of gravers in good condition if care is not taken to keep clean and flat the surface of the stone on which they are set; if it has suffered irregular wear, the level may be restored by rubbing the stone on a flat, smooth board, covered with a thin paste of fine sand and water. Most kinds of oil thicken on the surface rapidly, when the graver will slide over without being ground down at all, turning around in the hand and thus destroying the flat face and wearing the softer parts of the stone, rendering it uneven. A strong solution of potash or soda is very effective for removing this gummy mass; benzine is also recommended for the same purpose. Various substitutes for common oil are used; such as the mineral lubricating oils or petroleum. Dr. Latteux advocates the use of a mixture of alcohol and glycerine, the proportion of the latter decreasing as the extent of metallic surface in contact with the stone at once increases. Thus, for example, in setting a razor the stone will bite better if alcohol be in excess; but for a graver, of which only a small surface touches the stone, the amount of glycerine present should be relatively much greater.

=234.= =Circular oilstones.= Circular oilstones will be found very convenient for sharpening drills, gravers and other cutting tools, where it is desirable to have exact angles. An Arkansas or Turkey stone dressed down to circular form, and say 1½ inches in diameter, when mounted for the lathe will be found very useful. Apply the lubricant to the stone the same as you would to a flat one, and hold your graver or drill at the exact angle you wish the cutting edges to be and turn at a moderate speed. Truer angles and better work can be produced in this manner than by any other. Emery or corundum wheels can be mounted in a similar manner. Small circular stones can be obtained from material dealers and dental supply houses, in sizes varying from ½ × ■ to 3½ × ¾ inches. They can be mounted similar to Fig. 49, by turning down a piece of No. 30 Stubb's steel wire to the size of the opening in your wheel and riveting the wheel firmly upon it. The best sizes for watchmakers' use are ½ inch, 1 inch and 1½ inch in diameter.

[Illustration: _Fig. 49._]

=235.= =Small grindstones.= When it is necessary to remove a good deal from the face of a graver, the operation will take too long on the oilstone, and there would be considerable difficulty in maintaining the flat face; recourse must then be had to the grindstone, but it should be remembered that care is needful when using it. The grindstone must always be thoroughly wet in order to avoid heating the graver, as its cutting power would then be destroyed. The emery wheels described in paragraph =165= can be used for this purpose, but they are, for the most part, inconvenient on account of the rapid increase they occasion in the temperature of the metal. Some forms of emery wheel can, however, be moistened just as the grindstone.

When the cylindrical surface is rendered irregular by use, take a piece of sheet-iron, the tail of an old file or a cold chisel, and hold it with one hand firmly on a support against the edge of the stone, which is rotated by the other hand. The surface can thus be made smooth and true, providing it is only attacked gradually and the handle is not turned too rapidly. An excessive velocity will heat the iron, which is then less effective and is more rapidly worn down; whereas, with a slow motion, the iron will relatively wear little and the stone more. A rough diamond mounted at the extremity of a steel rod, affords an excellent means of trimming a grindstone, and is at the present day generally used in factories.

=236.= =Glasses.= Some particulars have already been given in regard to these simple microscopes in article =218=.

=237.= =Files.= A new file should never be used for steel; it is best to employ it for some time at first on brass, taking care not to use it too roughly. If employed to steel at once, or if sharp, quick strokes are applied, the cutting edges of the file will chip off, and the hard particles will be embedded in the metal operated upon; the work will thus be bad, and the file itself deteriorated. A file that has been carefully used, and has passed gradually from brass to steel, will last four or five times as long, and will always work well.

Watchmakers often fit files into handles by driving them firmly into round holes in the handles; this practice frequently leads to the handles being cracked, and the following method is preferable: Take an old worn out file or a piece of iron of the same form as the tail of the file to be fitted; heat it several times to bright redness and drive it, when so heated, into the handle, taking care to maintain it perpendicular. A hole will thus be made of the required form, in which the file will hold without there being any occasion to apply excessive force in fixing it in position.

When the surface of a file is choked with particles of iron, copper, wood, etc., while the cutting edges are yet good, it can be cleaned as follows: Place the file for a few seconds in a hot lye of potash in water, and on withdrawal, dry it before the fire and brush the surface with a stiff brush.

=238.= To renew the cutting edges of files, either of the following methods can be adopted: 1. First clean the file with potash or soda dissolved in water, if greasy or resinous substances have to be removed; with hydrochloric acid if it is rusty; and by rubbing with a metallic brush or piece of coke if particles of iron, brass, lead, copper or tin have to be removed. The file is now immersed in a mixture of 1 part nitric acid, 3 parts sulphuric acid, and 7 parts water. As the action of the acids become less energetic owing to the combination with iron, the temperature of the mixture must be raised, since rapidity is a condition of success. The time during which the file should remain in this bath varies from 10 seconds to 100 or more, the roughening of fine-cut files being far more rapid than when they are of a coarser cut. On removal from the bath, immerse in lime wash, dry, and then cover them with a mixture of oil and turpentine by means of a brush, after which they are ready for use. 2. After being cleaned, as explained above, the file is supported in a dish full of water, resting on two cross wires, so that all its surface is in contact with the liquid. Now add strong nitric acid in the proportion of 1 part to 8 of the water, mix it thoroughly and allow it to remain for 25 minutes. Remove the file, and, after washing in water and rubbing with a hard brush, place it again in the bath, to which a second eighth part of acid is now added, and leave it for 50 minutes. Again remove and brush the file, add a sixteenth part of concentrated sulphuric acid, and replace the file in the bath. Then wash successively in pure water and in lime wash (to remove the last traces of acid), and dry. The file will be found to possess both the qualities and the appearance of a new one.

=239.= _To cut an equaling file._ It often happens that a workman is called upon to modify the shape of, for example, the bottom of a rectangular notch, and he is not provided with a file of suitable shape. In such a case he can adopt one of the following methods of extemporizing a file:

[Illustration: _Fig. 50._]

1. Clamping the small steel strip, L, Fig. 50, in a vice, cut the notches with a chisel, _n_, as follows: Holding _n_ a little inclined, cut the first notch, _i_. This will slightly raise the metal, presenting a rounded face at the back. To make the next cut, hold the chisel with its edge on L and, after drawing it backward until arrested by the back of _i_, incline it to the requisite amount and give a second blow with the hammer, then continue the operation till the whole is finished. A few trials will enable any workman to make a small file with sufficient accuracy for his purpose.

2. Employ an arrangement similar to that of the micrometer divider (=44=) only more rigid. A study of this article and examination of the corresponding figure will afford all the information that is necessary.

3. This is identical with the method of dividing a rule described in =46=, except that the divisions are closer together and the tracer is replaced by a revolving cutter with its axis a little inclined, to give the requisite slope to the teeth of the file. This cutter is supported in a hinged frame and provided with a washer of ivory or other such substance, as seen at _s_, Fig. 50, to determine the depth of cut.

=240.= _Beaupuy files and burnishers._ Most watchmakers are acquainted with the files and burnishers that M. Beaupuy has introduced for rapidly forming conical pivots, the main characteristic of which is that the corner presented to the pivot is rounded to the desired form and roughed; they do their work rapidly and well, but some skill is necessary in their management. To the

instructions which accompany them we would add the following:

They must never be used when quite new on a pivot that is to be employed in a watch; it will be reduced too rapidly. The freshness must be worn off the cutting edges of the teeth by preliminary use.

The pressure must only be applied perpendicularly to the surface of the staff as in making a square-shouldered pivot; the file is held against the flat surface without pressure. A lateral force will have the effect of straining the pivot and causing it to break.

=241.= =Pliers, tweezers, etc.= It is advisable to have a considerable number of these, as their strength should always be proportional to the force that has to be applied to them. For example, if a pair of sliding tongs is used when a hand-vise is needed, the former will be strained beyond its limit of elasticity and the tool becomes nearly useless.

The same might occur with any other form of pliers or tweezers. In the hands of a good workman they will last for a long time, but if used unintelligently, without proportioning the size of tool to the force that has to be applied, taking up the first that comes to hand, all the tools will soon become unsatisfactory and the work itself will suffer. It is very desirable to have one or more pairs of brass pliers and tweezers for handling metal work without the risk of scratching.

=242.= =Compasses, gauges, micrometers, etc.= The common compass for measuring thickness, the douzieme gauge, is not always strictly accurate in its indications. The douzieme proper, has a scale divided into twelfths, though some patterns are now made that have a scale divided into tenths and hundreds of an inch and again there are others that measure the fractions of a millimeter. The greater majority of these tools on the American market are correctly divided, but we sometimes come across those of foreign make that are divided incorrectly and care should be used in selecting. In the inaccurate tools the objection is that the opening of the jaws gives a measure of a _chord_ whereas the displacement of the index measures the _arc_ of a circle. It follows from this, that, if the index is first arrested when pointing to 15, for example, and again when at 30, the interval between the jaws in the second case will not be exactly double the first. Before purchasing, it is well to test the gauge for accuracy in this regard by some reliable standard.

=243.= _Caliper for mainspring height, depth of sink, etc._ A simple instrument for taking such measurements is shown at G, Fig. 51.

[Illustration: _Fig. 51._]

The finger _a_ travels over a graduated arc whenever the rod _c_ is pressed inwards; _b_ is a fixed stop, with its extremity in the plane of _n_. Any movement of _a_ below _o_ measures the space traversed by _c_ within the line _b n_.

Laying a coiled mainspring, for example, on a plane surface, stand the base _n_ of the caliper upon it, and the end _c_ pressing on the table will be forced upwards and move the needle. To take the depth of a barrel, press _c_ on the bottom, allowing _b_ to rest on the edge of the cover recess.

It will be evident, from the figure, that _a_ and _c_ are connected by a spring passing around drums at corresponding axes. The smaller _j_ is, the more sensitive will the instrument become.

=244.= =Figure 8 caliper.= For ordinary work, the calipers to be bought at material stores will suffice; but when it is required to verify escape wheels, balances, etc., there is some risk of accidents in consequence of the variableness of the friction at the joint. To remove this source of danger, true the rubbing surfaces in the mandril and replace the brass discs at the center by similar discs of steel, then carefully re-make the rivet that forms a hinge, after oiling all the acting surfaces. The arms will now move with a uniform degree of stiffness, so that there need be no danger of jerks.

=245.= =Riveting stake and punch.= The holes in a riveting stake are made to increase downwards, so as to avoid any accident occurring through the oscillation of the axis. The riveting punches made of a plain steel rod, with a hole drilled at one end in the direction of the axis, are the best. Those that are perforated transversely like the lanterns of screw-point tools, do not produce such good riveting, since the parts of the end, from behind which metal has been removed, are more or less elastic.

=246.= =Burnishers.= Burnishers will not remain in good condition unless their surfaces are prepared, from time to time; in the case of those used for very fine work, by passing over a buffstick charged with polishing rouge or very fine emery, and other kinds on an emery stick more or less fine, according to the degree of roughness the burnisher is required to possess.

=247.= _To re-face a burnisher._ Pivot burnishers are usually re-faced by a lapidary; a watchmaker can, however, do it for himself very effectually in the following manner: Prepare a dry, smooth piece of wood, rather thick, and of a width equal to the length of the burnisher. On this board carefully glue a piece of emery paper, of a fineness corresponding to the degree of cut required, stretching it as even as possible, and turning the edges down towards the under side. Then lay the board on a firm smooth surface, resting a weight upon it, and allow it to dry.

In using this lap, it is fixed or allowed to rest against the side of the bench; holding the burnisher with two hands at its extremities, the workman places himself at one end of the board, and draws the burnisher along it towards him, maintaining the surface quite flat and applying considerable pressure. On reaching the nearer end, raise it, and after again placing it on the farther end, draw towards the body, and so on.

By proceeding in this manner and always in the same direction, placing the burnisher so that the acting edge is farthest away from the operator, all risk of rounding this angle will be avoided.

=248.= =Broaches.= Great care is needed in adapting handles to broaches. Resting the point against a finger of one hand and causing the handle to rotate by two fingers of the other hand, the broach itself should be seen to remain true.

It is a good precaution, suggested by M. H. Robert, to gently draw a piece of iron, charged with rouge, along the edges of pivot broaches in order to remove the thread of metal from them. Minute particles of this thread would otherwise remain in the holes, and occasion wear of the pivots.

These fine broaches are not fixed in handles, but a piece of sealing-wax is melted on to the upper end; then, holding the broach between the fingers, with its stem downwards, it is rotated while held to a flame, so that the sealing-wax forms a regular, oblong handle.

=249.= =Blow-pipes.= In order that a long even flame may be obtained, the hole should be of moderate size and perfectly clean around the edge; otherwise the jet cannot be straight and sharp. Difficulty will always be experienced by anyone who has not learned to breathe without interrupting the continuity of the blast. Where a supply of gas is available, the gas blow-pipe presents advantages from the point of view of convenience.

[Illustration: _Fig. 52._]

Fig. 52 shows a gas blow-pipe for jewelers, which is simple and convenient. It consists of a blow-pipe of the ordinary form, having a gas pipe inserted in the lower half, and a threaded hood or sleeve at the lower end, which changes the shape of the flame by screwing in or out, so as to vary the influence of the current of air upon the flame. A ring adapted to slip over the finger while working, is soldered to the middle joint of the pipe, and the quantity of gas is controlled by the stop-cock and spring lever shown in the cut, the gas being supplied to the pipe by a rubber tube connecting it to the nearest gas jet in the usual way. Thus having the shape of the flame under control and the quantity variable at will, the workman is in position to accomplish the desired end speedily and effectually.

To use to the best advantage, set the jamb-nut so that with the valve lever in its normal position, the flame at the end of the pipe will just keep alight. The blow-pipe can then be laid down temporarily and again used without the trouble of turning off the gas or relighting.

When used as a mouth blow-pipe, the most convenient way to hold it is with the third finger through the ring. For bellows work it is better to pass the ring over the index finger. The ring also serves, with the valve-lever, as a rest to hold the flame-nozzle away from the table when the blow-pipe is laid down temporarily.

To produce an oxy-hydrogen flame, connect the air-pipe with a cylinder of nitrous oxide, opening the cylinder-valve carefully, so as to permit the escape of only sufficient nitrous oxide to produce with the illuminating gas a very small flame. Regulate the illuminating gas flow with the thumb-screw or with the finger on the lever of the blow-pipe valve.

[Illustration: _Fig. 53._]

Fig. 53 shows an automatic hand blow-pipe for use with a foot blower. One of the rubber tubes shown is connected with the blower and the other to the gas supply. It is self adjusting for both gas and air, requiring only a slight motion of the lever, shown under the

thumb, to obtain instantly any flame, from the smallest to the largest; so that these pipes have all the delicacy of the best mouth blow-pipe, used with the utmost skill, together with the power and advantages obtained with a mechanical blower.

=250.= =Small gas furnaces.= The workman will frequently have occasion to anneal pieces of steel or to raise to a red heat objects that are too large for the blow-pipe; an ordinary open fire aided by bellows is often resorted to in such a case. A better plan, however, is to use any small portable gas furnace, provided with a hood that completely closes it at the top.

Fig. 54 shows a gas melting furnace, which is kept by material and supply houses. It is powerful enough to melt gold, silver, brass and copper, but is not recommended for cast iron. It can be used for scorifying and cupelling. The lid can be pushed sideways sufficiently to give access to the interior of the furnace.

[Illustration: _Fig. 54._]

The following points in the management of a gas furnace will be of service to all novices in their use. The power and speed are practically without limit, depending only on the gas and air supply, and are under perfect control. Allowing five cubic feet of gas for heating up, it requires about four feet of gas for every pound of cast iron melted. For small work it is as cheap as a coke furnace, and not one-quarter the trouble.

The quantity of air required depends upon the gas supply. One must be equal to the other, so that perfect combustion will take place, and that entirely within the furnace. An excess of either gas or air renders a high temperature an impossibility.

See that all gas taps have a large clear way through. High temperatures and rapid working require a free supply of gas.

To adjust a new furnace to its highest power, connect both gas and air supply with the burner. Turn on the full gas supply, light the gas, the air-way being full open, work the foot blower and then put the gauze nozzle of the burner tight against the hole in the casing, so that no flame escapes around it. If the flame comes out of the lid about two inches, the adjustment is right. If the flame is longer, open the air check until the proper flame is obtained, or reduce the gas supply. If smaller, or not visible, close the air check until the flame appears.

The cap-nut, which will be found at the throat of the horizontal “mixing tube,” where the air enters and mixes with the gas, is used for changing the size of the orifice from which the gas escapes. When the escape is from a large orifice, a smoky, yellow, or “reducing” flame is the result. By contracting the orifice by screwing the cap-nut on to the gas delivery tube, a blue or oxidizing flame will be obtained. Adjustment for the proper flame should first be made by this nut, and the size of the flame regulated afterwards by means of a cock at the gas main. A slightly yellow flame gives the best results when a high heat is desired. The arrangement above described is clearly shown at the left-hand lower corner of the sectional illustration above.

A chimney or stove-pipe 8 or 10 feet high may be used as a fixture, and the draft partially stopped by the damper or slide when lower temperatures are required, the gas being turned down in proportion; the guide for the proper adjustment being that UNDER ALL CIRCUMSTANCES THE FLAME MUST JUST COVER THE CRUCIBLE OR MUFFLE, but not extend into the chimney so as to make it red hot. When the flame covers the crucible or muffle, the gas is doing its extreme duty under the most favorable circumstances, without waste.

Keep all fluxes away from the furnace jacket, as they are injurious to fire clay, and are liable to cause the lids, etc., to stick to the furnace.

A thin layer of quick lime on the bottom of the furnace will prevent the crucible adhering to it when very hot.

When using a furnace for high temperatures, care should be taken not to use a fire clay casing, as it melts at a temperature a little above that of cast iron; plumbago or asbestos only should be used when very high temperatures are required.

[Illustration: _Fig. 55._]

Fig. 55 represents a small gas furnace, which is extremely useful for small meltings, experimental work, etc. It consists of a pot made of a mixture of fire clay and asbestos, bound with rivetted iron hoops, and having a hole in the side at which the flame enters. A lid pierced by a central hole permits the escape of the products of combustion, and the crucible is placed in the center so that the flame surrounds it. It is worked with gas and a foot blower. Gas from a ■-inch supply pipe will work it efficiently. About ten cubic feet of gas per hour is sufficient for most purposes.

The casing holds the heat so perfectly that the most refractory substances can be fused with ease, using a Fletcher foot blower. Half a pound of cast iron requires from seven to twelve minutes for perfect fusion; the time depending on the gas supply and pressure of air from the foot blower. The crucible will hold about ten ounces of gold.

The power which can be obtained is far beyond what is required for most purposes, and is limited only by the fusibility of the crucible and casing.

[Illustration: _Fig. 56._]

Fig. 56 represents a small apparatus, which, owing to its speed and economy of operation, has a very extended use in the jewelry and silversmithing trades. With this apparatus a sound two-ounce ingot of gold or silver can be moulded in two minutes. A crucible of moulded carbon is supported by a sheet-iron slide, or plate, which is clamped to an ingot mould by a clamp which swivels in the U-shaped cast iron stand. The metal to be melted is placed in the crucible, and the flame of the blow-pipe directed on it until it is perfectly fused. The whole is then tilted over by means of the upright handle at the back of the mould. The waste heat serves to make the ingot mould hot. No flux should be used with the carbon crucibles. For the smaller operations, such as making small quantities of colored golds, for electroplating solutions, testing ingots, and the smaller operations of the jeweler and plater, it is invaluable.

[Illustration: _Fig. 57._]

The air pressure used in operating gas furnaces varies from one to four pounds per square inch, though the latter is seldom required except for the severest work in large furnaces; as a general rule it is less than two pounds in the operations of the gold and silversmith. The pressure must be arranged so that the air supply equals that of the gas used. This can be readily seen by the color of the flame, as noted in instructions for handling the furnaces. For small operations foot blowers are used. These consist of a powerful bellows having a hemispherical pressure chamber on one side, and adapted to work either by the hand or foot; see Fig. 57.

[Illustration: _Fig. 58._]

[Illustration: _Fig. 59._]

The perfect combustion of the gas is secured by mingling equal quantities of gas and air in a mixing chamber, and then igniting the mixture. In the larger furnaces this is accomplished by a mixing chamber placed under the furnace, so as to heat the mixture before ignition, and no pressure supply of air is necessary. In the smaller apparatus, this mixing is done in the burner, which consists of an inner tube carrying an air supply, surrounded by a gas tube, and the whole surmounted by a sliding nozzle for changing the shape of the flame. The mixing chamber being so small, the air and gas pass through it so rapidly that considerable pressure of air must be provided to prevent it from being excluded by the normal pressure of the gas; hence the necessity for a blower when using small burners.

When it is not desirable to use gas, for pecuniary, or other reasons, melting may be carried on by means of a gasoline gas flame, which is noisy, but otherwise little inferior to coal gas. The furnaces for gasoline differ but little in construction from the others, as will be seen by Figs. 58 and 59. The only difference being that the burners are applied from the side and no air pressure tubes are needed, while the furnace is supported on legs to insure safety from fire.

[Illustration: _Fig. 60._]

The burner for gasoline is radically different from that for gas, being, in fact, a small gas machine, Fig. 60.

In Fig. 60 _P_ is an ordinary force pump, at the bottom of which, at _A_, is a valve which closes automatically upon releasing the pressure from the pump, _C_ is a check valve which closes the inlet to the tank _T_ completely; _F_ is a filling screw for introducing gasoline. _V_ is a vent screw for letting off the pressure when through; _H_ is a pipe leading from the tank to the burner _D_; _E_ is the burner regulator, terminating in a fine point, closing the orifice of the burner; _S_ _S_ are packing boxes. Upon opening _C_ and pumping a few strokes a pressure is created in the tank and on top of the fluid, forcing it through the tubes of the burner, which being previously heated, vaporizes the gasoline. This issues from the orifice at the end of _E_ as a highly heated gas and burns as such in the form of a powerful blast, Fig. 61. After being once started the heat of the flame passing through the burner, vaporizes the fluid in the tubes, and hence the apparatus is automatic.

[Illustration: _Fig. 61._]

The air which is forced in is not consumed, so that to keep up the blast it only requires a few strokes of the pump occasionally to maintain the pressure lessened by the consumption of the fluid.

To operate the blow-pipe: close _E_; unscrew _F_, and introduce from two quarts to one gallon of gasoline of 76° according to the capacity of the tank. Replace _F_ and close _V_; open _C_ one or two turns and give three or four full strokes of pump _P_, and close _C_. Heat the burner by burning some of the fluid in a suitable vessel placed under the burner; when hot enough apply a match and open _E_ gradually, until the action is more or less uniform. If no spray or liquid issues from the orifice, the burner is hot enough; if not hot enough, burn slowly until no liquid or spray issues. When sufficiently heated the blast can be made of any intensity desired, by the use of the pump as above. To stop its action, shut the regulator _E_, or open screw _V_, or both. When not in use the vent _V_ should invariably be kept open. The mouth of the burner _D_, should be two or three inches from the inlet of the furnace, or there will not be perfect combustion.

For very high temperatures and muffle work, light the burner as above and heat the inside of the furnace to a bright red; then place the burner against the inlet of the furnace; turn out the burner by means of the cock _E_, and immediately turn it on again without lighting it, when if the furnace is hot enough, the gas will ignite inside the furnace. The heat can be regulated as in the first method of burning. When burning inside of the furnace, there must be no flame in the burner tube; it should all be inside the furnace, and the tube of the burner must be close to the fire hole, or there will not be enough heat in the tubes.

Use a drop or two of sperm oil on the piston of the pump occasionally, also on leather washer at _F_, otherwise the apparatus will be apt to leak, corrode and work badly.

[Illustration: _Fig. 62._]

=251.= =Muffle Furnace.= This consists of a fire-clay furnace, mounted upon a powerful gas burner and containing an oven, also of fire-clay or plumbago, so placed as to receive the full heat of the flame, without permitting the direct action of the flame upon any object placed within it. The objects are placed in and withdrawn from the muffle, or oven, through the door shown in the cut. This door is made of two pieces so that the upper one may be removed to watch the progress of the work without chilling the contents of the muffle by too great an entrance of cold air. They are extensively used for assaying, annealing, etc., and for many other purposes where an exact temperature is required. The illustration shown in Fig. 62, is of a gas muffle, but they are also made to be used with the gasoline burner previously described.

THE LATHE.

=252.= Of all the tools and machinery employed by the watchmaker, the lathe is the most important. Very poor work is often turned out by those possessing a first-class lathe, but there are very few persons who can turn out good, true work, from a poor, cheap lathe, and if it is untrue it is utterly impossible to turn out good work. Wonders can be accomplished by the ingenious mechanic who thoroughly understands the capabilities of the lathe. By patient skill of manipulation, the Chinese and Japanese turn out some truly wonderful work; they succeed in turning sphere after sphere, one inside the other, from a solid piece of ivory, the opening from one to another being comparatively small.

The earliest form of the lathe in the trade was the dead center: that is, a lathe whose parts did not revolve, the object to be operated on being placed between centers and made to revolve by means of the bow. This form of lathe was succeeded by the live spindle or live mandril pattern, although there were many good points about it that must be acknowledged. It contained one great element that many modern appliances, termed lathes, lack, i. e., the element of truth. No matter how coarsely or crudely constructed, this truth was not eliminated, except by the ignorance of the artisan, for the centers must remain the same relatively, whatever may be their position in relation to the lathe bed.

With the introduction of the live spindle lathe in this country, the verge, Jacot and other lathes and tools of that type were rapidly abandoned. In Europe, however, the live spindle lathe did not meet with such a cordial reception, and it has taken many years, in some localities, to overcome the prejudice against them; in fact, there are still many workmen there who cling to the dead center patterns.

The all-important point in lathes of the live spindle type is accuracy of fitting, and particularly in regard to the spindle and its bearings, for unless a certain degree of perfection is attainable in this particular, it is worse than useless, as it not only does not do

the work, but leads the artisan astray. The workman, sometimes, through motives of economy, purchases foreign made lathes, that closely resemble the American in outline and finish. These lathes, as a usual thing, are not accurate, and in the greater majority of cases the chucks which accompany them are worse than nothing, and yet these lathes, in nearly all cases, are declared to be as good as the American. There are some foreign lathes that are very carefully made, and are quite as true as the best American, but they are the exception and not the rule. The workman who buys one of these lathes cannot, of course, tell whether it is right or wrong until he has placed it on his bench and tested it, and even then he cannot be sure, for although when a certain chuck is placed in the spindle and tested it may apparently show no deviation from truth, there may still be untruth in the spindle or chuck or both, as the errors in one may be counteracting the errors in the other, and if the chuck be turned or an absolutely true chuck placed in the spindle, the error will be made quite apparent. If an American lathe, by any possibility, is allowed to pass the inspector, and finds its way upon the market, the maker is only too glad to replace it with a perfect one, for his reputation is at stake; but if one of the imitation pattern proves untrue you will have to do the best you can.

[Illustration: _Fig. 63._]

There are American made lathes upon the market that are as inferior in many respects as the imitations, and the watchmaker will do well to do without a lathe until such time as he can afford to purchase one of known reputation. Among the first-class American lathes upon the market may be mentioned the Webster-Whitcomb, shown in Fig. 63; the Moseley, shown in Fig. 64; the Hopkins, shown in Fig. 65, and the Rivett, shown in Fig. 66, and others.

An excellent lathe for the heavier work of watchmakers and jewelers, such as cannot be performed with satisfaction on the watchmaker's lathe, is the No. 4 Barnes, which is shown in Fig. 67.

[Illustration: _Fig. 64._]

For screw-cutting, the manufacture of watchmaker's tools, fishing reels, repairs on tower clocks, in fact, all the heavier work of the trade, it is admirably fitted.

=253.= =Care of the Lathe.= The American lathe of to-day is a marvel of completeness in its parts, and how many hours, yea months, of study and experiment have been bestowed upon it by its projectors and makers to acquire these points of utility and excellency? What a vast amount of care has been exercised for the production of a perfect lathe! Must this care cease at the moment it passes into the hands of the watchmaker?

It is a very easy matter at any time to wipe off the dust and oil that may accumulate, but does this alone constitute due care? There may be a nice glass case to cover it and keep off the dust, and a very good idea it is, if faithfully used; but if a counter shaft is on the bench, or much lathe work is to be done, it soon falls into blissful desuetude, or finishes its usefulness by being broken. Then, often, a cloth is wrapped about the lathe, which soon gets soiled and looks badly, let alone the poor protection it affords.

[Illustration: _Fig. 65._]

Dust is omnipresent, and the greatest enemy to all active machinery; it insidiously makes its way into every crease and crevice, and if not promptly removed will cause untold damage. We cannot get rid of it and must (like the industrious housewife) wage a constant warfare against it.

The care necessary to be given to a fine lathe differs from most other tools; it is not confined alone to the removal of dust and keeping clean, but the fitting properly of the several parts as used. There should be no overstraining when tightening screws, chucks, etc., or when fitting articles in both wire and wheel chucks, and so on through the list.

[Illustration: _Fig. 66._]

The face of the lathe bed when it comes from the makers is (or should be) perfectly true from end to end, in order that head and tail stocks will meet on a direct line of centers, even should they be changed end for end, and a good lathe will meet those requirements. Now, it is obvious to any thinking mind that if this face becomes injured by neglect, whereby the nickeling is removed in spots or portions, they will, in all probability, become rusty; this rust will then eat away and throw off more, and soon the face presents an uneven surface, which will tend to destroy the line of centers between head and tail stocks.

The head stock, usually occupying one position, causes less wear at this point or place, while the hand-rest and tail stock are constantly being shifted, so where there is more motion or action there must be more wear, especially if dust, chips, or grit be

allowed to accumulate beneath them, and though the wear is seemingly imperceptible, it nevertheless is there, and will sooner or later manifest itself, and this is a signal that the level of the bed is becoming impaired, and, necessarily, the truth. Thus too much care and attention cannot be exercised in guarding against chips and dust when sliding hand-rest back and forth on the bed.

[Illustration: _Fig. 67._]

At the end of the bed, where the tail stock takes position, many watchmakers have the tail stock off, and this portion is more exposed to atmospheric action, also receiving perspiration from the hands when they come in contact. Again, others let the tail stock remain in position, only removing when it comes in the way. In the former case, it is well to devise some means for the protection of the bed; this is easily done by making a sheath of chamois skin to slip tightly over the bed; it can be removed and replaced readily, and when it becomes soiled, can be washed.

This sheath should be fully two-thirds the length of bed, or reaching from tail end up to hand-rest when it is close to head stock. It preserves the bed from dampness, which is considerable in some climates, also the perspiration of the hand and flying chips and dust. In the second case, if the tail stock is allowed to remain on the lathe, or, if removed and placed on the bench, it is subjected to all the evils the bed is in the former. Our opinion is, the tail stock should be kept in its compartment in a tight-fitting drawer, away from dust and accidental knocks of other tools on the bench; the tail spindle not being nickeled, is more liable to rust if left exposed, and should be kept in a sheath of oiled paper. This may seem superfluous and too much bother, yet it is taking proper care which tells in the end.

The bottom of tail stock should always be brushed off before placing in position, not only for its protection, but for fear some particle of grit may be adhering, thereby throwing it out of truth, and screwing it down tight only adds injury to the lathe if allowed to remain.

The head stock demands close attention; the spindle should run freely without end-shake, and about once a week should be speeded, meanwhile administering oil until it leaves the bearings clean, and then wiped off. A little oil should be added every day. See that the mouth of the spindle is kept bright and clean; thrust a piece of cloth clear through spindle every now and then, that all dust and dirt may be removed.

Wire and wheel chucks should often be washed in gasoline to remove gummy dirt and oil which is constantly adhering, and it is even well each time a chuck is used, to wash off first, then wipe dry. A little dirt on the mouth of spindle, or on the chuck, often throws it out of truth, and consequently the article fastened therein also.

When fitting head or tail stocks, or in fact any attachment, do so carefully. Do not bang it in place as if you held a grudge against it, and when in position see that they are tightly screwed in place.

Having too much end-shake on live spindle, especially in soft lathes, causes uneven wear in its bearings, besides not being reliable for true pivoting or any such work.

When the cost of a lathe is taken into consideration, it goes to prove that it is not easily replaced. Where is the jeweler with a stock of goods who would retire without first seeing that his valuables were in the safe, but how many are there that think of giving this protection to their lathes? Some do, but the greater per cent do not. It is a good plan to see that the head stock, the tail stock, and attachments are in the safe and should a fire break out that endangers the store, and no chance to save it, the feeling of satisfaction is great to know the lathe is safe, that is, the most expensive parts, for the bed can be purchased at a nominal cost compared to the attachments.

THE FOOT WHEEL.

[Illustration: _Fig. 68._]

=254.= In the selection of a foot-wheel the workman must be governed by his own experience and taste, for the variety that exactly suits one person is very distasteful to another. The swing treadle pattern shown in Fig. 68 is a very popular one with American workmen. These swing treadles are made in various ways by the different manufacturers, but the methods of using them are alike. There are workmen, however, who prefer the heel and toe motion and others that prefer the up and down motion. This is all a matter of taste and it matters but little what form of lathe wheel is used provided the motion is steady and the exertion is light. As a general rule a heavy wheel, say forty pounds in weight, will be found, on the whole, much better than a light one and the motion will be more uniform.

=255.= =Driving Bands and Belts.= Most foot-wheels are so constructed that either a flat or round belt may be used in transmitting the power to the countershaft or lathe, as the case may be. Many watchmakers use a flat belt between foot-wheel and countershaft and a round leather belt, or cord, between countershaft and lathe. If we may judge by appearances, this is the favorite fitting. Others use round leather belts in both instances, while others again use cotton or hemp cord or gut. All things considered, the round leather belt seems to possess advantages over all others. It does not slip as easily as cotton cord, is more elastic than gut and throws less strain on the bearings, absorbs less power and works much smoother. The ends are fastened together by means of an S hook and the cord may be readily tightened by giving it an additional twist or two.

[Illustration: _Fig. 69._]

=256.= =The Countershaft.= The countershaft is indispensable in using milling tools, wheel cutters and pivot polishers. The pattern shown in Fig. 69 is but one of many on the market.

In some of the patterns the uprights extend through the top of the bench and are held securely in place by means of thumb screws or wing nuts. The pattern shown in the illustration is mounted on a solid metal base which is intended to be fastened to the bench by means of screws. The advantages of using a countershaft are three fold: First, you are able to regulate your speed perfectly without changing the motion of the foot from fast to slow or vice versa; second, your belt is carried to the back of the bench, where it is out of the way, instead of coming down in front of the head; and third, you obviate the necessity of having holes in your bench on each side of the lathe, that small articles are liable to drop through. Fig. 70 illustrates the favorite arrangement of foot wheel, countershaft and belts.

THE BENCH.

[Illustration: _Fig. 70._]

=257.= As previously suggested (=230=) it is of the utmost importance in doing good work, and doing it rapidly, that your bench be kept orderly and clean at all times, and that all your tools and devices be in their proper places, exactly where you can put your hand on them at a moment's notice. An excellent arrangement for a watchmaker's bench is shown in Fig. 70. This bench was designed by G. W. Laughlin, and is complete in every detail. Benches can be purchased ready made from material dealers, both with and without curtain tops, but there are many watchmakers that prefer to make, or have made for them, a bench varying from the usual pattern. The bench illustrated is made of black walnut, veneered with French walnut and bird's eye maple. The top is 21 inches wide by 41 long and is 33 inches from the floor. The drawers on the right-hand side are 10 inches wide. In the center are two shallow drawers, while the left-hand side is entirely boxed in.

IDLERS.

[Illustration: _Fig. 71._]

[Illustration: _Fig. 72._]

[Illustration: _Fig. 73._]

=258.= Idlers are especially valuable for use on slide rest tools, such as pivot polishers, milling attachments, wheel cutters, etc., and with traverse spindle tailstocks, traverse spindle drivers, etc., to give a vertical direction to the belts. Idlers are constructed in various forms, some of them being mounted on upright posts, fastened to the bench just back of the lathe, as shown in Fig. 71; others consist of steel rods terminating in a ball, and socket joint, where it is fastened to the bench, as shown in Fig. 72, while in other patterns the rod is fastened by means of a wing nut to a brace running from one to the other of the supports of the countershaft and may be placed at any desired angle. The idler shown in Fig. 73 can be used in this way. Some watchmakers prefer to place their idlers on an overhead countershaft, which is usually fastened just back of the bench and about two and a half or three feet above it. The idler shown in Fig. 72 can be screwed to the bench or to the wall above the bench, in the latter case it will extend out horizontally over the lathe and is out of the way of the watchmaker when not in use. In the forms shown in Figs 71, 72 and 73 the belt passes from the countershaft over the idler and one long belt only is used. This style is sometimes varied by using two separate belts one from the countershaft to the idler and another from the idler down to the lathe. If in the latter style, a cone pulley of rubber is used on the countershaft and also for the corresponding pulley on the idler and a plain pulley for the down belt. Of course in this form the idler stand must be in the form of a countershaft, as the pulley must be fast on the shaft and the shaft

itself must revolve. In the styles shown above, the shaft is rigid and the pulleys revolve upon it. The advantage of using the cone pulley style is that the speed of the cutter or other attachment may be varied at will without in any way increasing or decreasing the speed of the wheel.

CHUCKS.

[Illustration: _Fig. 74._]

[Illustration: _Fig. 75._]

[Illustration: _Fig. 76._]

[Illustration: _Fig. 77._]

[Illustration: _Fig. 78._]

[Illustration: _Fig. 79._]

=259.= True chucks are the most important adjuncts to a watchmaker's outfit. A true lathe with poor, untrue chucks is almost useless. Chucks hold the work truest that comes the nearest to fitting the holes in them. If you try to hold work in a chuck that is too large or too small, you will soon get the chucks out of true and you will soon become dissatisfied with your chucks, your work and your lathe. Care should always be taken to select a chuck that will take the work without straining it open and yet is not so large that undue pressure will have to be used in holding it. The American split chuck, when true, will hold almost any piece of work with the greatest precision as regards truth; but the split chuck is a delicate attachment and will not stand hard knocks and rough treatment. After using them, you should clean them in benzine to remove all dirt, rinsing them in alcohol and drying with a soft linen rag, and see that no small chips of metal are left in the openings that may throw the work out of truth the next time they are used. Fig. 74 illustrates the regular pattern split chucks that accompany American lathes. Fig. 75 is a conoidal wire chuck, so called because the shape of the mouth of the chuck is conoidal in lieu of the shoulder usually left on wire chucks for the bend in the spindle. Fig. 76 is an arbor chuck. This is a solid chuck on the end of which is a threaded arbor for the reception of saws, laps, wheels, etc., which are held firmly in position by means of the nut on the threaded arbor. Fig. 77 is a screw chuck. This is a solid steel chuck having a threaded hole in the end for the reception of cement brasses, etc. Fig. 78 is a shoulder chuck. It is a split chuck with a large opening in the end with square shoulders for the work to rest upon. Fig. 79 is a taper chuck, which is solid and has a large opening for the reception of tapers, centers, laps, etc. Fig. 80 is a step or wheel chuck, which usually comes in sets of five, and as each chuck has nine steps, a set of them will accommodate forty-five different sizes of work. These chucks are useful for holding mainspring barrels when fitting in the cap, should it become out of true; for trueing up the barrel of English lever watches that are damaged by the breaking of a mainspring and for holding almost any wheel in a watch, such as the fitting of a center wheel to a pinion, or in making sure that hole in the wheel is in the center. These chucks will the hold wheels from 5 to 2.25. The chucks mentioned above are the most common ones in every day use and usually accompany the American lathe in combination sets. As intimated, these chucks are delicate and as a usual thing they do not receive the care they should, when their cost and the delicate exactitude demanded of them is considered. The watchmaker who prides himself on his good work and the orderly condition of his tools, attachments and bench generally will purchase or make for himself a nice chuck box with a glass or wooden cover to exclude all dust and flying chips. You cannot expect to do good true work with a chuck that is thrown carelessly into a drawer containing an assortment of files, a hammer, staking block, oilstone, screw driver, sliding tongs, etc., and yet how many watchmakers take just this kind of care of their chucks, and complain of their untruth, and declare that a wax chuck is the only thing that can be absolutely relied upon for truth. Fig. 81 illustrates a neatly arranged chuck box made by the Faneuil Watch Tool Company. In it all the various chucks may be arranged and the whole may be covered with a glass shade to keep out all dirt. A wooden cover might be used and perhaps would be preferable to many as it is less liable to be broken and occupies less space and therefore admits of the box being placed in a drawer, leaving more room on the bench for the necessary tools and attachments.

[Illustration: _Fig. 80._]

[Illustration: _Fig. 81._]

A chuck box should be well soaked in oil so that the wood will absorb no moisture and thus tend to rust the chucks. A small envelope made of tissue paper and filled with quicklime will, if placed in the chuck box, take up the moisture in the air and prevent the chucks from rusting.

[Illustration: _Fig. 82._]

=260.= The chuck stepping device, invented and patented by Mr. Moseley, is a valuable attachment for the lathe. In this device, shown in Fig. 82, _a_ rests in chuck slightly less than diameter of work; _b_ tightens in rear end of draw-in spindle, and turning _c_ regulates the depth of step. By the use of this tool any wire chuck will accurately serve as a step chuck. It is a device of great service to the watchmaker when used and understood. It enables him to make a step in any wire chuck of any depth he may desire, and will push out the work at any time when he so desires. It is very useful many times for a stop for marking or cutting off when you want a number of pieces of the same length or kind. Many object to the stepped chuck for general use.

[Illustration: _Fig. 83._]

=261.= In addition to the regular chucks which usually accompany American lathe combinations may be mentioned some others which from time to time have been placed upon the market by manufacturers of watchmakers' tools. These chucks were devised for holding work which it was found in practice could not be held by the ordinary chucks.

=262.= The bezel chuck, shown in Fig. 83, was originally made with a view of holding bezels only, but is now made so that it will hold watch plates, coins, etc., and is adjustable to any size. It can be fitted to any lathe and it requires but very little practice to use it, as it is extremely simple and any one who uses a lathe can make or repair bezels in a workmanlike manner. It holds the work as in a vise, and no amount of turning or jarring will loosen the jaws, while it may be opened or closed instantly by simply turning the milled nut behind the face plate, thus enabling the operator to turn and fit a bezel perfectly, by trying on the case as many times as necessary. It holds the bezel by either groove, so that the recess may be turned out when too shallow or too small for the glass, or the bezel may be inverted and turned down when it rests too hard against the dial. It will be found especially useful in turning out the inevitable lump of solder from the recess of the bezel after soldering, and in fitting to case, as the process of soldering generally makes the bezel shorter, and consequently it will not fit the case. It also renders the operation of polishing bezels, after soldering, the work of but a few moments. In turning out the recess for glass in bezels, especially those of the heavy nickel variety, it will prove a friend indeed. When, for instance, you look through your stock of flat glasses and find none to fit, but have one that is just too large. Any watchmaker knows that if the groove in the bezel is imperfect, it is very apt to break the glass. This chuck is also useful as a barrel closer, holding work while engraving, and many other uses that will present themselves to the watchmaker.

[Illustration: _Fig. 84._]

=263.= The Hopkins' patent adjustable chuck, shown in Fig. 84, is designed to grip and hold firmly and accurately any size of work, from the smallest staff to the largest pinion, watch wheels of all sizes, mainspring barrels and other large work, and can be adjusted to any make of lathe, by simply placing it friction tight on a plug chuck fitted properly to the lathe. In using this chuck for staffs, pinions, wire, etc., fasten a V-piece, 7, of proper size, in the hole of attachment 6, taking care that both the V and the seat in which it rests, are free from chips, dirt, etc. Then lay your work in the V and fasten it there by means of the sliding jaw above it. This done, place the attachment on the face of the chuck body, with the disc slipped under the heads of the two spring bolts, and then spin the work to center the same as when using wax. After centering thus, fasten the disc to place by tightening the nuts on the back ends of the spring bolts. For holding work by the web of the wheel, place the wheel under the screw cap, on the face attachment 8, and screw the cap down firmly on it, with the staff or pinion projecting outward through the center hole. This done, proceed the same as when using attachment 6. For mainspring barrels and like work, use attachment 11, and place a bit of broken mainspring between the work and the ends of the three binding screws, and tighten the screws down on this instead of directly on the work.

[Illustration: _Fig. 85._]

[Illustration: _Fig. 86._]

=264.= The Spickerman patent cement chuck, shown in Figs. 85 and 86, holds and centers accurately any wheel in a watch while drilling, polishing or fitting new staffs or pinions, and all danger of injuring the wheels is obviated. It will fit all kinds of American or Swiss lathes. The holder shown in Fig. 86 at _a_, is turned down to nearly the size of the screw for the lathe, and the screw is cut so the holder will set as close as possible to the lathe. The face of the holder is then turned perfectly true. Put the wheel to be centered in cap _c_, as near to the center as convenient, and then screw on _b_. Then place the cemented face of chuck _b_ against the face of holder _a_ on the lathe, and with a lamp warm the cement between the surfaces, holding the chuck by means of a pegwood against the pivot of the wheel in the cap _c_, and it will move to an exact center as soon as warmed sufficiently. New

cement should be added occasionally between the surfaces, as the old cement hardens and burns away, and does not center as well as when new. Fig. 85 shows chuck with wheel inside ready for centering and drilling.

[Illustration: _Fig. 87._]

[Illustration: _Fig. 88._]

=265.= The gem patent pivoting chuck, shown in Figs. 87 and 88, is intended as a substitute for wax when performing pivoting and like work. By the means of the ball _b_, placed between the two sliding sockets _c_, _c_, with the several other parts as represented in Fig. 87, a combination of sliding and ball and socket movements, in connection with a spring pump-center is obtained. A set of ten or more supplementary chucks _g_, with different sizes of center holes, and attachment _n_ for all sizes of wheels, are furnished with each chuck. The supplementary chuck _g_, in the form of a small split chuck, is made to fit into a hole with taper mouth, in the center of the ball _b_, and is drawn into place and the work fastened firmly in it by means of the binding nut _m_, which screws on to a projection extending outward from the front of the ball. To use this chuck, proceed as follows: Remove the nut _m_, and give freedom to the working parts by loosening the large back nut _k_. Then to bring the hole through the ball _b_ into line, spin the ball to center, first at the base of the projecting screw and then at the mouth of the hole through it, and in this position again fasten the parts, by tightening the nut _k_. Then give freedom to the pump-center by slightly loosening the set screw _j_. When doing this, hold your finger against the front of the chuck, to prevent the center rod from shooting out of its place when freed. Then having placed a supplementary chuck _g_, of proper size, in its place in the chuck, and your work in it, with its back end resting properly in the countersink in the end of the pump-center, fasten it there by screwing the cap _m_ down snugly over it, using a small lever pin when necessary for the purpose, but not with undue force. Then again loosen the nut _k_, and spin the work to center at its outer end; and then tighten both the nut _k_ and set screw _j_. In tightening the set screw _j_, make sure it is so tightened as to prevent the pump-center from slipping from place when working. If from tightening the screw _j_, it is found that the work has been thrown in any degree away from true center, loosen the nut _k_, leaving the pump-center fast, and again spin to center and fasten as before. After a little practice this can all be done in a few seconds, and the work brought to absolute center.

In using attachment _n_, for wheels, the nut _m_ and chuck _g_ are removed, and n is substituted therefor; the work being held on the face of the attachment by flat-headed screws that grip the arms of the wheel. For cylinder escape wheels a special attachment _n_ is furnished.

[Illustration: _Fig. 89._]

[Illustration: _Fig. 90._]

=266.= Fig. 89 illustrates a crown chuck, which is used for holding crowns while undergoing repairs. The Dale chuck shown in Fig. 89 is made on the lines of the ordinary split wire chuck, a large recess being turned in the end for the reception of the crown. The Johanson chuck is illustrated in Fig. 90, and is quite different in construction, a ball-shaped cap with right hand thread screwing down onto the body of the chuck, thus holding the crown from the outside, while a screw-center with left hand thread, holds it firmly from the inside. This chuck is made in two patterns, one for use in a No. 40 wire chuck, as shown in Fig. 90, and the other is mounted on a regular chuck and is ready to insert into the lathe-head the same as an ordinary wire chuck.

THE SLIDE REST.

[Illustration: _Fig. 91._]

=267.= The slide rest is an expensive but very useful adjunct to the lathe. It is used so extensively in this country, however, that a full description of it seems superfluous. Fig. 91 is a fair example of a modern slide rest for the American lathe. The tool-holder varies with the different makers, but the rests proper are all made on the same general principles, that of two sliding beds working at right angles to each other, and carrying a tool-holder, capable of being raised or lowered or set at any desired angle.

=268.= Brass is easily turned with the slide-rest in an ordinary lathe arranged for the purpose, but the turning of steel demands more care in setting the cutter so as to obtain the best cutting edge as well as in determining the point of application of the tool. Preliminary trials must be made, and the following remarks will be of service as a guide.

[Illustration: _Fig. 92._]

=269.= Engineers use a hooked tool to a very great extent for both planing and turning. Both experience and reasoning point to the conclusion that a tool of the form _b_ or _d_ Fig. 92, possesses many recommendations, and numerous designs of hooked tools more or less resembling these figures are employed with advantage; the tool occupies the best possible position in reference to the surface it is required to cut, and the cutting edge is both sharp and solid. It will be evident that a certain relation exists between the cutting angle and the point of application of the tool to the cylindrical object that is being turned, and this it is necessary to determine. With a hooked tool, as with the ordinary slide-rest cutter, a cutting angle which is too acute will wear away rapidly; when too obtuse, the tool scrapes and will only act when considerable pressure is applied.

In conclusion, it is clear that in forming or re-grinding any tool for cutting a surface, it must be so arranged that its edge makes the least possible angle with the surface that is consistent with the securing of a sufficient degree of resistance to the cohesion and the hardness of metal operated upon; in other words, the end of the tool must be almost tangential to the circumference of the object, and the angle of the cutting edge must be obtained by removing metal from the top face of the tool. These principles are applicable to all tools for metals; to the blades of drills as well as to the cutting edges of gravers, etc.

=270.= The angle of the cutting edge of the tool used in the slide rest for steel should be less than that employed for operating on brass. According to Holtzapffel, it may vary in the former case from 60° to 80° and, in the latter case, 70° to 90°, according as the tool is required for rough turning or finishing. 60° and 80° may, however, be taken as convenient angles in the cases respectively. Simple methods of ensuring that the cutting edge has any required angle are described in article 396.

The velocity with which the lathe revolves should also be less when turning steel, and care must be taken that both the tool and object are constantly moistened with oil.

It is sometimes desirable to arrange a small dropping-can for the purpose of keeping up the supply; this may be easily done by placing a can containing the fluid above the level of the work and allowing a piece of lamp-wick, previously moistened, to hang from it so as to almost touch the work: a continuous series of drops will fall, owing to the influence of capillarity.

[Illustration: _Fig. 93._]

=271.= When roughing out work it is best that the cutter first travel perpendicular to the object, from _a_ towards _b_, Fig. 93, and then in the direction of the arrow. The corner _a_ should only be used for finishing an internal angle or for roughing it out, and, in this latter case, the cutter must advance along _a b_ and be withdrawn from the metal in the direction of the arrow. The small face at the end, _a c_, should be narrow.

[Illustration: _Fig. 94._]

=272.= =Forms of slide-rest cutters.= The usual forms of cutters for use in the slide-rest are shown in Figs. 94 and 95. A and A′ are respectively the plan and side view of the most common form. Two inclined planes _i n_ and _d c_ are formed on the left-hand and under sides. The point on which they terminate is cut off square, a cutting edge, which is more or less acute according to the metal to be operated upon, being obtained by a third incline _c n_. The width of the square cutting edge, indicated at _n_ in figure A, varies according to the metal to be operated upon, as well as this incline _c n_. It is advisable to be provided with at least half-a-dozen cutters of this form, with edges of varying width and inclination, and even this number is often found insufficient; cutters for steel should never be used in turning brass.

[Illustration: _Fig. 95._]

A cutter may be sharpened in the usual manner for ordinary work; but if it is desired to produce very smooth sinks, etc., one that has been carefully polished must be used for the final cut.

The blade should cut with both its edges; the straight edge will serve to form right-angled corners of sinks, while the other edge will form bevels. It is hardly necessary to add that, when a square corner formed by the first of these edges requires to be beveled by the second, the lathe must rotate in the opposite direction and the cutter be passed over to the opposite side of the center.

=273.= C, in the same figure, is a rounded cutter for making circular grooves. F, Fig. 95, is for cutting the groove that receives a barrel-cover. J and V are for forming the “tallow-drop” shoulders of pivot-holes, etc.

It will doubtless be observed that these cutters would form nipples that are dome-shaped and relatively somewhat high, and, for small pivot-holes, the blade would require to be narrower and of a shape that corresponds with the nipple it is desired to produce. L is for rounding off angles. S is a convenient shape for smoothing the bottom of a barrel without damage to the hook. T has a square point; it is used narrow for cutting, for example, the passage under the escape-wheel cock in a cylinder watch, and, when made wider, will serve to cut the settings for jewels. In the latter case it may either be square at the end or a little rounded at the corners.

In addition to the use indicated above, V can be employed for raising the edge of a jewel setting.

=274.= =Sharpening slide-rest tools.= A flat surface turned in the lathe will never be even unless the cutting face _n_ in A Fig. 94, is smooth, and indeed polished, and its edge parallel to the face-plate. Some care is therefore necessary in sharpening this face. The requisite parallelism can be secured by the following method.

=275.= Sharpen the tool while it is held in the tool represented in Fig. 96.

[Illustration: _Fig. 96._]

On a thick brass plate _l_ and parallel to its plane at one extremity _b_, a plate _p_ is pivoted. The inclination of _p_ to _l_ can be varied and it is fixed in any required position by the curved arc passing under the clamping screw _j_.

A small bar _c_ is fixed to _l_ with its edge set accurately at right angles to the line at _b′_ in which the two planes intersect. An examination of the figure will suffice to indicate the manner in which such a tool is used. Having set _p_ so that it makes with _l_ the angle to be given to the cutting face, the cutter _b_ is held against the bar _c_, where it may be fixed with a screw _v_, or in any convenient manner, taking care to leave the portion of the cutter that is to be removed projecting beyond the face of _p_ as shown at _b′_. Now pass a piece of smooth oilstone or disc of steel charged with oilstone dust over the face of _p_ until the projecting portion is removed; if a polished face is required, this must be succeeded by a bronze or ground glass disc charged with rouge. If the plate _p_ is of sufficient dimensions, it will not be distorted, even though only made of hammered brass; but it would of course be better made of steel, hardened if possible.

=276.= If the watchmaker will make a rectangular holder to fit in his tool post, with a square groove planed in its upper side that will fit some particular size of tool steel, say one-fourth or three-sixteenths of an inch, he can then buy bar steel of that size and make his cutters by simply cutting off a piece from the bar and grinding one end to the desired shapes and angles, thus saving a vast amount of time and labor in the preparation of his tools, facilitating their rapid interchange in the tool post, when working, and securing the greatest possible rigidity of the tool, as the cutting edge projects from the holder only far enough to allow the holder to clear the work.

GRAVERS AND OTHER HAND-TURNING TOOLS.

=277.= =Hooked gravers.= It is needless to do more than mention the gravers that some watchmakers are in the habit of making of worn-out files, of various forms to suit their special requirements; but we would remind learners that care is essential in fixing the position of the rest and the inclination that has to be given to the tool so as to obtain a smooth surface, and at the same time a rapid removal of metal.

The most usual forms of the hooked graver are shown in Fig. 97. A will serve to hollow out a plate, barrel, etc.; B for turning the bottom of a barrel without touching the hook; C for forming a barrel-cover groove after it has been roughed out with an ordinary graver. The bottom of a barrel can also be turned with a graver of the form D held on the =T=-rest at right angles to the bottom, and a slide-rest cutter can be made of this form with advantage.

[Illustration: _Fig. 97._]

Some workmen incline the end cutting face of A slightly backwards from the perpendicular to _d d_, fearing lest, in sharpening, it should accidentally be made to incline in the other direction, and so make it difficult to form internal square corners.

=278.= =Gravers for turning square shoulders, etc.= Very few watchmakers are able to finish off a square shoulder by using a graver with the usual point; as a rule, when they are smoothing the surface of the pivot they allow the point to cut a ring in the shoulder, and if, instead of being sharp, the point is dull, a rough groove is the result.

To avoid such a fault it is a common practice to employ gravers with very short faces, but their inconvenience is evident. It is much better to retain the long lozenge-shaped face, but with the point modified, as indicated by B or C, Fig. 98.

The ordinary point, shown at A, can be used for cutting the back slope of a shoulder, B for forming the square-shouldered pivot, and C for beveled shoulders. The inclination of the face _e d_ of B may vary, the angle _e_ being more or less acute, according as more or less use is required to be made of the point. This form of graver has the double advantage that a pivot can be turned and smoothed at one operation, very little polishing being needed. Moreover, the point is less fragile, and such a graver combines the advantages of those with pointed and square ends.

[Illustration: _Fig. 98._]

The length of this small face depends on the work required of it, thus for making a cylinder pivot it may be about a third the length of the pivot; this is found convenient for ensuring that the pivot shall be of uniform diameter. The direction to be given to the face is indicated by the dotted line _e d_, and a lozenge-shaped graver is preferable to one of square section for this purpose. This direction _e d_ is very important, and frequent trials should be made so as to ensure its being always produced. The form C for beveling off a shoulder does not call for explanation.

Although of less importance than when turning with the slide-rest, the cutting angle of the graver should correspond with the nature of the metal operated on. In reference to this question see article =270=.

=279.= =Spherical turning tool.= A very simple and convenient tool for forming a sphere of metal may be made by taking a hardened steel tube whose internal diameter is less than that of the sphere to be produced. This is ground square and flat at one end, and sharpened by rubbing this flat end on an oilstone. The tool is moved about over the surface of the ball, previously roughed out, and a perfect sphere will soon be obtained, the metal being removed by the internal edge of the tube. If a steel tube is not accessible it will be enough to drill a hole in the end of a softened worn-out file, subsequently hardening it.

DRILLS.

[Illustration: _Fig. 99._]

=280.= The forms ordinarily adopted for the blades of drills are shows at A and C, Fig. 99. The form C is best suited for perforating brass and other metals having a similar degree of hardness. The blade must not be too thick, as, if it were, there would not be a sufficient cutting edge. As the hardness of the metal operated on is greater, the thickness of the blade must proportionately increase, or what amounts to the same, the two slopes that give the cutting edges must have a less degree of inclination. If this condition of sufficient thickness be satisfied by a drill of the form C, it will perforate steel very well, but its point will rapidly wear. When operating on this metal, therefore, the form A is preferable, especially when the steel is at all hard. Such a drill with the corners rounded off and sharpened will last for a long time, if the cutting angles are not too acute. If the metal is not hard, more rapid progress may be made by adopting a blade less flattened than A, that is to say, something intermediate between A and C.

A drill may be asserted to be good if it satisfies the following conditions: the point must be in the middle of the blade; it must be made of good steel that is carefully hardened, without being heated beyond the proper temperature; lastly, it must be quite true—in other words, in rotating it must run with sufficient truth throughout its entire length, so that it withstands the end pressure required to cause it to bite, and does not bend.

=281.= It must not be forgotten that: (1) if a drill is driven too rapidly it will heat, and thus become softened as though too much tempered; it is with a view to prevent this that, when operating upon iron or steel, many workmen now and then dip the drill into a cold liquid (turpentine is good for this purpose), dry it, and recommence drilling, the hole being liberally supplied with oil; (2) when the blade is left too hard, the cutting edge too acute, or if a feather edge has been left by the oilstone, small hard particles that are detached from the drill will embed themselves in the hole, and this will be especially the case if it is worked too rapidly or with jerks; such particles render the operation of drilling very slow and difficult.

=282.= =To drill steel of a blue temper.= At first not much difficulty will be experienced; but when the drill reaches a certain depth and the metal seems to oppose a gradually increasing resistance, the operation must at once be stopped. If the blade of the drill be now examined with a glass, it will be easy to see which points have ceased to cut, producing instead a series of bright rings at the bottom of the hole that are very difficult to remove. Exchange the drill for one of a different form or, without reducing its width,

change the form of the blade; if it was arrow-headed for example, make it a semicircle, or semi-oval, or chisel-shaped with sloping edges. All that is essential is that the form be so changed that the bright portions of the surface shall be gradually removed, and that no attempt be made to act on the whole bright surface at once. Until this hard portion is removed, the blade will require frequent sharpening.

Some authorities recommend that the hole be moistened from time to time with dilute nitric acid, which is then washed off, and renewed when a shiny surface is produced. Oil can with advantage be replaced by turpentine as a lubricant for the drill blade.

The formation of hard shining surfaces is attributed to three causes: (1) to the cutting edge being rounded, rolling as it were and hardening the surface of the metal against which it continues to move; (2) to the drill being made of bad steel or imperfectly hardened, so that small particles break off and are embedded in the metal operated upon; and (3) to a deficiency in the supply of oil, or an excessive velocity of rotation of the drill.

These difficulties may usually be avoided by observing the following precautions:

[Illustration: _Fig. 100._]

=283.= _Blade of the drill._ This should be neither as thin nor as acute as is used for drilling brass. Its angle should never be less than 100° and the incline should be at about 45°. The forms generally employed are shown in Fig. 100, at A, B and C. At first the form A is used, and, as the operation progresses, it is modified with an oilstone slip.

=284.= _Drilling slowly with considerable pressure._ If the drill rotates too rapidly or there is not sufficient oil, the surfaces of contact will be heated and shining rings will form. It is well to practice slightly, varying the speed of the wheel, in accordance with the pressure applied; the speed should be more decided when the pressure is, for the instant comparatively great. With continuous rotation, considerable pressure should be applied with moderate velocity. Constantly remove the drill to sharpen, clean the hole and have an abundant supply of oil. Whatever liquid is most effective in maintaining the drill cool will probably be the best; turpentine is better than oil, since it has the additional advantage of increasing the “bite” of the drill.

=285.= _The part against which the drill acts should be very rigid._ For example, if a hole is being made for a pivot in a cylinder plug which is not provided with a shellac backing, and is, therefore, flexible, the operation will be more tedious than when the cylinder is filled with shellac. The firmness is usually greater when the object is centered about the point to which the drill is applied.

=286.= _Making the drill._ The very best steel should be used, and the precautions indicated in article =87= should be taken in the hardening. If the steel is burnt in this process, no satisfactory results are to be expected of it. To avoid such a danger it is often advisable to leave the blade nearly round and thicker than is required, finishing with a piece of oilstone. Although somewhat more tedious, this method has the advantage of ensuring that, after hardening, all the metal that is most liable to have been burnt is removed.

The drill must be short, the blade being thick and not much reduced at the shoulder, in order to stand pressure when in use. A drill that has been several times hardened is rarely good.

=287.= =Finished drills.= We would here draw the attention of watchmakers to some beautifully made drills that have been introduced and are known in the trade as “finished” drills, in contra-distinction to the well known pivot drills that are always sold in the rough. They are of two forms, corresponding to A and C, Fig. 99, for steel and brass respectively; they are made of the best steel, carefully hardened and tempered to the requisite degree; and a principal recommendation consists in the fact that, while being moderate in price, they are of definite graduated sizes, extending from 0.1 mm. to 2.5 mm. (0.004 to 0.1 inch), a range which comprises 37 distinct sizes.

=288.= =Semi-cylindrical drills.= These drills give excellent results when driven by a wheel, and, although they have been long in use by engineers, they are hardly known to watchmakers.

[Illustration: _Fig. 101._]

The simplest form is a cylindrical rod rounded at its end and then filed down to a trifle less than half its thickness, as seen at _b d_ and _l i_, Fig. 101.

The length of the point is greater or less according to the nature of the metal to be operated upon, but under no circumstances must the point itself be sharp. With the form shown at _b d_, some of the rod that is left cylindrical must be partially filed away; a better shape is indicated by the dotted lines, all the metal being removed that is outside the line _i l_. With such a drill the hole is smoothed immediately after it is made by one or the other cutting edge of the portion _i l_. It should be sharpened on the round, not on the flat surface (or at any rate very slightly), because the thickness would be rapidly reduced and the blade made smaller. When such a drill does not turn true the back of the blade can be reduced, starting from the cutting edge, it being observed that, with the continuous motion of the wheel, only one edge acts. After a few trials it will be found easy to use this form of drill.

It possesses this very great advantage: when fixed in a drill-chuck, it can be turned exactly round, of the required diameter and finished; so that, whenever replaced in the chuck, one can be certain beforehand that the hole drilled will be of a definite diameter.

[Illustration: _Fig. 102._]

=289.= Fig. 102, shows, at C and D, another form of semi-cylindrical drill; the first, C, is a front and the second a side view. The angle _a_ is formed by a sloping semicircle and the stem of the drill is of less diameter than the head, as indicated by the shoulder _j_. The angle _t s r_ and the one between the face D and the plane _b a_ must not be too acute.

This drill works evenly, but two conditions must be satisfied; it must be maintained perfectly true by the chuck, and, in commencing, both sides of the blade must engage against the sides of a conical opening that forms the beginning of a hole which has to be enlarged.

[Illustration: _Fig. 103._]

=290.= At F and N M, Fig. 103, are seen front and side views of another form of drill. While acting in a similar manner to the others described above, it differs from them in that the blade also cuts with its two sides; the edges, _p_, _i_, _i_, _o_, are sloped off backwards to form cutting angles. The shape is indicated to the right of M, this portion being the exact inverse of the side N.

As with the drills previously considered, a few trials must be made to decide upon the best slopes for the cutting angles, etc., according to the metal operated upon. They may be retained as left by the lathe, or very slightly inclined, on the faces _p_ and _i_. All these forms of drills require to be mounted so as to run very true. The point _o_ must be accurately central. A hole that has been already drilled small can be rapidly enlarged by such a drill as this last, the pin _o_, having the same diameter as the one originally drilled.

[Illustration: _Fig. 104._]

=291.= =The Twist Drill.= The Morse twist drill, shown in Fig. 104, is rapidly coming into favor with watchmakers for the heavier classes of work, and is very desirable when drilling deeply, as this form of drill heats slowly and the particles are carried to the surface of the work. A large range of sizes in these drills are now carried in stock by the material dealers.

LATHE ATTACHMENTS.

=292.= =Tailstocks.= Besides the regular tailstock which accompanies the American lathe there are several other varieties made for use on special kinds of work. Fig. 105 illustrates the half open tailstock which is cut away so that the spindles can be laid in, instead of being passed through the holes. The fixture will be found exceedingly convenient when several spindles are to be used for drilling, counterboring and chamfering. Fig. 106 illustrates the screw tailstock, an attachment which is very convenient for all kinds of heavy drilling, the spindle being moved by a screw with hand-wheel attached. Fig. 107 illustrates the traverse spindle tailstock, which will be found very convenient for straight drilling and especially where the watchmaker has considerable drilling to do.

[Illustration: _Fig. 105._]

[Illustration: _Fig. 106._]

[Illustration: _Fig. 107._]

[Illustration: _Fig. 108._]

=293.= =Jeweling Caliper Rest.= Although this tool was invented and manufactured for the purpose of cutting jewel settings it may be used to great advantage in countersinking for screw heads, opening wheels for pinions or bushings, etc. The sliding jaws of the calipers should be so adjusted that when the swinging part is brought back snugly against them, the front cutting edge of the cutter in the sliding spindle will exactly line with the center of the lathe spindle. Then if the calipers are at the right height, when a jewel or jewel setting is placed in the jaws of the caliper it will move the edge of the cutter outward from the lathe center just half the diameter of the jewel then in the caliper and the cutting made at that distance from the center will exactly coincide with the size of the jewel to be set. If however, when set and worked as above, it is found that the hole cut is too large for the jewel, it will indicate that the calipers are too low down and should be raised, provision for which is made in the construction of the tool. Upon the other hand, if the cutting is found too small to fit, it will indicate the calipers should be lowered. The final cutting for the jewel seat should be made by running the center straight inward from the face of the plate; the adjustable stop screw on the back end of the sliding spindle, serving to gauge the depth of the cutting.

[Illustration: _Fig. 109._]

[Illustration: _Fig. 110._]

[Illustration: _Fig. 111._]

[Illustration: _Fig. 112._]

=294.= =Pivot Polishers.= The pivot polisher is used for grinding and polishing conical and straight pivots and shoulders. It is also used for drilling, polishing or snailing steel wheels, milling out odd places in plate or bridge, where only a part of a circle is to be removed, etc. In the style shown in Fig. 109, the American Watch Tool Co.'s polisher, and Fig. 110, the Moseley pattern, the circular base is graduated to degrees and the fixture can be set at any angle. The spindle has a taper hole for drill chucks, which makes the fixture very useful for drilling either in the center or eccentric and by using the graduations on the pulley of the headstock an accurately spaced circle of holes may be drilled. Fig. 111 illustrates the polisher made by the Faneuil Watch Tool Company, and is intended to be mounted on the slide rest. Fig. 112 illustrates the Johanson pivot polisher and in general principle is like the others. This style is made both for use on the slide rest and also for the hand rest. When used in the latter, a stud, shown in Fig. 113, is screwed into the base plate and supports the tool in the hand rest, so as to be readily adjustable in any direction. When used in the slide rest, this stud is removed and the plate clamped between two hollow cylindrical supports by a stud which is slipped into the groove of the slide rest and fasted by a nut at the top, the whole forming a turret-like mount of great strength and upon which the machine can be readily swiveled in any direction. In general, polishers are used as follows: After the pivot is turned to proper shape, put on your polisher, with the lap back of the pivot, usually the cast iron lap first. A square-cornered lap for square shoulders and a round-cornered lap for conical pivots. The laps for conical pivots can be readily cornered with a fine file, and cross-ground with fine oilstone to remove any lines made by graver or files. Lines on the end can be removed the same way, or by means of the fingers often rubbing them on a piece of ground glass which has on it a paste of oilstone powder and oil, well mixed. Oilstone powder and oil used on the lap, or No. 1 crocus will rough out the work well. When roughed out to your liking, wipe off the oilstone powder or crocus and with a little oil touch the pivot gently; repeat the second time. Then change lap for one of boxwood or brass and use crocus No. 4, very fine, and ground down to a paste. Proceed as with the first lap, being careful at all times to keep the lap properly oiled and not pressed too hard against the work, particularly in the last operation. Be sparing of your grinding and polishing material as a little will accomplish as much work as a large quantity and do it better. Bring the lap up carefully against the work until spread all the way around, then proceed, bearing in mind that grinding is not polishing, and that to polish nicely the work and lap must be very nearly the same shape. Fig. 114 illustrates the Hardinge pivot polisher, which is a hand polisher and much more simple in construction and use than those mentioned above. It is attached to the lathe bed the same as the T or hand rest. Polishing and grinding slips are furnished with this attachment, as with the others.

[Illustration: _Fig. 113._]

[Illustration: _Fig. 114._]

=295.= =Centering Attachments or Back Rests.= These attachments are very useful in rapidly bringing work to an accurate center, when pivoting, staffing, etc., and particularly where a large number of pieces have to be centered successively. Fig. 115 illustrates the Potter patent self-centering lathe attachment which is made to fit any pattern of American lathe.

[Illustration: _Fig. 115._]

It consists principally of the slide bed pieces _R_ and _D_, the upright plate _A_ and the reversible anti-friction sliding jaws _O U V X_. The upright plate _A_ is attached to the slide _D_ in such a way that it may be readily raised or lowered, or adjusted in any other direction at pleasure; and may be set with either side facing the lathe-head. The sliding jaws are made of phosphor bronze anti-friction metal and four sets, of three in a set, are furnished with each attachment, as shown at _O_, _U_, _V_, _X_, the forms differing so they may be adapted to the various kinds of watch work, and they are operated in radial grooves in the upright plate _A_ by means of the rotating lever _L_, which moves the three jaws in and out, to and from the center, or opens and closes them in perfect unison. One set of jaws may be withdrawn and another set substituted therefor in a few moments. With each change of the jaws, however, the plate _A_ requires readjustment, but this too, may be done in a few moments, as follows: Having previously provided yourself with a bit of straight wire or a small steel rod, turned to run perfectly true in your lathe, and having fastened this in your chuck in the lathe, loosen the nuts _C C_, so as to give freedom of movement to the plate _A_; then bring the attachment to proper position on the lathe bed and fasten it there, after which move the sliding jaws inward until they bind tightly on the piece of straight wire held in the chuck and in this position again tighten the nuts _C_ _C_. Once adjusted to accurate center in this way, no further adjustment, whatever the size of the work to be operated upon, is required, until you make another change of jaws.

In use, the end of the work to be operated upon is placed in an accurate split chuck in the lathe, and the chuck tightened on it, just sufficiently to hold it in place and to rotate it, the other end being supported in the central bearing, formed by the sliding jaws. In this position the jaws may be opened or closed as often as desired, and each time they will bring the work to accurate center.

A similar attachment to the one above described is extensively used by machinists and is known as the back rest. In principle it is very similar, but is more simple in construction, and ambitious workmen can make them without difficulty. This attachment, which is shown in Fig. 116, differs in its mode of fastening to the lathe bed and the jaws cannot be opened and closed at one time as in the Potter attachment.

[Illustration: _Fig. 116._]

The illustration shows the rest in position on the lathe bed, looking from the right-hand end of bed; _m_ shows the base, looking from above, in direction of arrow _k_; _d_ shows bolt for binding it to the lathe bed. It does not seem as though it needed much explanation, as it will be readily seen that the head _d_ of bolt, passes up through the longitudinal slot in the lathe bed, through the round hole in base of back rest and is slipped back into slot _m_, when about half a turn of nut _g_ binds it firmly to the bed. The washer _h_, on the end of the binding screw, is riveted or soldered in place and should be close enough to nut _g_ to allow only about half a turn to loosen the bolt, as that is sufficient, and more space would occasion a loss of time in running the nut back and forth to bind or loosen the rest. It will be seen that when the nut _g_ is slackened, it binds against the washer _h_, and it will stay there, and be just where you want it when you are ready to use it again. The jaws are of hard brass; about three sets, with points of different widths, will cover a large range of work. Those shown in Fig. 116 are suitable for such work as pivoting small French clock pinions, etc. It will be observed that the jaws are so made that they may be changed by slightly loosening the screws. The screw heads should have thin steel washers under them.

[Illustration: _Fig. 117._]

[Illustration: _Fig. 118._]

=296.= =Universal Head.= The universal head has entirely superseded the clumsy universal mandrel in this country. The example shown in Fig. 117 is more accurate, less clumsy and complicated and will perform all the work that can be performed on the universal mandrel. The face-plate is 3½ inches in diameter, but by the use of the two crescent-shaped slots it will hold anything in size and shape of watch work. The pump center is operated from the back by the rubber knob and can be used either with or without a spring. The jaws, which will pass the center, are held in position on face of plate by springs and are fastened from the back. Peep holes are provided in these heads in order that the workman may examine the back of the work at all times. In the Moseley head, shown in Fig. 117, these holes are of taper form. Fig. 118 shows a universal face-plate to be used in a chuck in the lathe. It is smaller and less expensive than the universal head and answers very well for some work, especially that of the lighter kind, but cannot be recommended as highly as the universal head, as it is not so accurate. The pump center is used to center, from the back, any object confined in the jaws, but it sometimes becomes necessary to mount the object, by means of wax, upon a plate, and hold the plate in the jaws. In such a case the work must necessarily be centered from the front. This can be done accurately by means of a piece of pegwood, as ordinarily done on the lathe, by placing the point in the center hole and the pegwood resting on the T-rest and observing if the free end of the pegwood remains stationary.

=297.= =Traverse Spindle Grinder.= This tool will be found very useful for grinding cutters, lathe centers, pump centers, reamers, countersinks, squaring up barrel arbors after hardening, or work on any hardened steel tool. In the hands of an ingenious workman, it will be found exceedingly useful, as by its aid a great variety of work can be performed that cannot be accomplished without it. Fig. 119 is intended to be attached to the slide rest.

[Illustration: _Fig. 119._]

[Illustration: _Fig. 120._]

=298.= =Milling Fixture.= This attachment, which is shown in Fig. 120 is designed to be fitted to the slide rest and holds the wire chuck vertically under the center of the lathe, so that articles held in the chucks can be fed under mills or saws held in the saw arbor in the lathe-head.

[Illustration: _Fig. 121._]

=299.= =Wheel Cutters.= The wheel cutter is a valuable addition to the lathe. Several different styles of these attachments are made, each possessing points of merit. They are designed for cutting all kinds of wheels and pinions used in key and stem-wind watches. When the cutter spindle is vertical the belt runs directly to it from the countershaft, but when horizontal, the belt passes over idler pulleys held above the lathe. One style of wheel-cutting attachment is shown in Fig. 121, while another style is shown in Fig. 71.

[Illustration: _Fig. 122._]

=300.= =Rounding-up Attachment.= The Webster rounding up attachment, shown in Fig. 122, is a very useful adjunct to the lathe. It is attached to the top of the slide-rest. To operate, a pointed taper chuck is put in the lathe spindle. The wheel to be rounded up is put into the fixture and the wheel adjusted vertically so that the point of the lathe center will be at the center of the thickness of the wheel, after which the lower spindle of the fixture should not be moved. Now remove the wheel, also the taper chuck, and put the saw arbor, with the rounding-up center, in the lathe spindle, and adjust the longitudinal slide of the slide-rest so that the rounding-up cutter will be back of and in line with the center of the rounding-up fixture, after which the longitudinal slide of the slide-rest should not be moved. Now put the wheel and supporting collet in place, and proceed with the rounding-up.

MISCELLANEOUS SMALL TOOLS.

[Illustration: _Fig. 123._]

=301.= =Screw Head Sink Cutter.= This is usually made in the form of an arbor terminating in a cutting edge similar to the rose-cutter, but having a projecting pin from its center. This tool will be found especially useful in replacing broken end-stones. The jewel being set in brass, is held by two screws, on opposite sides, the screw heads being let in or sunk even with the surface, half of the screw head projecting over on the end-stone. The end-stones furnished by the watch companies are not sunk for these screw heads, but are round and of the proper diameter. These cutters will cut away from the jewel setting the space to be occupied by the screw head in a very few moments and in a very perfect manner. All of the watch companies do not use the same diameter of screw head in the cock and potance, consequently you will be compelled to make separate tools for the different makes of watches. With a set of five or six of these cutters you can fit any American watch. After you have completed your set, of say five or six cutters, select a small brass plate and bore five or six small holes in a row, in which the guide pins of the cutters will enter, and then cut with the tools a number of sinks, numbering these holes in the plate and also the arbors of the tools with corresponding numbers. You will then have a plate similar to Fig. 123 which can then be used as a gauge for measuring the heads of screws.

[Illustration: _Fig. 124._]

These cutters are easily made as follows: cut off a piece of wire of the required diameter, about one inch long, and place it in a chuck that fits it snugly and turn one end to a center, about 40°; now reverse the wire in the chuck and be sure it is true; select a drill that will pass through the screw hole in the cock or potance freely and proceed to drill a hole in the center of the end of the wire, about ½■■ of an inch deep. Remove from the lathe and with a sharp file and graver, proceed to cut a series of teeth as equal and even as possible. Use a good strong glass while working and be sure you have every tooth sharp and perfect, as upon this depends the quick and nice work you expect from the tool. When this is well done, proceed to temper fairly hard and polish up the

outside to make it look workmanlike. Now select a piece of steel pivot wire, of a size that will almost fit in the hole drilled in the end of the tool and polish down to the proper size to drive in the hole tightly. Allow the wire to project about ½■■ of an inch, taper the point and polish. The tool is now complete and will resemble Fig. 124. Select an end-stone of a diameter to fit tightly in the cock or potance, as maybe required; set the hole jewel in place and then the end-stone pressed down tightly against the hole jewel. Place your cutter in a chuck that fits it true; select a smaller medium sized drill rest and place it in the tail stock spindle. Hold the cock, or potance, with the jewels in place, against the drill rest, level, and proceeding to run the lathe at a fair speed, slowly feed the cock or potance to the cutter, the projecting pivot in the end of the cutter passing through the screw hole and acting as a guide to keep the cutter in the center of the hole. Caution must be exercised, or you will cut the recess for the screw heads too deep, as these little cutters are very deceiving and cut much faster than you would suppose. In fitting an end-stone, select one that is more than flush when the jewel hole and end-stone are in the proper position, and after sinking the screw head as described, turn off on the lathe almost flush or level. Make a small dot on one side of the end-stone as a mark or guide in replacing it. Remove the end-stone and proceed to polish the top of the setting on a plate glass polisher.

=302.= =Screw Extractors.= The Bullock Screw Extractor, shown in Fig. 125, is a simple yet very valuable tool to the watchmaker who finds he has a plate in which a screw has been broken off. To use this tool, first fasten it in your vise, then bring one end of the broken or rusted-in screw against screw center and the broken screw head against screw driver; turn the washers so as to hold the broken screw firmly in place; turn the plate gently and the broken screw will follow the screw driver point out of the plate. It may be necessary in some instances to turn the screw driver point against the broken head with a good deal of force in order to start the screw. A little benzine or kerosene applied to the screw will help to loosen it.

[Illustration: _Fig. 125._]

The ingenious workman can, with the expenditure of a little time, make an attachment for removing broken screws, somewhat similar to the above. Take two common steel watch keys having hardened and tempered pipes—size, four or five—having care that the squares in each are of the same size and of good depth. Cut off the pipes about half an inch from the end; file up one of these for about one-half its length, on three equal sides, to fit one of the large split chucks of the lathe. Drill a hole in one of the brass centers of the lathe of sufficient size and depth, into which insert the other key-pipe, and fasten with a little solder. Soften a piece of Stubbs' wire, to work easily in the lathe, and turn down for an eighth of an inch from the end to a size a little smaller than the broken screw in the plate; finish with a conical shoulder, for greater strength, and cross-file the end with a fine slot or knife-edge file, that the tool may not slip on the end of the broken screw; cut off the wire a half inch from the end and file down to a square that will fit closely in one of the key-pipes. Make a second point like the first one and fit it to the other key-pipe; harden in oil, polish, and temper to a dark straw color. Fit the brass center into the tail stock. To use, put the tools in place in the lathe, place the broken end of the screw against the end of the point in the lathe-head; slide up the back center and fasten the point firmly against the other end of the screw, that it may not slip or turn; revolve the plate slowly, and the broken screw, being held fast between the two points will be quickly removed. To remove a broken pillar screw, place the broken screw against the point in the lathe-head, holding the plate firmly with the right-hand, the pillar on a line with the lathe center; turn the lathe-head slowly backward with the left-hand, and the screw will be removed. Should the tool slip on the broken screw, and fail to draw it out, drill a hole in the lower or dial side of pillar, down to the screw point (if the size of the pillar will admit of it), and with the second point in the back center, remove the screw in the same manner as in the first process. Five or six sizes of these points will be found sufficient for the majority of these breakages that may occur.

It sometimes happens that a screw gets broken off in a watch plate in such a manner that it is impossible to remove it with tools without marring the plate. In such an event proceed as follows: Put enough rain water in a glass tumbler to thoroughly cover the plate and add sulphuric acid, until the water tastes a little sharp. Place the plate in the solution and allow it to remain a few hours, when the screw will partially dissolve and drop out. Remove from the solution, wash thoroughly in clean water, then in alcohol and dry in saw dust. The solution will not injure the brass plate or gilding in the slightest, but care must be taken to remove all other screws or cemented jewels, previous to immersion.

[Illustration: _Fig. 126._]

=303.= =Roller Remover.= There are numerous designs in the way of roller removers upon the market, some of them good but many of them weak and liable to bend where the roller is very tight on the staff. All points being considered, the Hardinge remover, shown in Fig. 126, is perhaps the strongest and best on the market and is built on true mechanical principles.

The nose in the center and top of the illustration is drilled up so as to receive a balance pivot without bearing on its point, and can be moved towards or from the two bent prongs by means of the thumb nut at the bottom of the tool. The prongs can be spread apart or drawn together, and are secured in place by means of the binding screws at the sides. In using the remover the feet of the two prongs are brought under the roller and secured by the binding screws. The nose is now advanced against the shoulder of the bottom pivot and the staff can be driven out without damage to either roller or staff.

[Illustration: _Fig. 127._]

=304.= =Balance Protectors.= These are of two kinds and for entirely different operations. The Arrick protector, shown in Fig. 127, is used for protecting balances while working upon the pivots while in the lathe. No matter how careful a person may be, accidents will happen, and the least accident to a compensation balance gives the workman considerable trouble. The least slip of the graver, polisher or hand rest and great damage is the result. The staff is passed through the hole in the protector, and held in a wire chuck, and the protector is secured to the arms of the balance by two screws. The Bullock protector, shown in Fig. 128, is designed to protect the balance and other wheels from heat while drawing the temper from staff or pinion for the purpose of pivoting.

[Illustration: _Fig. 128._]

[Illustration: _Fig. 129._]

=305.= =Beat Block.= This simple device obviates the necessity of marking the balance to see that it is in beat. Before taking off the hair spring lay it on the block, shown in Fig. 129, turn the balance so the roller pin hits on the side the arrow points, then turn the table so that the line comes under the stud. In replacing the balance put the stud over the line and it will then beat the same as before. By using this tool you also avoid getting the balance out of true.

=306.= =Female Centers.= Centers are of two kinds,, male and female. The ordinary centers that accompany the lathe, which are male centers, are familiar to all watchmakers. Female centers, however, are not so well known among watchmakers, and they can be used to great advantage in many operations where other and less simple attachments and means are usually resorted to. You should have at least six pairs of female centers, the largest being one-fourth of an inch in diameter, which will accommodate as large a piece as you will wish to handle on your watch lathe, viz: winding arbors for clocks. These female centers are made from steel tapers, the same as male centers are made, but instead of turning the end to a sharp point they are countersunk, Fig. 130. First place the taper in a chuck and turn off the outside and end true; drill a small hole in the center of the taper, while the lathe is running, and deep enough so the countersink will not reach the bottom of the hole, or one-eighth of an inch deeper than the countersink. Harden the end only, and after tempering polish off the bluing. After you have made all the sizes you require, test all of them in your lathe to make sure they did not get out of true in tempering.

[Illustration: _Fig. 130._]

These female centers are very useful for holding or suspending any article in the lathe that is too large to be held in the split chucks. Pivots of clocks can be turned and polished very quickly and accurately in these centers.

Almost any kind of large work can be done on a medium sized watchmaker's lathe by fitting to it a face plate one and three-fourths inches in diameter, with four slots, and fitted to a chuck with a standard taper hole to receive both male and female centers interchangeably. With two styles of dogs, almost any kind of large clock work can be readily handled.

These centers prove very useful for many odd jobs. As an example: It is a very common occurrence to hear an American clock beat irregularly, caused by the escape wheel being out of round. Select a pair of female centers that will admit the ends of the pivots of the escape wheel snugly; place one center in the taper chuck and the other in the tail stock spindle, and suspend the escape pinion in these centers; fasten on a dog, run the lathe at a high speed and hold a fine sharp file so it will touch the teeth of the 'scape wheel slightly, and in a moment the wheel will be perfectly round, after which sharpen up the teeth that are too thick.

[Illustration: _Fig. 131._]

=307.= =Drill Rest.= In using the lathe for drilling, a great saving in both time and drills can be effected by using a drill rest similar to that shown in Fig. 131. It is well to have a half dozen different sizes, starting at ¼ inch and increasing by ■ inch, for various classes of work. These rests are not kept by material dealers, but can be made by the watchmaker. Saw from a piece of rolled sheet brass, say 1-16 inch thick, the circles required, leaving metal enough to finish nicely. Place a steel taper plug in the taper chuck of your

lathe and turn down a recess, leaving a shoulder on the taper. Drill a hole through the brass plate to fit the steel taper tightly. Place the end of the taper on a lead block and proceed to rivet the brass plate, on the taper, making sure that it is true replace the taper in the lathe chuck and proceed to turn the face and edge of the brass plate perfectly true and to the proper size. Those who have tried to drill a straight hole through an object by holding it in the fingers know just how difficult it is to do, but by placing one of these drill rests in the spindle of the tail stock, placing the article to be drilled against it and bringing it up against the drill, you can drill the hole perfectly upright and avoid all danger of breaking the drill.

[Illustration: _Fig. 132._]

=308.= =Filing Fixture or Rest.= These rests will be found very convenient in squaring winding arbors, center squares, etc. There are several makes of these tools, but they are all built upon the same principle, that of two hardened steel rollers on which the file rests, and Fig. 132 is a fair example. One pattern is made to fit in the hand rest after the =T= is removed, while the other is attached to the bed of the lathe in the same manner as the slide rest. The piece to be squared is held in the split or spring chuck in the lathe, and the index on the pulley is used to divide the square correctly. Any article can be filed to a perfect square, hexagon or octagon as may be desired. The arm carrying the rollers can be raised or lowered as required for adjustment to work of various sizes.

=309.= =Filing Block.= A contrivance made to take the place of the filing rest, which was made of box wood or bone. Ide's filing fixture, shown in Fig. 133, consists of a cylinder of hardened steel, riveted upon a staff which in turn enters a split socket. The surface of the steel cylinder is grooved with various sizes of grooves for the different sizes of wire, or to suit any work.

[Illustration: _Fig. 133._]

[Illustration: _Fig. 134._]

Fig. 134 illustrates Melotte's revolving bench block, which combines both anvil and filing block. No. 1 is a steel anvil which may be instantly revolved and stopped on quarters. No. 2 is a rubber block, held by friction on its arm, and can readily be turned to any position. This rubber, being slightly elastic, makes a very suitable filing bed for small articles of any material and may be used without risk of scratching or defacing polished surfaces. No. 3 is a wooden block, held on to its arm by a spring friction device, which also allows it to be turned around to any desired position. The three-armed hub is revolved by pulling out slightly and is automatically held perfectly firm and solid in any of the three positions.

[Illustration: _Fig. 135._]

=310.= =Micrometer Caliper.= Fig. 135 is a full size cut of the Brown & Sharp Mfg. Co.'s micrometer caliper. It measures from one-thousandth of an inch to one-half inch. It is graduated to read to thousandths of an inch, but one-half and one-quarter thousandths are readily estimated. This instrument is also graduated to the hundredths of a millimeter, but when so graduated the table of decimal equivalents is omitted. They are also made to read to ten thousandths of an inch. The edges of the measuring surfaces are not beveled, but are left square, as it is more convenient for measuring certain classes of work. It will gauge under a shoulder or measure a small projection on a plain surface. Watchmakers will especially appreciate micrometers of this form. This tool will be found very useful for gauging mainsprings, pinions, etc. In the caliper, shown by cut, the gauge or measuring screw is cut on the concealed part of the spindle C, and moves in the thread tapped in the hub A; the hollow sleeve, or thimble D is attached to the spindle C and covers and protects the gauge screw. By turning the thimble, the screw is drawn back and the caliper opened.

The pitch of the screw is 40 to the inch. The graduation of the hub A, in a line parallel to the axis of the screw, is 40 to the inch, and is figured 0, 1, 2, etc., every fourth division. As the graduation conforms to the pitch of the screw, each division equals the longitudinal distance traversed by the screw in one complete rotation, and shows that the caliper has been opened 1-40th or .025 of an inch. The beveled edge of the thimble D is graduated into 25 equal parts, and figured every fifth division 0, 5, 10, 15, 20. Each division when passing the line of graduation on hub A, indicates that the screw has made 1-25th of a turn, and the opening of the caliper increased 1-25th of 1-40th, or a thousandth of an inch.

Hence, to read the caliper, multiply the number of divisions visible on the scale of the hub by 25, and add the number of divisions on the scale of the thimble, from zero to the line coincident with the line of graduation on hub. For example: As the caliper is set in the cut, there are three whole divisions visible on the hub. Multiply this number by 25, and add the number of divisions registered on the scale of the thimble, which is 0 in this case, the result is seventy-five thousandths of an inch. (3 × 25 = 75 0 = 75). These calculations are readily made mentally.

Differences between Wire Gauges in Decimal Parts of an Inch.

Key: A - No. of Wire Gauge. B - American or Brown & Sharpe. C - Birmingham or Stubs'. D - Washburn & Moen Manufacturing Co., Worcester, Mass. E - Trenton Iron Co., Trenton, N.J. F - New British. G - Old English from Brass Mfrs. List. H - No. of Wire.

A	B	C	D	E	F	G	H
000000	----	----	.46	----	----	----	000000 00000
----	----	.43	.45	----	----	00000 0000	.46
.454	.393	.4	.4	----	0000 000	.40964	.425
.362	.36	.372	----	000 00	.3648	.38	.331
.33	.348	----	00 0	.32495	.34	.307	.305
.324	----	0 1	.2893	.3	.283	.285	.3
----	1 2	.25763	.284	.263	.265	.276	----
2 3	.22942	.259	.244	.245	.252	----	3 4
.20431	.238	.225	.225	.232	----	4 5	.18194
.22	.207	.205	.212	----	5 6	.16202	.203
.192	.19	.192	----	6 7	.14428	.18	.177
.175	.176	----	7 8	.12849	.165	.162	.16
.16	----	8 9	.11443	.148	.148	.145	.144
----	9 10	.10189	.134	.135	.13	.128	----
10 11	.090742	.12	.12	.1175	.116	----	11 12
.080808	.109	.105	.105	.104	----	12 13	.071961
.095	.092	.0925	.092	----	13 14	.064084	.083
.08	.08	.08	.083	14 15	.057068	.072	.072
.07	.072	.072	15 16	.05082	.065	.063	.061
.064	.065	16 17	.045257	.058	.054	.0525	.056
.058	17 18	.040803	.049	.047	.045	.048	.049
18 19	.03539	.042	.041	.039	.04	.04	19 20
.031961	.035	.035	.034	.036	.035	20 21	.028462
.032	.032	.03	.032	.0315	21 22	.025347	.028
.028	.27	.028	.0295	22 23	.022571	.025	.025
.024	.024	.027	23 24	.0201	.022	.023	.0215
.022	.025	24 25	.0179	.02	.02	.019	.02
.023	25 26	.01594	.018	.018	.018	.018	.0205
26 27	.014195	.016	.017	.017	.0164	.01875	27 28
.012641	.014	.016	.016	.0148	.0165	28 29	.011257
.013	.015	.015	.0136	.0155	29 30	.010025	.012
.014	.014	.0124	.01375	30 31	.008928	.01	.0135
.013	.0116	.01225	31 32	.00795	.009	.013	.012
.0108	.01125	32 33	.00708	.008	.011	.011	.01
.01025	33 34	.006304	.007	.01	.01	.0092	.0095
34 35	.005614	.005	.0095	.009	.0084	.009	35 36
.005	.004	.009	.008	.0076	.0075	36 37	.004453
----	.0085	.00725	.0068	.0065	37 38	.003965	----
.008	.0065	.006	.00575	38 39	.003531	----	.0075
.00575	.0052	.005	39 40	.003144	----	.007	.005
.0048	.0045	40					

[Illustration: _Fig. 136._]

=311.= =Registering Gauge.= The registering gauges shown in the illustrations are two of the best examples of this class of tools. They are manufactured by A. J. Logan, Waltham, Mass., and are very accurate and nicely finished. Fig. 136 is an upright and jaw gauge, and Fig. 137 is designed as a jaw and depth gauge. They are both made to gauge one-thousandth of a centimeter or one-thousandth of an inch. Fig. 137 shows the piece of work marked A being gauged, while B represents a sliding spindle to get the depth of a hole or recess, or the thickness of any piece of work, which will be indicated on the dial.

[Illustration: _Fig. 137._]

[Illustration: _Fig. 138._]

[Illustration: _Fig. 139._]

Another form of registering gauge is shown in Fig. 138. It is an English gauge and but little used in this country. The principle of its construction, however, is good, and any ingenious watchmaker can make it. The back of the dial is recessed and arranged as in Fig. 139. One limb is fixed; the other is pivoted, and has a few rack teeth meshing into a center pinion. The pinion carries the hand, which should make a revolution in closing the calipers. The spiral spring attached to the pinion is to keep it and the hand banked in one direction for shake. The spring _s_ is to keep the jaws open. The milled headed screw and the clamp _c_ are to fix the jaws in case it is required to do so. A cover is snapped into the recess, and takes the back pivot of the pinion.

[Illustration: _Fig. 140._]

=312.= =Staff Gauge.= The tool shown in Fig. 140 is designed for measuring the height of the balance staff from the balance seat to the end of the top pivot. The illustration is enlarged to give more distinctness. _E E′_ is a piece of curved steel about ⅛■■ of an inch thick, and ⅛■■ of an inch wide. On the lower side from _E′_ to the end, the arm is filed down in width and thickness to correspond to an ordinary balance arm; _C_ is a slot in the upper arm _E_, which allows _A_, _B_, _D_, _A′_ to be moved backward and forward. _D D′_ is a round brass post drilled and tapped. The part _D′_ has a thread cut on it, and the part shown in the slot _C_ fits with easy friction. _B_ is a lock-nut, drilled and tapped to fit the thread on _D′_. It is for the purpose of clamping _D D′_ against the arm _E_. _A A′_ is a small steel screw with milled head, and is made to fit the tapped hole in _D D′_.

Mr. Beeton describes his method of using this tool as follows: Take your measurement of the distance _the balance seat is to be from the end of the top pivot_, as follows: remove the end-stone in balance-cock, and screw the cock on the top of the top plate (18-size full plate movement); then taking the plate in your left-hand, and tool (shown in Fig. 139) in your right, place _H_ in position, so that the end of the screw _A′_ rests on the jewel in the balance cock, and notice the position of the arm _E′_ which corresponds to the balance arm, between the top plate and under side of the balance-cock. If the distance between the arm _E′_ and end of screw _A′_ is too great, the arm _E′_ will be too low and touch the plate; if not enough, it will be too high and touch the regulator pins. Therefore, all that is necessary to do is to move the screw _A A′_ up or down as the case may be, sufficiently to ensure that the arm _E′_ will assume the position the _arm of the balance_ is to have. Take an 18-size balance with oversprung hairspring, the arm is at the bottom of the rim; in that case, when measuring, the screw _A′_ is adjusted so as to bring the arm _E′_ close to the plate, when _A′_ is resting on the balance jewel; if the balance is old style with undersprung hairspring, the balance arm is at top of rim, in which case _A′_ is adjusted so that the arm _E′_ is close to the balance cock; if the balance arm is in the center of the rim, as in some English and Swiss balances, the screw _A′_ is adjusted so that the arm _E′_ is midway between the plate and cock.

The reason the part _A_, _B_, _D_, _A′_ are arranged to move laterally in slot _C_ is, because all balance shoulders are not the same distance from the center, and where, in some cases, the screw _A′_ would be in a line with the center of the staff when the arm _E′_ was resting on the balance seat, in other cases it would reach past the center, of course, short of it; and, therefore, it is made adjustable to suit all cases.

[Illustration: _Fig. 141._]

=313.= =Staff or Cylinder Height Gauge.= The obvious advantage of this tool, which is shown at Fig. 141, is the automatic transfer of the measurement so that it may be readily applied to the work in hand. The tool, as the illustration shows, consists of a brass tube terminating in a cone-shaped piece. To the bottom of this cone is attached a disc through which a needle plays. Around the upper end of the tube is a collar upon which is fixed a curved steel index finger. A similar jaw, which is free to move, works in a slot in the tube. The movable jaw is tapped and is propelled by a screw that terminates in the needle point. This tool is very useful in making the necessary measurements required in putting in a staff. To use it in this work, set the pivots of the gauge through the foot hole, and upon the end-stone project the needle such a distance as you wish the shoulder to be formed above the point of the pivot. Next set the gauge in the foot hole as before, and elevate the disc to a height that shall be right for the roller, which is done by having the lever in place, the little disc showing exactly where the roller should come. Finish the staff up to that point; then take the next measurement from the end-stone to where the shoulder should be, for the balance to rest upon. This point being marked, the staff can be reversed and measurements commenced from the upper end-stone, by which to finish the upper end of the staff. Distances between the shoulders for pinions and arbors can be obtained with the same facility, a little practice being the only requisite.

=314.= =Vernier Caliper.= Fig. 142 is an illustration of the Vernier Caliper, a light, convenient and valuable instrument for obtaining correct measurements. The side represented in the illustration is graduated upon the bar to inches and fiftieths of an inch, and by the aid of a Vernier is read to the thousandths of an inch (see description below). The opposite side is graduated to inches and sixty-fourths of an inch. The outside of the jaws are of suitable form for taking inside measurements, and when the jaws are closed, measure two hundred and fifty thousandths of an inch in diameter.

[Illustration: _Fig. 142._]

These instruments can be furnished with millimeters (in the place of sixty-fourths of an inch), and provided with a Vernier to read to one-fiftieth of a millimeter.

On the bar of the instrument is a line of inches numbered 1, 2, 3, each inch being divided into tenths, and each tenth into five parts, making fifty divisions to one inch. Upon the sliding jaw is a line of divisions (called a Vernier, from the inventor's name), of twenty parts, figured 0, 5, 10, 15, 20. These twenty divisions on the Vernier correspond to extreme length with nineteen parts, or nineteen-fiftieths on the bar, consequently each division on the Vernier is smaller than each division on the bar by one-thousandth of an inch. If the sliding jaw of the caliper is pushed up to the other, so that the line 0 on the Vernier corresponds with 0 on the bar, then the next two lines on the left will differ from each other one-thousandth of an inch, and so the difference will continue to increase one-thousandth of an inch for each division till they again correspond on the twentieth line on the Vernier. To read the distance the caliper may be open, commence by noticing how many inches, tenths and parts of tenths the zero point on the Vernier

has been moved from the zero point on the bar. Then count upon the Vernier the number of divisions until one is found which coincides with one on the bar, which will be the number of thousandths to be added to the distance read off on the bar. The best way of expressing the value of the divisions on the bar is to call the tenths one hundred thousandths (.100) and the fifths of tenths, or fiftieths, twenty thousands (.020). Referring to the accompanying cut, it will be seen that the jaws are open one-tenth of an inch, which is equal to one hundred thousandths (.100). Suppose now, the sliding jaw was moved to the left, so that the first line on the Vernier would coincide with the next line on the bar, this would then make twenty thousandths (.020) more to be added to one hundred thousandths (.100), making the jaws then open one hundred and twenty thousandths (.120) of an inch. If but half the last described movement was made, the _tenth line on the Vernier_ would coincide with a line on the bar, and would then read, one hundred and ten thousandths (.110) of an inch.

[Illustration: _Fig. 143._]

=315.= =Hair Spring Stud Index.= Fig. 143 illustrates Johanson's hair spring stud index. The engraving shows the full size of the tool, which consists of a steel plate mounted on feet, and pierced with a number of holes for the reception of screws, when taking down a watch. In the center of the index is a hole for the staff, and an oblong slot for the reception of the roller jewel. To get any American movement in beat, proceed as follows: In front of No. 100 is a small spring; push same towards No. 10; then place the balance on top of the stand, with staff in center and roller jewel in the oblong hole; let the spring back gently; the balance will then take its own position. Set degree hand in front of the desired degree, as per direction on index table; place hair spring stud in front of degree hand, and push on the collet.

INDEX TABLE FOR HAIR SPRING STUDS.

Size. _Degree._ Columbus 18 Open Face Breguet 23 Columbus 6 Open Face Breguet Elgin 18 Open Face Breguet 66 Elgin 16 Open Face Breguet 52 Elgin 16 Flat Hair Spring 52 Elgin 10 Flat Hair Spring 50 Elgin 6 and 8 Flat Hair Spring 50 Elgin 0 Flat Hair Spring Illinois 18 Open Face Breguet 33 Illinois 18 Hunting 84 Illinois 18 Open Face Flat 89 Illinois 16 Illinois 6 Hunting 52 Illinois 4 Hampden 18 Dueber Hunting 80 Hampden 18 Open Face 75 Hampden 16 Hampden 6 Hunting 50 Howard 18 Old Model 5 Howard 18 New Model 23 Howard 16 Howard 6 Rockford 18 27 Rockford 6 Waltham 18 Key Flat Hair Spr'g 48 Waltham 18 O. F. Hair Spring 61 Waltham 18 Breguet 50 Waltham 14-16 42 Waltham 4-6 50 Waltham 1 42 Seth Thomas 18 Open Face 50 Seth Thomas 18 Hunting 52

=316.= =Oil-cup Drills or Chamfering Tools.= The reservoirs that contain a supply of oil at the ends of pivot holes are made in the lathe with a semi-cylindrical drill, or by hand with a chamfering tool of the form shown at B or C, Fig. 144. A drill gives a clean cut, but necessitates a subsequent polishing of the hole; as to the chamfering tool here referred to, some inconvenience will be experienced in its use, owing to the point being apt to jump out of the hole and make irregular scratches on the brass, which are difficult to remove.

[Illustration: _Fig. 144._]

[Illustration: _Fig. 145._]

The best shapes of drills for making, or at any rate for re-forming or finishing oil-cups, are shown at D and F, Fig. 144, and in Fig. 145.

D and F are two drill-blades that terminate in non-cutting circular arcs. The flat curved end is more and more inclined from the top towards the corner, from _i_ towards the side _e_; the angle at _i_ becoming more acute, and at _e_ more obtuse towards the corners. The drill will, of course, only cut when rotating in one direction; in the other direction the obtuse angles and the reverse sides of the cutting angles will act as burnishers. Thus if the angles on either side are well formed and the blade has been polished, the surface of the oil-cup will be clean cut and polished. F is similar to D, but made from a steel rod.

=317.= _Observations on making the oil-cups._ Reservoirs that are made with a drill, or with a chamfering tool by hand, will often be found to be eccentric, and, when a pivot-hole is bushed and re-drilled, it proves to be struck from a different center from the oil-cup. In such cases watchmakers often give themselves endless trouble without securing a cup of good form and well centered. This difficulty can be avoided by using the tool in a lathe driven by a wheel; then, holding the plate in one hand square against a drill rest in tail stock, advance the tail stock with the other hand so as to bring the plate in contact with the drill.

When it is only required to correct the form of an oil-cup, the drill may be replaced by a rod with file cuts on its rounded extremity (H, Fig. 144). The reader will find no difficulty in making such a cutter for himself, drawing a file with both hands over the rounded end, but always in the direction of the file-cuts. After covering the surface with lines in this manner, rotate the cutter through a right angle and form a number of cross cuts. Or roughen the surface with a chisel of the form shown at H; after making a few cuts parallel to each other, turn the chisel through an angle and repeat the operation.

=318.= =Chamfering Tool.= As is well known, this is used for removing the roughness that a drill leaves at the edge of a hole, or to take off the cutting edge around a screw head sink, etc., thus forming a bevel edge. The tool commonly has a flat semicircular blade, the diameter of which depends on size of hole to be made; this semicircle is ground to a cutting edge like a drill, as shown at A, Fig. 144. Chamfering tools are also made pyramidal, with flat faces, as at B and C; the angle at the apex is more or less acute, according to the depth of chamfer required.

The oil-cup drills D and F are also used for chamfering the edge of a hole.

A cone formed at the extremity of a piece of pinion wire with a cutting edge on each leaf and hardened will be found very useful for this purpose.

=319.= The two forms of chamfering tool first described leave a series of undulations on the bevel edge, so that, instead of being conical, it presents a number of small facets. This inconvenience can be avoided by using the tool shown at Z, Fig. 145.

A small disc of hardened steel is pivoted within a recess formed at the end of a rod, the pin on which it rotates being at right angles to the direction of the rod. As is seen in the figure to right of Z, the section of this roller is a rectangle, and the surface is carefully polished, the edges being left sharp.

Clockmakers make use of a tool for forming oil-cups that only differs from the one above described in two particulars: (1) The disc is fixed on its axis; and (2) the edge, instead of being square to the two faces, is inclined as shown at _j_ and at the same time is slightly rounded crosswise.

A few trials will be found necessary before the most convenient thickness and inclination of edge are arrived at.

=320.= =Hollow Chamfering Tools.= These, as is well known, are used for removing the angles at the ends of cylindrical rods, of steady-pins, etc., or for rounding them off. Three forms are shown at O, Q, N, Fig. 146.

[Illustration: _Fig. 146._]

O is a round rod, the flat end of which has been filed across with the corner of a triangular file. Four cutting edges are thus produced which will act on the end of any object that rotates within them, or _vice versa_. If it be required to form a very acute angle, two slits must be cut with a screw-head file and the sides afterwards inclined to the required extent with a flat file. This tool will serve a double purpose: (1) to chamfer off the edge of a rod; and, (2) by prolonging this operation to form a point at the end.

As a rule, when it is desired to round off, say, a pillar of a clock after reducing its length or from any other cause, a hollow chamfering tool of very open angle is used, a rocking motion being imparted to it round the axis of the spindle; it is better to use a tool of the shape shown at N or Q. The latter, Q, is easily formed by strokes of a rat-tail file at right angles across its end; the other, N, is cut internally with a shaped chisel or with a small rotating cutter to which different inclinations are given during the cutting, as is also done when using the chisel.

=321.= The tool shown at O, Fig. 146, has been modified as follows by M. Roze. The two notches at right angles are replaced by three equidistant notches of equal depth. To make these in a piece of round steel it should be divided on the circumference into six equal parts; then cut the three notches as follows: Calling the points marked on the circumference 1, 2, 3, 4, 5, 6, one notch will lie parallel to the line joining 1, 3, and equidistant between this line and the point 5; a second will be parallel to 3, 5, and midway between that line and point 1, and the third will be parallel to 5, 1, and midway between this and the point 3.

In a hollow chamfering tool thus constructed it will be found that only the three long sides 1, 3, 5, actually cut, and at 2, 4 and 6 are short sides that are set back. But when a file is laid on the face joining two of the former sides, say 1, 3, the short faces 4, 6, will protect the cutting edge 5 from contact with the file.

=322.= =Tool for Centering Rods.= These appliances are well known to watchmakers, who often employ them for marking the position of the hole in the brass wire when making bushings. It is advisable to have such a tool somewhat large, about a third as large again as that shown at _s r_, Fig. 147.

[Illustration: _Fig. 147._]

The head of the centering punch or drill is filed flat on either side, and this flattened portion passes into a notch in the spring _r_, which maintains it in position and prevents rotation when the triangular-pointed blade is pressed against the end of this rod, this rod being caused to rotate in the hollow cone of _s_. Instead of a spring such as _r_, a helical spring is often used; but it then becomes necessary to fix a pin in the drill that slides in a groove in _s_, so as to prevent the drill from rotating.

=323.= =Centering with a Set-Square.= The set square may be used for centering round rods, and the following is a very simple mode of applying it:

[Illustration: _Fig. 148._]

On one arm of the square R, Fig. 148, a triangular plate _c d_ is screwed or riveted so that its edge _c d_ exactly bisects the right angle, that is, divides it into two equal angles. The flat end of a round rod is held within the angle and against the plate, a line being traced on it along _c d_; it is then turned through about a right angle and a second line traced. The intersection of these two lines gives the axis of the rod.

=324.= =Tool for Roughing Out Points.= This is merely the inverted chamfering tool of which two forms are described in paragraphs =320-21=, one of them being also shown at O, Fig. 146. It will be evident that when the end of a rod is caused to rotate in this hollow cone it will take its form.

In some cases it may be found convenient to place such a tool in the tail stock of the lathe.

If the bottom of the cone at the end of O were prolonged by continuing the cuts farther down with a thin flat file, the point of the rod might be formed like a conical-headed screw before it is tapped.

=325.= =Balance-spring Collet Tool.= This convenient little tool for rotating the balance-spring collet is commended almost as much by its simplicity and facility of construction as by its usefulness.

[Illustration: _Fig. 149._]

A steel rod _n_, Fig. 149, is fixed in a handle T; it terminates in a cone _a_ and is drilled with a fine hole as indicated by the dotted lines. A thin wing _b_, pointed at its extremity, is also attached to the handle.

Holding the balance between the fingers of the left hand and the tool in the right, the blade _b_ is introduced into the slit in the collet while _a_ rests on the balance staff shoulder, the pivot being within the hole _n_. Now rotate to the right or left until the stud is opposite to the mark on the balance rim, and this may be done without danger, providing the tool is held firmly and vertical.

[Illustration: _Fig. 150._]

=326.= =Watch-hand Holder.= A very convenient form of tool, in which to clamp a hand while enlarging the center hole is represented in Fig. 150. Two brass plates, _f_ and _g_, are hinged at _m_ like a sector. A collar, _a b_, surrounding the two is pivoted at _a_ and has a clamping-screw _b_ by which the two plates can be forced together. Several circular sinks of different sizes and equally divided between the two plates, are cut of a depth varying from one-half to two-thirds that of the plates, and they must be made to increase in diameter as they get deeper, thus resembling the internal groove that receives a barrel cover. The plate _a_ is cut away along the portion _c d_ and grooves are formed to leave passages open between this surface and the bottom of the sinks in _g_ and _f_.

When it is required to enlarge the hole of a watch-hand, place it, inverted, in the hole of suitable size, as shown at _c_ of the figure, and tighten the screw _b_. Held round the whole or greater part of its circumference, the hand is thus firm and its center hole can be enlarged without risk, either with a drill or broach; the hand will not show marks due to the pressure with which it has been held.

=327.= =Common Hand fitting Pliers.= The sliding tongs with large flat head, perforated with a number of holes in which the head of a hand is clamped when the opening requires to be enlarged, are often useful, but we feel them to be less so than the holder just described. It is desirable that the inner faces of their jaws, which are usually left rough, be at least smoothed.

[Illustration: _Fig. 151._]

=328.= =Another form of Watch-hand Holder.= M. Fiquemont has devised the simple little tool shown in Fig. 151. It consists of a short brass rod R, perforated lengthwise and having a thread cut externally on the surface _a b_. It should be reduced in thickness below this tapped portion. The rod, shown also in longitudinal section at P, is cut into four quarters by two slits from _a_ to _b_, which are at right angles and leave the points as indicated apart at _d_. The elasticity of these four quarters should make them take the form of a reversed cone when holding a hand, so that the ascent of the screw _c_ shall tighten them.

Within the head _a_ of the tool is formed a circular recess, so that, if the reversed head of a watch-hand be placed within it and the screw made to ascend, it will be held very firmly by the circumference, as seen in the figure. The hand will thus be perfectly free to adjust in any way that is needed for fitting it while held at the end of the tool, and without being removed before the work is complete. Three or four sizes will suffice for all ordinary watch-hands.

A tool may be made in a similar manner, except that the screw is not divided by the longitudinal slits, and the hand is held against the point by a lantern (similar to those of a screw-point tool), which must be cut away in the manner indicated in Fig. 150, explained above (=326=). An assortment of three or four lanterns will render the tool serviceable for all sizes of hands.

[Illustration: _Fig. 152._]

=329.= =Clip for Holding Escapewheels while Cleaning.= A mere inspection of M, Fig. 152, will make the arrangement of this little tool evident. The fork is made of a piece of brass rod and its two arms are elastic, a handle being screwed into the lower extremity.

Two small steel jaws are fixed to the upper ends inclined towards each other, and, in using the tool, it is only necessary to press with two fingers on the heads of the screws, when the jaws will open. Having placed the escape wheel pinion between them, the wheel will be firmly held so that its teeth can be easily cleaned, etc.

[Illustration: _Fig. 153._]

=330.= The appliance shown in Fig. 153 can be used for a similar purpose, and is further especially serviceable for holding an escape-wheel that is not riveted to its pinion. It consists of two parts, a handle T, shown separate at _t_, which is drilled throughout its length and tapped externally at the portion _t_, and a collar or nut D, the end of which is traversed by two cuts at right angles that resemble the letter =T= in section. If the tool is intended for holding escape-wheels that have three instead of four arms, this cross must be replaced by three radiating grooves of similar section. The position occupied by the wheel is indicated by the dotted lines _r r_, and it will be evident that, when the flat end of T is screwed up against this wheel, after dropping it into the cross and slightly turning round the axis as in a bayonet joint, it may be firmly held. The safest mode of introducing the wheel is by holding it on a broach, which is subsequently removed.

[Illustration: _Fig. 154._]

=331.= =Tool for Testing the Truth of a Cylinder Escapewheel.= The small tool shown at D, Fig. 154, can be advantageously used in place of the plain arbor commonly employed for testing the equality of the spaces in such a wheel. The plate D, which may be mounted on three feet, is traversed at its center by the smooth conical portion _f_ of the screw _f v_, tapped somewhat tightly into a cock fixed to the other side of the plate. There is a radial slot, _a c_, cut in the plate large enough to allow an escape-wheel pinion to move freely. An inspection of the figure will make evident the manner in which the tool is to be used: a wheel being placed as shown, or with reverse side upwards, is made to slide towards the center, gradually raising the screw until the largest space is found to admit _f_ with contact at both sides. All the smaller spaces are then carefully opened until they admit the cone in the same manner as the largest.

=332.= _Novel tool for the same purpose._ When the spaces are adjusted in the manner explained above, or if the length of the teeth is measured in a narrow gauge plate, there will nearly always remain a certain degree of irregularity in the teeth. A more efficient means would be for the gauge to embrace both a tooth and space, and this condition is satisfied by the following appliance.

[Illustration: _Fig. 155._]

The slide _k k_, Fig. 155, is dovetailed into a plate, level with its surface, so that _k k_ can be moved in a vertical direction by a screw; it is perforated with a series of holes of gradually decreasing diameter. To the same plate are also fixed: (1) a smooth tongue, _b_, with a foot and screw; and (2) a second tongue, _j_, terminating in an index _x n_, which is movable about a pivot, _x_, and held against a pin in the plate by a light straight or spiral spring. The extremity, _n_, traverses a graduated arc.

Having introduced the pinion of the wheel, or the arbor on which it is held, into a hole of the slide that it fits without shake, and brought this hole to the position indicated in the figure, apply a slight pressure to the wheel in the direction of its rotation. With one tooth resting against _b_ the tongue _j_ will be held by the spring against the next and the reading of the index is to be noted accurately. Withdraw the wheel slightly, and, placing the succeeding tooth against _b_, take a second reading, and so on around the entire circumference.

Of course, the delicacy of the instrument will be increased by lengthening _x n_ in comparison with _x j_.

[Illustration: _Fig. 156._]

=333.= =Tool for Removing Studs.= Fig. 156 represents a small tool which may be employed for this purpose. It consists of a thick strip of metal, C, spreading out like the letter T at the end which is not shown, so as to form two feet, the screw, _j_, being a third, so arranged that the T rests horizontally. The disc, _d_ (shown also in plan), rotates on the screw, _j_, and is partially enclosed in a horizontal slot. Around the circumference of _d_ are four rectangular notches of different sizes. The holes indicated by black dots on the plan receive the point of the screw, _v_, which clamps the disc when the notch corresponding in size with the stud to be removed has been brought under the small cone projecting from the spring, _b_; the other end of _b_ is fixed to the T-shaped piece, C. The mode of using this little instrument will at once be evident. Resting the right arm on the bench, and, with the left-hand, bringing the wing of the cock above the notch in _d_, the other hand presses upon the milled button of _b_, forcing the conical pin against the stud and thus removing it from the cock. The screw, _a_, can be adjusted so as to prevent too great force being applied.

[Illustration: _Fig. 157._]

=334.= =Tweezers for Removing Studs.= One form is shown in Fig. 157. The upper arm, H, is bent downwards as indicated at _g_. The lower arm is shorter and carries a separate piece, _n m_, which slides under two screws, _s_, and is pressed forward by a spring, _r_. The action will be easily understood; the extremity, _m_, rests against the stud, and _m n_ is forced backwards until the point, _g_, is exactly over the stud pin. A simple pressure of the finger will then suffice to remove the stud.

A still more simple pair of tweezers for this purpose may be made by filling a square notch in the end of one prong of an ordinary pair with broad noses, and setting a pin opposite to its center in the end of the other prong.

=335.= =Staking Tool.= The modern staking tool will perform the same work as the last two tools described and many other operations. It consists of a shifting table, around which holes of various sizes are arranged in a circle, so that any desired hole may be brought under a suitable punch moving in a vertical holder. Usually twenty-four tempered steel punches and four stumps are provided, which will be found sufficient to cover all the operations in the ordinary run of watch repairs, and the ingenious workman can from time to time add to these by making punches in his spare moments, if he finds from experience that he is in need of punches of a different shape. Fig. 158 illustrates the Johanson combination staking tool, on the front end of which a hairspring stud indicator is arranged.

[Illustration: _Fig. 158._]

=336.= The staking tool can be used as a cannon pinion tightener by making a punch for it having a blunt chisel edge. When a cannon pinion is placed on a stump which is slightly dished in that portion of its face opposite to the punch, and the punch gently struck with a hammer, it will be sufficiently contracted to insure the requisite adherence to the set-hands arbor. If fears are entertained lest the pinion should be cracked with the blow, it may be placed loosely on an arbor and held in position.

=337.= It may also be used to advantage for tightening the set-hands arbor in the center or cannon pinion, but care must be exercised or the arbor may be bent so that the minute hand which it carries passes nearer the dial at one place than another.

An arbor that is too loose is introduced into a suitable stump and at the top and bottom of the slack portion two punch marks are made opposite one another. The punch having a conical or three-sided point, will occasion an expansion of the metal round each mark; if a smooth file be passed over the surface so as to remove the burr, which would not offer any permanent resistance, sufficient projecting metal will be left to secure a sound and lasting friction when a little oil is applied.

If the arbor is well supported immediately beneath the punch, it will not be distorted by any moderate impact. It is advisable before operating on the metal to ascertain its degree of hardness.

=338.= It may also be used as a pinion riveting tool. The pinion, with its wheel in position, is placed on the hardened steel stump, the end to be riveted being upwards. The riveting is then struck with the polished end of a hollow punch. If it be required to spread the riveting, a punch must first be used that is rounded from within outwards, to be followed with a perfectly flat punch. A little practice will at once enable a workman to select the best form of punch.

The stump should be very hard and polished, funnel-shaped downwards and carefully fitted to the bed, so as to be firm and central with the punch. If these precautions are not taken the pinion will spring and the riveting will be imperfect.

=339.= The staking tool may also be used for closing up barrel holes, screw-holes, etc. In repairing watches it is often found that the screws hold badly or not at all, and the holes at times cannot be satisfactorily bushed. In such cases it becomes necessary to close them, an operation which any intelligent workman can perform very well in the following manner: Make a stump rounded at the top and provided with a pump-center. This can be merely a pointed steel rod that passes through the stump from below with slight friction, and is forced upwards by a light spring fixed by a screw, so that, on undoing the screw, the rod can be removed. The one pump-center can be used for various stumps as the openings are funnel-shaped downwards. Center the hole to be closed by means of the pump-center, then bring down the hollow punch and strike it as in riveting a pinion. A small circular groove will be formed around the hole, which, if the punch is in good order, will be perfectly even. The form of the punch is very important; the watchmaker must decide for himself by trial as to the most convenient shape. The thickness of the ring of metal may be modified; it is rounded off in a semicircle by some, and curved inwards or outwards by others.

Instead of a pump-center below we have used punches that were themselves provided with a pump center and helical spring. Either form gives satisfactory results.

The holes of barrels can be closed with a punch that is only depressed at its center enough to avoid the point of the pump-center. When the face is more or less rounded the hole will be closed by forming a cup as with a chamfering tool. The tool may then be enlarged if requisite with a round broach or an arbor covered with white wax. It will thus be hardened, and the cup-shaped recess will serve to retain the oil, while the somewhat thinner hole will probably be in a condition to resist friction as long as formerly.

When the hole is of moderate thickness, and it does not require much reduction in diameter, this method will be found satisfactory; barrels that have been thus treated have been found to stand ten years without appreciable wear. When the metal is thicker, however, the spreading inwards is very slight, and there is some danger, in using a round broach to do it, of straining the metal or detaching the central ring of the barrel or its cover.

It should be observed that the methods explained above are absolutely useless for closing pivot-holes, and should only be resorted to for barrels, on an emergency.

=340.= =Drifting Tool.= This appliance, shown in Fig. 159, is very useful for making holes of round, oval or square, or, indeed, any required form. It takes the place of a punching machine for light work.

[Illustration: _Fig. 159._]

The punch, or "drift," is screwed into the stock C C′. A pin, _p_, fixed in C C′ prevents its rotation while allowing an end motion along the slot _m_ _n_. The end C′ is hollowed out to receive the point of a screw, B, and a pin, shown near C′, is received in a groove turned in B, thus enabling it to draw the stock in the direction C C′. The part H is gripped in the jaws of a vise, and a strong handle, E, is used to advance the screw B B′. With a tool about three times the size of the figure there is no difficulty in punching the eyes of mainsprings, square holes in stop fingers, etc., and it can be made by an apprentice. Of course its strength depends on the pitch of the screw and the radius of the handle E.

=341.= For heavier work it will be necessary to resort to the punching machine. There are several constructions in use, but the most usual is essentially the same as that of the tool just described. The screw works vertically in a strong bridge that is fixed to the bed in which the counterpart of the punch is held. Great use is made of this machine in factories at the present day, almost every part of a watch being in the first instance roughly shaped by its means. Indeed, thin metal is often left as it comes from the punch, and very perfect crossings of wheels, etc., are thus produced.

Steel does not cut well in the press unless it is soft and homogeneous, and the final dimensions of the object can be more nearly approached according as these conditions are satisfied. Attempts have been made to cut levers, etc., of the exact dimensions required, but it is better to leave a slight excess of metal to be afterwards removed by a mill cutter or other means. The crossings of steel lever and cylinder escape-wheels are punched out, but the metal used is of special excellence. Before introducing a piece of steel into the press it is advisable to remove any scale, etc., by pickling, or with a file.

=342.= =Draw-Plate.= Every watchmaker should possess a plate for drawing round wire so as to be able to obtain it of any required diameter. They are to be had at all material houses. In bushing holes in a brass plate, it not unfrequently happens that the brass used for the bushing is not of the same color as the plate. To avoid such a difference cut off a piece from a plate of the same color and round it by hand, making one end to taper. Fixing the draw-plate in the vise, pass this end through one of its holes, and, gripping it in the hand-vise, pull the brass through the plate. Continue this operation through successive holes until the requisite thickness is attained.

No special precautions are necessary, further than keeping the holes well greased and annealing the brass from time to time so as to counteract the hardening caused by the operation.

Such a plate can also be used for steel wire, and plates with holes of special form, for example those for drawing click and pinion wire, are well known in the trade.

[Illustration: _Fig. 160._]

=343.= =The Grammaire, or Dividing Plate.= This tool is shown in Fig. 160. To mark out the crossings of a wheel, etc., fix it by the conical-headed screw _t_ to the middle of the plate, on which are traced a series of concentric circles (not shown) divided into 6, 8, 10 and 12 equal parts. By laying the little ruler _r_ _r_ over the wheel blank and using these division marks as a guide, 3, 4, 5 or 6 radii can be drawn to serve as guides for cutting out the arms.

If it is desired to indicate the width of the arms instead of a mere central line, a series of holes must be drilled at the division marks and screws with tapered points tapped into them from below. Resting the ruler against these cones, the arms can be drawn of any required width, according to the distance to which the screws project. No further explanation is necessary, for the figure shows: (1) a grammaire adapted to mark out a four-armed wheel, these arms being indicated by the dotted lines; and (2) the small ruler _r_ _r_ cut away at the middle so as to avoid coming into contact with the conical-headed screw.

[Illustration: _Fig. 161._]

=344.= =Jewel-resetting Tools.= Hopkins' patent jeweling and staking tool, shown in Fig. 161, is an ingenious device, and one that will be found very useful to the watch repairer. As the spindle, or handle, to which the cutters and burnishers P P P are attached, is sustained in upright position when in use, by the long bearings through which it passes in the upright F, independently of the lower center, the hole to be cut may be centered either from above or below as preferred; and the depth to which it is desired the cutter shall work is regulated by adjustment of the sliding collar E, and this being a correct uprighting, as well as jeweling tool, with it a pivot hole, or a jewel setting, the correct center (upright) of which has been lost, may readily be corrected, or its true center again found, and, what in some cases would be a very desirable consideration, by careful manipulation with the cutter, which is under perfect control of the operator, the position of jewel settings may be changed so as to alter the depth of locking of the wheels to any desired extent. To regulate the depth to which it is desired a cutter shall work below the surface of a plate, lower the spindle D until, when moved out sufficiently far, the end of the cutter will rest down on the top of the plate to be operated upon, and fasten it there by lightly tightening the screw K; this done adjust and fasten the collar E on the spindle D, to the same height above the top of the upright F as it is desired the cutter shall work below the surface of the plate on which it now rests. This, when the spindle D has been again set free by loosening the screw K, will of course allow the cutter to sink into the hole to be operated upon to the exact distance the collar E had been set above top of F. In adjusting the collar, E, the graduated wedge No. 4, or the jewel to be set, as preferred, may be used as a gauge. The burnishers, No. 9, are used both for opening and closing settings; the same burnisher,

having chosen one of proper size, is used for both purposes; the side being used for opening the setting, and the beveled and rounded end for burnishing it down again over the jewel. The pieces 13 and 14 are made to fit in the lower end of the spindle D (the cutter P having been removed), same as an ordinary drill-stock, and are used for burnishing the edges of a jewel setting down flat over the jewel, countersinking screw heads, giving end-shake to wheels, etc.; and being easily made, any one owning the tool can make these for himself, of forms and sizes to suit the particular work in hand. For uprighting purposes, withdraw the spindle D and substitute No. 5, the rings, No. 3, being intended for laying the work on, on the tool bed. For upright drilling through watch plates, mark the place to be drilled (prick punch it slightly) with the cone point of No. 5; which done turn the spindle No. 5 upside down and rest the upper end of the drill in the countersink in its end, the drill being operated with a fiddle bow acting on a collet placed on its shank for the purpose. For cutting off bushings level with a watch plate, either a cutter of the No. 13 or 14 class, or one of the P cutters can be used. For staking or riveting wheels upright on their pinions, lay the stake No. 7 level on the tool bed (the center M having been fastened down out of the way), and with No. 5 center accurately the hole to be used in the stake, and fasten it there by means of the clamps N; then remove the cone end of No. 5, and place a punch with a hole in its end of the required size, on the part _m_, and proceed as in an ordinary upright staking tool.

=345.= =Tool for Flat Polishing.= A thick brass plate is provided with three strong screws arranged in triangular form (G, Fig. 162), and far enough apart to ensure that, if the plate is reversed and rests on their heads, it will remain flat when moved by hand over a polishing surface.

[Illustration: _Fig. 162._]

The screws should fit tightly or be provided with lock-nuts.

We believe that every watchmaker must be acquainted with this little tool. The object to be smoothed or polished is fixed with shellac or sealing-wax to the middle of the triangle formed by the screws; the level is then adjusted so that, when resting on a flat surface, the object to be polished coincides exactly with it. The polisher (for example, a sheet of ground glass) is charged with oilstone dust or polishing rouge, and the object is passed over it until perfectly flat and smooth.

=346.= For smoothing, it is best to use a large sheet of iron or steel. For polishing, copper or bronze is preferred. Ground glass may be employed for both operations; it must be hard and perfectly flat.

A disc rotating in the lathe or mandril, etc., is often used.

The tool may be inverted and rest firmly on a cork, the polisher being then moved backwards and forwards by hand, and always in contact with the three screws.

It is best to use pith for cleaning the polished surface; in its absence use soap, then wash and dry with a soft linen rag. The object is detached by heating the tool, and is cleaned by boiling in alcohol; afterwards pass through pure alcohol at the ordinary temperature and dry.

=347.= This tool can be employed for polishing small surfaces, such as the end of a rod, of a barrel-arbor or a screw-head, as well as for those of greater extent. But it appears needless to enter into further detail.

Instead of three screws some workmen only use two, at some distance apart. The object to be polished, being placed at the third corner of the triangle, takes the place of the remaining screw.

Lastly, if a band be fitted to one side of the brass plate, as shown at _b_, Fig. 162, and held by two screws, it will often be of service as a clamp for fixing the object, as at _s_.

=348.= Flat pieces can be polished on a revolving lap worked by the foot, being simply held in the hand or in a piece of soft leather; but a certain amount of practice is needed in order to do this successfully.

ACCESSORIES

AND MISCELLANEOUS OPERATIONS TO BE PERFORMED IN THE UNIVERSAL HEAD.

=349.= With a view to simplify the work, we will here give, in a collected form, a number of operations that may be performed in the mandril, or universal head, among which the practical watchmaker will easily be able to distinguish those that can be done in the

ordinary lathe; we will also describe numerous accessories that the workman should make for himself, if he is desirous of making his mandril or universal head still more generally useful.

[Illustration: _Fig. 163._]

=350.= Prepare a number of chucks of the form shown in Fig. 163. Some of these carry a small bar with screws, by which an object may be clamped firmly to the chuck, an arrangement which is also shown at A, Fig. 163; others have a hole drilled through their axis; others again have a projecting arbor, etc. They may also be made with a flat face on which to cement objects in the ordinary manner.

[Illustration: _Fig. 164._]

As it is often necessary to have a considerable surface to cement, for example, a watch-plate, one or more may be made of the form shown at T, Fig. 164. The lower plate being clamped in the dogs, the disc _e_ will be free. If this disc be made of bronze or steel it may be used as a lap; if of brass, it may be turned true and used as a wax chuck, etc.

The chucks should, as far as possible, be well made, so that they can be truly centered by means of the pump-center.

TO CENTER AN OBJECT.

=351.= When there is a hole at the center on the side towards the face-plate, in the universal head, as is usually the case, it is only necessary to place this hole over the point of the pump, pressing it inwards, and then to clamp the object in the dogs; the pump is then drawn within the body of the arbor. Very often, however, there is no central hole, or there is only a mark on the face that is towards the cutter; in such a case it becomes necessary to center from the front or by the circumference.

=352.= =To Center from the Front.= If the object is held by wax on a plate, it may be centered as in the ordinary lathe while the plate is hot, by resting a piece of pegwood on the T-rest with a point placed in the central hole, and observing whether its free end remains stationary.

After the plate has cooled, the accuracy of the centering should be tested by means of a long piece of pegwood which rests on the T-rest brought close up to the object. The pegwood is held parallel to the lathe-bed, and, if the centering is satisfactory, its outer end will not move. The detection of any slight movement is greatly facilitated by placing some fixed object close to the free end of the pegwood. If a motion is still observed the centering is imperfect, and must be corrected in the manner explained below (=354=).

=353.= _Perrelet's method of Centering._ In principle, this is identical with the one just described; but the pegwood index is replaced by the small apparatus shown in Fig. 165.

[Illustration: _Fig. 165._]

A hollow cylinder, of which _a c c a′_ is a section, is firmly held by friction by its portion a _b b′ a′_ in the tailstock. In the front of this cylinder is fixed a steel ring that is thick at the circumference and tapers inward, so that the central hole has a cutting edge. The two black triangles represent a section of this ring. The rod _r_ _n_ passes without play through this hole, and carries a projecting ring at _s_ to determine the distance to which it enters the collar _c c_; there is also a small key that corresponds with a nick in _c c_, and thus prevents rotation.

An inspection of the figure will show that, when _s_ rests against _c c_, if the finger be placed on _r_ and communicate motion to it, the rod _n r_ will be able to oscillate in any direction, and to an extent limited by the diameter of the hole in the cylinder.

The error in the centering at _r_ will be multiplied at _n_ in the proportion of _n s_ to _s r_; thus if _n s_ is ten times _s r_, the motion at _n_ will be ten times as great as the actual error at _r_.

=354.= The instrument is used as follows: The object to be centered being placed between the jaws, having the centering spindle in position in tailstock. Slide tailstock towards the face-plate until the point _r_ of the rod enters the hole, or central mark of the object, and, setting the T-rest close to the point _n_, rotate the face-plate. If the centering is exact, the point _n_ will remain stationary. If _n_ moves to and fro, give a gentle blow against the edge of the object, which should not be held firmly in the dogs; the blow must be on the side opposite to that at which _n_ shows the greatest deviation from the point of reference. Repeat the process until the centering is perfect or sufficiently accurate; then clamp the dogs firmly, taking care not to disturb anything.

In centering from a jewel hole, an aluminium rod _n s_ may be employed on account of its lightness, and it may be terminated in an ivory cone at _r_.

=355.= There is one precaution to be observed, as it facilitates the use of this appliance; it is advisable that the portion _a b b′ a′_ of the cylinder be somewhat long and well made, in order that, while being in the first instance inserted in tailstock up to the shoulder, the cylinder may be partially withdrawn and still held firmly. The reason for this is as follows: When the tailstock is pushed along, a considerable amount of friction resists its motion, and, as the hand cannot always control this motion, it may happen that _r_ comes up against the object with some force. To avoid this, bring the point near the hole and then rotate the collar in the tailstock so as to gently withdraw it to the requisite amount. The cylinder may, if desired, be fixed by a small screw after the point _r_ has been set in position.

[Illustration: _Fig. 166._]

=356.= =Another Centering Device.= The centering indicator shown in Fig. 166 will also be found useful for testing for exact center. The body of the indicator is made of sheet brass, and should be about five inches long by two inches in width at the larger end. The shank _C_ is made to fit in rest holder, and is either riveted or soldered to the body; _R_ is steel or copper wire sharpened to a fine point, and balances on a pivot at 1; _B_ is a clock hand pivoted to the body at 1; 2 and 2 are pivot joints only, and do not go through the body; _C_ will perhaps give a better idea of the end _R_. To center with this tool, unscrew your rest and remove it, then place the shaft _C_ in rest holder and adjust it till the needle point _R_ touches the top of hole, as shown at _A_. The index hand will then note the variations as the head revolves. If too low, the hand will point above center, and if high, vice versa.

=357.= =To Center from the Circumference.= Two cases may occur: Either the entire rim of the object is exposed, as when the teeth are to be cut in a wheel blank; or the rim can only be used as a means of determining the center, as when a barrel has been bushed with an undrilled bushing.

=358.= The tool shown in Fig. 166 may also be used for the test if the short end of arm R rests against the under side of the object that it is desired to center.

=359.= When it is required to drill or merely to center the hole in a wheel, barrel, etc., that does not run true, clamp a piece of sheet brass in the dogs and turn out a sink that will exactly receive the wheel, etc., but allowing it to project slightly. Now unscrew one dog and advance it a little, so as to grip the edge of the object as well as the plate; move the other dogs inwards in succession, and it will only remain to drill or true the hole with a suitable drill.

UPRIGHTING AND DRILLING.

=360.= =When the Lathe is Provided with a Tailstock.= Let it be required to mark and drill a pivot-hole in the cock when the plate-hole is accurately centered by means of the pump-center. Place the tailstock in position on the lathe-bed, and mark the position of the hole with a center, as in an ordinary uprighting tool; then, if the hole is to be very fine, make it with an ordinary pivot-drill.

If the hole to be drilled is somewhat large, it may be drilled with the twist drill, the bed of the lathe being, as usual, horizontal.

=361.= =When the Lathe is not Provided with a Tailstock.= In such a case it is possible to upright and drill by using fine drills, and making points so formed as to take the place of the cutter. Or a stock may be made to receive drills, points, etc., and it may be well here to remark that stocks of the same form are convenient for receiving chamfering or sinking tools.

[Illustration: _Fig. 167._]

This stock is shown in Fig. 167. An inspection of E _c_ will suffice to show its form, and it may be used for holding either a drill or a marking point, or a small hollow center in which to support a pivot drill.

The following method should be adopted for securing accuracy in the adjustment of these stocks:

There must be no shake of the stock in the tool-holder; it is especially important to avoid any displacement during the act of clamping. If there is any reason for doubt on this point, drill a hole at the foot of the cutter in which an index, _y_, can be temporarily inserted; any displacement can be detected by its deviation from a fixed mark. As a rule, however, there will be no occasion for

doubt if the plate that is screwed down upon the stock is parallel to the bed of the tool-holder.

The cutter is then replaced by a stock of the form shown at E′, in which a hole has been previously drilled to receive the drill or other bit, but somewhat smaller than it is required finally to be. The pump-center must now be replaced by an accurately fitting piece B that terminates in a short semi-cylindrical drill.

It will be evident that if the mandrel be revolved, and, at the same time, the tool-holder advanced towards this drill, the hole in the stock E′ will be enlarged and smoothed, and its axis will accurately coincide with that of B. Any drill, chamfering tool, etc., that has been turned true, will, therefore, on being inserted in the stock, prove to be strictly in the axis of the lathe.

[Illustration: _Fig. 168._]

=362.= =To Drill a Series of Holes.= Mount on a stock similar to that just described, a small frame carrying a drill-stock, as shown in Fig. 168. If this be fixed in the slide-rest in place of the cutter, it can be used for drilling a hole or a series of holes previously marked out, or, if the pitch of the transverse screw of the slide-rest is known, for a series of equidistant holes in a horizontal line. When it is required to drill a series of holes in a circle, as, for example, in the escape-wheel of the pin-escapement, bring the point of the drill onto the circumference and then proceed as when using the ordinary wheel-cutting engine provided with a vertical drill-holder, taking care to fix the face-plate by means of an index.

This index should have a means of slightly modifying its length, so that the point of the drill may always be brought into exact coincidence with the points that have been previously marked on the object.

It will be observed that, if the drill were replaced by a round milling tool, the U's of a cylinder escape-wheel might be polished, or, indeed, cut, the concave ends of the teeth of the star-wheel in a Geneva stopwork could be corrected, etc. But it is unnecessary further to insist upon the many uses to which this form of tool can be applied.

=363.= =To Cut the Teeth of a Ratchet, Minute-Wheel, Etc.= When the face-plate is divided on the circumference, it is easy to cut the teeth of an ordinary wheel of a timepiece, escape-wheel, barrel ratchet, to cut or true a star-wheel for the stopwork, etc. After mounting the wheel on a chuck and carefully centering it, replace the cutter by a small revolving cutter-frame after the model of that shown in Fig. 168.

The stock _d_, shown in both plan and elevation, carries a piece _c_ at right angles, which has a slot cut throughout its length. In this slot a U-shaped support can be clamped by a nut in any position. The U portion forms a bearing for a cutter, such as is shown at _f_ in the figure, and the axis projects so as to receive a ferrule for rotating the cutter.

It will be evident that, with such an arrangement, the height of the cutter can be adjusted in accordance with the teeth to be cut.

=364.= =To Cut a Circular or Elliptic Groove.= For this purpose no special accessory is needed; an ordinary cutter will suffice.

[Illustration: _Fig. 169._]

Let _a b c d_, Fig. 169, be the form of the required groove. Mark a series of centers so that circles struck from them will just overlap one another, and at the same time nearly reach the edge of the groove. Then turn out all the circular sinks, indicated by shaded lines, to the required depth.

Center the plate by the point _o_ from which the arc _a b_ is struck; now bring the cutter to such a position that its outer cutting edge coincides with the arc _a b_, and bring it against the plate; set the face-plate in motion, not, however, by using the treadle, but by the hand at its circumference, and traverse the arc from _b_ to _a_; then withdraw the cutter. By this means the projecting angles, left white in the figure, will be removed, and a clean edge will be left to the groove.

As an operation of this description will not present any difficulty, further explanation appears unnecessary; for the information above given will enable any watchmaker to make curved grooves of the kind indicated.

If it is required to smooth the surface of the groove, replace the cutter by a pegwood stick that can be rotated with friction, and the end of which just fits into the groove, charging it with pumice or other stone and oil. One hand moves the face-plate backwards and forwards, while the other rotates the stick.

[Illustration: _Fig. 170._]

=365.= _To Cut the Cylinder Escape-Wheel Cock Passage._ As a rule the cock is cemented, inverted, to a wax chuck, and the passage cut or enlarged on the lathe. It is more expeditious to use a plate provided with a clamping bridge, as shown at Fig. 170. The face-plate should be made to oscillate backwards and forwards by hand, and not rotated by the wheel.

=366.= =To Make a Straight Groove.= _First method._ The tool devised by M. Chopard, director of the school of horology at Besançon, and shown in Fig. 171, is used for this purpose. As will be seen, it consists of a small lathe which is adapted to the slide-rest as follows:

[Illustration: _Fig. 171._]

Two pins, _a a′_, are planted in the top of the tool-holder, the cutter together with the plate by which it is clamped having been first removed. Holes drilled in the frame _f f_ fit accurately onto these pins, while a screw, _h_, passing through an intermediate hole, affords a means of firmly fixing the apparatus to the tool-holder M.

This tool should satisfy the following conditions: The arbor C should fit into a recess that receives a cutter, but without coming into contact with it; this arbor should be parallel to the bed of the lathe; and, lastly, the axis of C should be on a line with the lathe center.

=367.= Having set this little appliance in position, trace on the watch-plate two lines indicating the directions of the sides of the groove as well as lines fixing its length. Now place the plate in the dogs, setting the point of the pump-center anywhere on the line drawn along the middle of the groove. Turn the plate so that this line is horizontal, and fix it in any way that is convenient.

The arbor C carries a revolving cutter _k_, which can be changed as desired, and is held in position by the clamping screw _d_. Assume that the diameter of this cutter corresponds exactly with that of the required groove; advance it towards the plate, turning the wheel rapidly, the cord being round the ferrule _b_; a circular sink will thus be formed in the plate of the same diameter as _k_.

When this has been cut to a sufficient depth, the tool is moved parallel to the face-plate, and the cutter _k_, continuing its movement of rotation, will now cut, not with its extremity _i_, but with its sides. It will thus form a straight groove of any desired length.

=368.= The cutter is a three-sided prism, or it may have four sides with four cutting edges on the sides, and only one cutting edge at the extremity _i_. If it is preferred to retain only the two acting edges that start from either end of the cutting edge _i_, they may be made more acute, and the other pair reduced by means of a file.

[Illustration: _Fig. 172._]

=369.= _Second method._ This is simpler than the one just considered. At the end of a rod G, Fig. 172, which takes the place of the cutter in the slide-rest, a plate _p_ is fixed. A line is drawn across the face of this plate in such a position that, when G is clamped in the tool-holder, this line is horizontal, and in the plane that contains the axis of the pump-center.

Let it be required to cut a straight groove in the piece of brass _l_. Wax it to the plate _p_ so that the axis of the required groove is over the line traced on the plate. Now fix G in the tool-holder and replace the pump-center by a rod D, the extremity of which is formed into a cutter of a diameter equal to the width of the required groove; the rod D should be fixed in the hollow arbor by a screw. It is then only necessary to set the cutter in motion, forcing the piece _l_ against the revolving cutter, until the requisite depth is attained. Then, by making the tool-holder travel parallel to the face-plate, the groove will be elongated until of the desired length.

=370.= The cutter may be of the form shown in Fig. 171, or it may be as shown at _b_ in Fig. 172, since the movement is always in the same direction. The cutting edges are each formed by two small inclined faces, one pair of which is shown at _b_; they occupy half the diameter of the cutter. At the back of this pair the cutter presents the appearance of the lower half shown in the figure and _vice versa_.

It will be evident that the two sides of this cutter will act while its motion is continuous in one direction.

Besides the numerous operations that can be performed on the lathe as we have hitherto indicated, it may be employed, if divided on the head stock, for tracing out angles, marking the crossings of a wheel, a balance, etc., and for other purposes, many of which are referred to in the course of this work.

PRODUCTION OF SCREW THREADS.

SCREW PLATES AND TAPS.

=371.= The lathes employed in the manufacture of screws are of two kinds; those intended for polishing and, where necessary, modifying the form of screw-heads, much used by watch examiners and repairers, and those specially designed for cutting the threads, which are mainly in use in factories.

Before discussing them, however, we will give some account of the screw-plates and taps in ordinary use.

=372.= =Common Hand Screw-plates.= The use of these is much facilitated by providing a second plate perforated with holes of such sizes that a spindle which just passes into a hole of any given number will be of the size most convenient for forming a screw in the hole of the same number in the screw-plate. For a long time we have made use of two Latard screw-plates so made that a rod which would enter one hole without play was of the most convenient size for forming a screw in the next smaller hole but one (thus the plate perforated with plain holes can be replaced by a second screw-plate, or by using the successively larger holes on a single plate as gauges).

[Illustration: _Fig. 173._]

In order to form a screw that is clean-cut and even, with the least possible straining of the metal, the holes in the screw-plate should have notches cut as shown at F, Fig. 173; they should be carefully hardened and well polished on each side of the notch, and this system is now even applied in the case of the smallest jewel screws.

=373.= =Screw Dies.= The ordinary plate, in which notches are not cut at the sides, squeezes up and strains the metal. This effect is less marked when separate dies are used, and disappears entirely if only a small quantity of metal is removed at a time, and the cutting edges of the dies are smooth and in good order. In addition to possessing other advantages, this form of screw-plate enables us to obtain at will screws of the same thread and different diameters or of the same diameter and different threads. The dies must be carefully fitted to the slides that receive them. Dies cannot be employed for cutting very small screws.

=374.= =Fine-threaded Screw-plates.= At the present day these can always be obtained at the material stores; but thirty years ago it was not so, and the watchmaker was obliged to make them for himself. The following method was adopted:

Take a screw formed with an ordinary plate, in which the thread is broad as compared with the hollow. If the screw does not satisfy this condition it must be modified thus:

Having ascertained that it runs true, and that it is larger than will be ultimately required, insert it in a chuck in your lathe. The T-rest must carry a smooth horizontal rod of hardened steel.

Rotating the screw, hold a slitting file in the hollow; the file should fit into this hollow accurately, and should be smoothed on its two sides, only cutting with one edge. The bar of hardened steel will determine the depth to which the file is allowed to cut. By this means a screw is obtained that has a thread thick at the bottom. With the graver remove the top of this thread, round off its corners, and harden the screw, filing three facets along its entire length, that make it taper.

The tap, having been thus prepared, is employed for cutting a thread in a piece of steel, not too thick, that has been previously annealed, and in which a hole is drilled of the proper size. The thread of this internal screw will be thin and the hollow proportionately broad.

The plate is now hammered cold with care until the thickness is so far diminished that the thread and hollow are as nearly as possible of equal thickness. Harden it and chamfer the ends of the hole with a conical steel point and oilstone dust. Then clean it and cut a thread on a piece of soft steel which may be formed into a tap.

If the operation has been properly conducted, this tap will satisfy the prescribed conditions, and, when hardened, it is to be employed to cut a thread in a second steel plate, which will be employed as a screw-plate; for that first formed must, in consequence of the hammering to which it was subjected, present irregularities in the hole, and can only be used to cut one or two taps cautiously. It is useless for making screws or tapping brass. (See also =378.=)

=375.= _To Clear a Stopped Hole in a Screw-Plate._ Drill a hole through the center of the piece of metal that fills up the hole, taking care to maintain it central, and to employ a drill that is sufficiently small to avoid all risk of contact with the screw threads. Pass a

broach through this hole and, after tightening it with a few gentle blows with the hammer, turn it in such a direction that it tends to unscrew the broken screw, which will in nearly every case, be removed without difficulty by this means.

TAPS.

=376.= Screw-cutting comprises two distinct operations—the formation of a spiral thread on the circumference of a cylindrical spindle, and of a spiral groove within a cylindrical hole to receive this thread.

Taps are made either by means of a screw-plate or in the lathe; we shall presently refer to this second method. Every watchmaker may be supposed to have received, early in his career, instruction as to the cutting of a tap with a screw-plate. Great caution is necessary in the hardening, for if the tap is not true or the metal burnt it will cut badly and be apt to break. Taps are cleaned after hardening with a piece of wood in the lathe or between two hard pieces of pith covered with oilstone dust, and either three or four cutting facets may be made. It is important to avoid the production of a burr in making these facets; a good plan is to make them while the metal is still soft, and to pass the tap through the plate subsequently, as a sharp cutting edge is thereby produced. The facets should be carefully smoothed, and the use of coarse rouge is an advantage.

A tap with three facets gives the cleanest cut and leaves the most space to receive the metal that is removed, but with four facets the roundness of the hole is more certain to be maintained.

[Illustration: _Fig. 174._]

We have seen taps formed as represented at M, Fig. 174, so that the object in which a thread is being cut is loose at the part _o_, when the direction of movement of the tap is reversed. They are also at times made semi-cylindrical, as at G, and work well in the lathe for tapping brass, but we have not tried this form with steel.

=377.= =To Cut a Tap when of Considerable Length.= The following precautions must be observed in order to ensure that a long screw shall be both round and true.

The steel must be of very goad quality, and loose dies should be used in preference to a screw-plate. It is a good practice to employ two pairs of dies (or even more); one to rough out the screw, leaving the thread somewhat larger than it will finally be, and the other to finish after having trued it, and even sometimes lightly turned the surface in places. Very little metal must be removed at a time, the dies should have sharp cutting edges, and a rather large number of threads.

A screw can be made in the ordinary manner in a screw-plate rather larger than is required, then reduced to the requisite diameter, and finished with a plate in which the holes are of the form shown at F, Fig. 173, or in a screw-cutting lathe; in either case, however, care must be taken to avoid straining the metal in its passage through the first plate, on account of the tendency which it then possesses to become distorted in the hardening.

If a micrometer screw is required, that is, a screw of absolutely uniform pitch, it is necessary to apply to makers of astronomical and other similar instruments of precision.

[Illustration: _Fig. 175._]

=378.= =To Cut a Screw of any Desired Pitch and Diameter.= Let it be required to cut a thread on the stem B, Fig. 175, of any pre-determined pitch that already exists in a screw-plate. Turn down the portion _d_ to such a diameter that a screw can be cut on it in this hole, and fit two runners to the lathe of the form shown at G and H. The end of H is drilled and tapped so that _d_ turns freely in it, and a hole is drilled in G to receive the stem B freely, but without sensible play, and a fine notch is cut at _a_.

It will be obvious that if now the ferrule _r_ is caused to rotate, while a fine saw or file is inserted in the notch _a_, a screw will be formed on B of the same pitch as that on _d_, although there may at the same time be a very considerable difference in their diameters. This method may be adopted in place of that explained in article =374= for obtaining a fine-threaded screw.

=379.= =Left-handed Screw Taps.= The manner in which these are made in the screw-cutting lathe will be subsequently explained; in its absence the watchmaker may adopt one of the following methods:

[Illustration: _Fig. 176._]

First method. If, when an internal screw has been cut with a right-handed tap, B, Fig. 176, it be required to tap a second hole in the reverse direction, the following plan may be resorted to:

File the original tap B on two opposite sides, so as to give it the flattened shape shown at A in the same figure. Insert the end into the hole to be tapped and turn the tap to the left with the application of considerable pressure, so as to force the tap to bite. When the tap has been passed in and withdrawn there will be found to be a left-handed thread cut in the hole. For, if the tap is turned towards the right, the thread _f_ passes into the groove already formed by the thread _a_; but, if turned towards the left, _f_ will originate a groove into which _b_ will pass, traveling in an inverse direction to that previously given to it.

The finer the thread of the screw, the better is the chance of success, and with a wide thread it is often necessary to recommence two or three times. If a plate or pair of dies be cut in this manner and hardened, they will serve to cut an even left-handed tap.

[Illustration: _Fig. 177._]

Second method. Attach a comb to one or two sides of a cylinder, as indicated at F, Fig. 177. This can be used to cut a thread in the piece of metal S, that is either right or left-handed according to the direction of rotation of F, sufficient pressure being at the same time applied to force it into the plate. The pitch of the thread will depend on the amount of pressure applied. This plan is only a modification of the one described above, and, as in that case, success can only be guaranteed when a means is adopted for securing a definite relative amount of motion in F around its axis and S vertically.

[Illustration: _Fig. 178._]

Third method. A tap of unhardened steel is filed into a triangular form, C, Fig. 178, and twisted so as to bring the angles _b_, _f_, towards _a_, _d_, etc.; we thus obtain a tap which will serve, throughout a certain portion of its length, to cut a left-handed thread, but the part that is not so adapted, at the extremities, will require to be removed before hardening.

[Illustration: _Fig. 179._]

=380.= _To Make a Left-handed Tap by Means of a Right-handed Tap._ A portion of the right-handed tap is filed off on three faces to the section shown at _b_, Fig. 179, and firmly set in the die _d_ so as to be held in the frame for screw-cutting dies. A second die, _f_ made of brass and having a semi-cylindrical recess opposite _b_ is fitted to the frame. The diameter of this semi-cylinder should be the same as that of the rod on which a left-handed thread is to be cut. Now grip this rod as shown at _a_ by means of the screw _g_, so that it is held between the die _f_ and the block _b_, and rotate the frame or the rod _a_ towards the left; a spiral groove will thus be cut by the thread on _b_. It is sometimes an advantage to cut this thread lengthwise in the manner indicated at _b′_.

[Illustration: _Fig. 180._]

This method enables us to cut a given thread on a rod of any given diameter. From an examination of Figs. 179 and 180, it will be seen that a simple comb of the form of C or D, carefully made by hand and fixed in the place of _b_, can be employed to cut a right or left-handed thread on any given rod; it is advisable, however, that the teeth of the comb be inclined to the axis of the screw, like the thread of an ordinary tap, as otherwise the operation becomes more difficult and success less certain.

[Illustration: _Fig. 181._]

The method may be simplified by taking a brass plate, D, Fig. 181, of sufficient thickness, and firmly setting in it the right-handed tap, _v_, having only filed away two opposite faces before hardening. The rod to be tapped is then introduced with considerable pressure into the hole _j_, and, if rotated towards the left, it will receive a left-handed thread of the same pitch. The notch shown at _b′_, Fig. 179, will facilitate the operation, as a cutting action will take the place of compression.

=381.= M. Gontard has suggested a modification of this arrangement, which consists in forming the die _f_, Fig. 179, so that the original right-handed tap can be embedded in a hole previously tapped in it and filed away on the side towards _b_ so as to expose a cutting edge; and he points out that, by suitably inclining the frame with reference to the axis of the rod to be tapped, the appliance can be used to cut a double or even a triple-threaded screw, right or left-handed. He further draws attention to the fact that in a screw formed in this manner the sides of the thread are smooth and polished, a condition which cannot be secured when either a plate or dies are used.

=382.= =To Increase the Diameter of a Tap.= It sometimes happens that a screw will not penetrate to a sufficient depth, or fits too tightly into its hole, owing to the tap employed being of a less diameter, either in consequence of the hardening, polishing or wear, or through having been formed in a different screw-plate. In such a case the following expedient may be resorted to:

[Illustration: _Fig. 182._]

Make a fresh tap in soft steel and file away two opposite sides so as to give it the section shown at A or B, Fig. 182: after measuring the diameter at several points in its length, hammer gently on the flattened sides. With a little care and by using a micrometer at intervals for testing the alteration in diameter, it will be found that the required increase can be obtained without much difficulty. The tap is then hardened and polished, etc.; indeed, it is best to make a fresh tap.

METHODS OF TAPPING HOLES.

=383.= It is needless to refer to the method of tapping by hand, as it is well known to all practical men.

=384.= =Tapping in the Lathe.= The plate of a watch is gripped in the dogs of a face-plate, the hole to be tapped being centered by means of the pump-center, which is then withdrawn, and a tap held to the hole; the face-plate is then caused to rotate either by the hand resting on its circumference, a slight backward motion being given after each advance, or the motion may be continuous and be given by the wheel. In the latter case, however, the tap must have a good cutting edge and only be held in the hand with the degree of force required to make it cut, so that it may rotate without breaking in case the resistance opposed becomes too great. The tap may be steadied on the T-rest.

=385.= =To Tap with a Mainspring Winder.= The ordinary mainspring winder will, if the click work is removed, be found very convenient for tapping holes, and indeed, for forming the external thread on screws. Having removed the winding arbor, replace it by a tap carefully centered; then introduce its coned end into the hole in the plate, which must be pressed forward while the handle is turned, a short backward motion being given to it at frequent intervals. When the tap is engaged sufficiently in the hole it is merely necessary to maintain the plate at right angles without applying pressure.

=386.= =To Tap with a Bow.= Instead of the mainspring winder, one of the small drill-stocks to be driven by a bow, consisting of an arbor, with a coned hole at one end and ferrule at the other, supported in a frame that is clamped in the vise, may be used. They are to be obtained at any tool-shop.

The bow being on the ferrule and the tap properly centered in the arbor, the hole is held against the coned end and the bow worked with an alternate forward and backward movement; but if the tap has a good cutting edge and the bow is strong (of steel or cane), a hole may be tapped with a single stroke of the bow. After a few trials the method will be found very easy and certain.

A regular and rather slow motion should be given to the bow, which should be long and strong. It is well to ascertain the number of revolutions of the ferrule that correspond to a stroke of the bow, so as to ensure that the tap is not introduced to a greater depth than is required. If it is desired that the screw work easily in the hole, the tap should be moved several times backwards and forwards.

=387.= The little turns here referred to, some of which are perforated throughout their entire length and others only at one end, are very cheap and will often be found useful; they can be adapted to receive drills, broaches, taps, etc.

=388.= =To Tap in an Ordinary Lathe.= In factories it is a common practice to tap the holes in plates, etc., and even to cut the threads of screws in a lathe specially arranged for the purpose. The tools adapted for such work are of two kinds: in some the tap enters to the required depth, when it is immediately arrested, disconnected, and then rotated in an opposite direction; in others, the tap advances to a definite point, and is immediately withdrawn. As a rule, however, the tap remains stationary and the object is caused to rotate.

=389.= =Beillard Lathe for Tapping Screws.= The axis F M, Fig. 183, is perforated throughout its length. At F, the screw-plate G is dovetailed into it. The inner end of the hole in this plate is slightly coned to facilitate the insertion of the brass wire D, and it must be exactly in the axis of F M. A guide B sliding on two rods _c_, _c_, is traversed by the rod D which can be clamped in it by the screw _a_.

By pushing D against the screw-plate at the same time that the handle N is rotated, a thread will be traced on it and it will emerge at _k_. When B has advanced to the point _m_, the screw _a_ is released, B is drawn back, and _a_ again clamped.

[Illustration: _Fig. 183._]

When a long screw, such as X _x_ has to be tapped, the screw-plate is fixed at _m_, and the guide B is fastened on to the portion X. Of course the hole in the screw-plate must always be abundantly provided with oil.

If the screw-plate F is replaced by a plate perforated with a round or square hole, a drill, broach or tap may be substituted for _k_, being clamped by the screw _h_, and the tool is at once available for drilling, broaching or tapping any given hole.

RAPID MODE OF MAKING A SCREW.

=390.= The methods ordinarily adopted by watchmakers are too well known to need description; we will therefore at once proceed to give a special plan recommended by M. Vissiere.

An eccentric poppet-head with boring-plate, Fig. 185, is fitted to the bed of the lathe, the eccentricity being such that the axis of the centers is at the point _a_ on the circumference of the circle _a y_. The conical hole, having a center at _a_, is cut away towards the rim of the plate to the degree indicated in the figure, and its center is so placed that the vertical line _f_ and the radius _d_ are inclined at 120°. The position of the T-rest is shown at _s_, and by bringing it into actual contact with the disc the steadiness of both is increased.

The fixed headstock of the lathe is provided with a runner of the form B, Fig. 184, terminating in a point _m_ at one end and a hollow cone or funnel _n_ at the other end.

Having filed the ends of a rod T, of any required diameter, square and fitted a ferrule, support it between the two cones, _a_ of the boring-plate and _n_ of the runner. Near the end _a_ cut a hollow _r_ sufficiently small to allow the stem to pass through the notch in the hole _a_, Fig. 185. After passing it through, the rod will be supported as shown at H, Fig. 184, so that the rim _e i_ rests against the cone.

[Illustration: _Fig. 184._]

[Illustration: _Fig. 185._]

Further explanation is hardly necessary; after removing the portion _c g_ with a graver, turn down to a point _p_. When making a screw, turn out a second hollow _o o′_; it then only remains to turn off the disc at the extremity, and the screw will be roughed out of the form _c p g v_.

If it is preferred to work with a point at the left-hand end of B, remove the rod after the point _v_ has been turned, replace _m_ B _n_ by a common runner, reverse B, and recommence the operation.

It would be difficult to devise a method for roughing out a screw and making a point that would be more expeditious than the one here described.

SCREW-HEAD TOOLS.

=391.= These are of various kinds: some work by hand and others by a bow. The jaws are brought together sometimes by a sliding ring, and at others by a milled head placed between them and rigidly attached to a pin tapped with right and left-handed threads that engage in the jaws. But neither of these plans is good; the screws are not held firmly and they are rarely well centered; owing to the slight displacements of the jaws.

[Illustration: _Fig. 186._]

A better plan is to arrange, either in the lathe or in the jaws of the screw-head tool (when driven by a bow), a series of chucks of the form shown at T, Fig. 186. They are easily made and tapped, the hole _i_ serving to remove the metal from the inner end of the hole that has to be tapped; such chucks occupy very little space, and, if numbered to correspond with the size of screw, any chuck required can be found without trouble. If the hole becomes too large owing to frequent use, a larger size of tap can be passed through the hole and its number changed.

=392.= A set of such chucks is almost indispensable at the present day to the watchmaker who wishes to repair watches well; for he rarely makes his own screws, as they are to be obtained well made and very cheap at the material dealers, whereby a great saving of time is effected. But their heads are seldom of the proper size to fit the original sinks, and by being provided with such a series of chucks the watchmaker can at once overcome this difficulty, as he can turn the heads down with a graver.

=393.= R, Fig. 187, is an arbor for a screw-head tool that is driven by a bow, and is adapted to receive such chucks, or it can be used in an ordinary lathe, _d_ being supported on a pointed center, and _g_ in a boring-plate, Fig. 188, or in a cone-plate center.

=394.= In this form of screw-head tool the portion A is sometimes perfectly cylindrical, so that the piece V can slide on to it, being clamped by the screw _b_.

This tube V is cut away through about half its length with a notch, as indicated in the figure; bent pieces of hardened steel _c_ and _n_ are screwed to either side of the notch. Screws, _h_ and _f_, provided with lock-nuts, determine the distance between these plates, and when V is in position on A the ends of _c_, _n_, will rest on the screw-head, leaving just sufficient space between them for inserting the file that cuts the slit.

[Illustration: _Fig. 187._]

Hard steel caps of the form shown at M may also be fitted to A, a notch being cut in them to receive the screw _b_. These will be found useful as guides for filing or polishing screw-heads, or the ends of arbors flat, reducing the heads of several screws to the same height, etc.

[Illustration: _Fig. 188._]

=395.= The tool for forming the U-spaces in a cylinder escape-wheel can be easily be converted into a screw-head tool with laps. A glance at Fig. 189 will at once make this evident. A number of chucks are adapted to the arbor A, and in the tube _c c_ either a T-rest or a spindle carrying a lap is fixed.

It will also serve as a tool for drilling; a drill-chuck with drill, _f_, being adapted to A, and the object to be perforated at _b_ resting against a plate that projects at right angles from a slide _d d_, which may be advanced by a screw _g_.

=396.= The modern watchmaker has so little call to cut screws that it does not pay him to purchase a screw-cutting lathe; for a very small sum he can have screws of any thread or diameter cut by those who make a specialty of such work, always provided that he cannot find what is wanted in the material stores. The same thing also applies to fuzees.

[Illustration: _Fig. 189._]

TOOLS FOR CUTTING AND ROUNDING-UP THE TEETH OF WHEELS.

WHEEL-CUTTING ENGINE.

=397.= The machine for dividing the circumference of a wheel, termed the wheel-cutting engine, and one form of which is shown in Fig. 190, is well known to nearly all workmen. The wheel is fixed to a chuck at B by wax or screws, or by the pressure of a hollow cone or “sugar loaf” of steel, to the apex of which pressure is applied by the arm D, or in other ways. The wheel may be centered either by a pump-center within the chuck or by an appliance such as is shown in Fig. 191, except that the arm _b_ is curved and its index much longer. This little addition may be fixed to the frame of the engine in any convenient position.

[Illustration: _Fig. 190._]

The chuck B that carries the wheel is rigidly connected with a large brass plate A A, on which are concentric circles of divisions, and the whole can be maintained stationary by setting the point of the index C C in any desired hole on the division-plate. The cutter is carried on an arbor (shown separate at L) between horizontal bearings in the frame J, and is caused to revolve by means of the pulley K. The several parts lettered E, F, G, H, are for bringing the cutter against the wheel and modifying the direction in which it moves, so that the machine can cut straight or inclined teeth, bevel or crown wheels, etc. It should be added that the engine here represented is more complex than those ordinarily used for cutting watch wheels, although the principle on which it acts is the same.

The teeth may be cut by circular cutters of the nature of files, by a small straight cutter, similar to those used in a slide-rest projecting from a rotating axis, or by several such cutters mounted on a disc which is caused to rotate. For the sake of distinction it will be well to refer to the first of these as _file_ or _mill cutters_, while the second and third may be termed respectively _single_ and _multiple blade_ or _composite cutters_.

[Illustration: _Fig. 191._]

Watchmakers rarely possess a sufficiently large assortment of file-cutters for making all the various forms of teeth that are met with in horology; but this deficiency can be supplied by making them for themselves to any required pattern in the manner subsequently described.

=398.= _Observations._ The wheel-cutting engine in which the plate is caused to rotate by means of a tangent screw is usually the most accurate. If the pitch of the screw is fine it will give all the subdivisions of a circle that are required for ordinary work, but it is essential that a good form of counter be attached to the screw, and a certain amount of calculation is always needful.

The engine that has a division-plate with conical holes arranged concentrically over its surface is simpler and better adapted for rapid work. The larger this plate, the greater is its chance of being correct and, at the same time, it affords room for a larger number of divisions.

It is preferable that the cutter frame rise and fall in a vertical dovetail, for when the arbor is carried in an H shaped arm pivoted on two screws, the teeth are always slightly dished. The entire apparatus should be somewhat heavily constructed and supported on a solid bed; so as to prevent the vibration of the cutter-arbor from being distributed over the entire machine.

The highest numbers on the plate should be used whenever it is possible, so as to diminish the error due to irregularities in the sub-division. For example, in cutting a wheel of 30 teeth, use the 90 or 120 circles, taking every third or fourth hole.

These remarks will probably be sufficient to enable any watchmaker who possesses a wheel-cutting engine to employ it with success; we will, however, add the description of a few appliances or processes that have a bearing on this question.

=399.= =To Divide a Wheel so that it has one Tooth more or less than any given number on the Division-plate.= It is to be observed that neither this nor the following method is mathematically exact, but if it is practiced with care and the division-plate is of sufficient diameter, the error may as a rule be neglected.

[Illustration: _Fig. 192._]

Let P, Fig. 192, be a division plate that has a 30 circle, but not one of 29 or 31 divisions. Divide the circumference of a disc _d_, seen on edge, into a large number of parts in the engine, 360 for example, and fix it to the end of the index, at the same time attaching a finger, _i_, to the support _s_. Now advance the screw of the index through a distance corresponding to the angle _l_ P _k_ included between the two successive points of the 30-division circle. To measure this distance a pointer should be previously fixed to the frame to correspond with the middle point of a hole in the circle under consideration, and the motion should be arrested when it coincides with the next succeeding hole. Assume that this amount of displacement has required three complete turns of the screw; 1,080 divisions on the disc have thus passed under the finger _i_. Dividing this number by 31, we obtain 34.83.

After observing the division on _d_ that coincides with the pointer _i_, cut the first space of the wheel; then cause 34.83 divisions to pass under _i_, in such a direction that the plate is drawn with the arrow, and transfer the index to the next hole of the circle, rotating this time opposite to the arrow; the second space can now be cut, and so on.

With a view to diminish errors arising from the omission of fractions, since 31 does not divide evenly into 360, a number of multiples of the number 34.83 should be determined. Thus 4 times 34.83 is 139.32, so that, when the fourth space is cut, the pointer _i_ must be at this number of divisions from its initial position.

The index should be so situated that, when half the arc _l k_ has been traversed, as explained above, _s a_ is at right angles to the radius P _r_ of the division-plate. If it is desired to move _d_ in a reverse direction, it must be moved backwards to a considerable distance and then forward up to the required point so as to avoid error due to backlash. The screw of the index should fit the support s firmly and without any shake.

=400.= =To Cut a Wheel with any Given Number of Teeth.= When the given number does not occur on the division plate, proceed as follows: Take a strip of metal, for example a pliant piece of soft steel, and cut in it a series of equal and equidistant notches as shown at B, Fig. 193. Cut the band to such a length that it has the same number of pairs of teeth and spaces as the wheel is required to have teeth. Now turn a lead disc of a diameter that the strip of metal will exactly enclose; fix this strip round the circumference with pins, screws, or in any convenient manner, as is shown at C. We thus obtain a temporary division plate which can replace the permanent one or be attached to its upper or under surface, and, when an index has been adapted to it, the wheel can be divided into the requisite number of parts.

[Illustration: _Fig. 193._]

When employing an engine the division plate of which is worked by a tangent screw, the above affords an easy means of making the divided head for the screw with any desired number of divisions.

=401.= With a view to insure accuracy, it is advisable to employ a disc of large diameter as the errors of division are thereby rendered less important and the metallic blade can be made to lie closer to the rim.

The blade is subdivided by a saw to which a guide is attached as indicated at H, Fig. 193, or the saw can with advantage be replaced by a file that only cuts on its edge and not on either face, or by a pair of mills or revolving cutters united together as shown at S. The following plan, however, appears to be more expeditious and to involve less trouble to ensure accuracy.

[Illustration: _Fig. 194._]

A hole _a_, Fig. 194 is drilled in a metallic band by means of a semi-cylindrical drill fixed in the chuck of a lathe or in a wheel-cutting engine, etc. It will be convenient if the drill can be set vertical. Beneath it is a brass bed-plate in which are fixed two pins equal in diameter to the hole _a_; this hole having been placed over one pin _b_, the band is held firmly against the other, while the second hole is drilled. This is then transferred to the pin, and so on.

In the absence of a suitable tool, a well made measure can be employed for marking a series of points with the aid of an eyeglass; the holes are then drilled with the bow or in any other manner.

=402.= =To Cut a Wheel, Ratchet or Pinion on an Ordinary Lathe.= When only a moderate degree of accuracy is required, the ordinary lathe can be adapted for cutting the teeth of minute wheels, ratchets, pinions, etc., by making the following appliance:

The piece B, Fig. 195, provided with a stud at _p_, slides on two horizontal and parallel cylindrical rods fixed to the slide C, or it may move in a dovetail. The cannon _d_, carrying a ferrule _k_ and a file-cutter _f_, rotates on the foot at _p_ without shake; and the cord of a wheel or bow passes round _k_.

[Illustration: _Fig. 195._]

R, the wheel to be cut, is supported between the runners, the divided plate V, which may even be an old wheel with the required number of teeth, being fixed to the axis of R. V is held stationary during the operation of cutting, by the index _l_. The mode of action hardly requires explanation: while _f_ is rotating, advance B until it is arrested by the stop _t_; then draw B back, advance _l_ to the next division on the plate, and so on.

=403.= We have said enough on this subject to enable any watchmaker to make such a tool, modifying it or completing it according to his requirements. We would only remark that: (1) If a cannon of the form _d_ is used, the stud should be diminished in diameter at its middle part for about three-quarters of its length, so that friction occurs only at extremities; and (2) if a wheel is used to rotate _k_, there should be an idle pulley at _m_ supported on a fixed arm independent of B, either attached to the lathe-bed or bench, or fixed in the vise, so that the ferrule _k_ can move backwards or forwards without altering the tension of the cord, in the manner indicated at Y.

=404.= =Wheel-cutting Arbor-chucks.= These appliances are specially useful in making wheels that are required to be rigorously true, such, for example, as escape wheels. The form is represented in Fig. 196.

It is simply the arbor of an ordinary lathe, formed in two pieces, _b a_ and _b c_, the body _b d_ being very accurately fitted into the conical hole in the plate of the wheel-cutting engine. If now a wheel is fixed with wax on the extremity _z_ and turned in the lathe to the required form, it is only necessary to unscrew _b c_ and introduce _b d_ into the socket of the wheel-cutting engine; then

having cut the teeth, the piece _b c_ is replaced, and the whole is set in the lathe, if required to test its truth, without the wheel having been displaced from the chuck.

[Illustration: _Fig. 196._]

It will, of course, be evident that the two parts must be accurately fitted together; the tapped hole and the screw must be true with the axis. M. Millot, with whom we have seen this form of arbor in use, has not been able to detect any eccentricity, although he often employs them.

=405.= They might be formed in one piece, as _a d b_, with a point at _p_. A boxwood ferrule is then fitted onto the portion _b d_, where it is clamped by two screws, and these can be released when it is desired to insert the chuck into the wheel-cutting engine. The points of these screws should be received in recesses in order to avoid the production of any roughness on the surface of _b d_.

Wheel-cutting engines have been made to receive these arbor-chucks without removing the pulley. The point _c_ is placed in a hole and the upper end is enclosed in a collar, which is tightened by means of a screw.

The arbor used by M. Millot had a lantern chuck, and this is very convenient in making objects that require to be measured during the progress of the work.

=406.= =Modification of the Ordinary Arrangement for Holding the Wheel While Cutting.= In the wheel-cutting engine as usually met with, the wheel (when not mounted on an axis) is held against the chuck by a hollow steel cone, on which presses an arm that slides on a vertical pillar and can be clamped in any position. The hole at the end of this arm does not always, therefore, correspond with the point of the cone, and, as a consequence, the wheel often gets displaced during cutting. This inconvenience can be avoided by adopting the following device, which we have seen in use with several watchmakers.

[Illustration: _Fig. 197._]

The pillar with its sliding arm is replaced by an iron or steel piece of the form G, Fig. 197. The point _a_ is received by the central hole at the lower end of the division-plate axis, while the screw _b_ presses on the point of the cone, clamping it firmly. Further explanation seems unnecessary; we would only add that the piece G must be made strong and perfectly rigid.

CUTTERS FOR FORMING THE TEETH OF BRASS WHEELS.

=407.= For making the teeth of the wheels of a train, a special form of cutter, set to revolve on an axis, is employed, and it may be constructed on either of three distinct systems.

[Illustration: _Fig. 198._]

[Illustration: _Fig. 199._]

(1) A single cutter mounted on an arbor, as at A, B, Figs. 198 and 199; this may be termed a _single cutter_.

(2) A circular cutter, formed of a series of such single cutters, which will be termed a _multiple blade_ or _composite cutter_. Two specimens are shown at F, J, Fig. 200.

[Illustration: _Fig. 200._]

(3) The pinion, or steel wheel cutter or mill, formed of a single piece of metal, as seen in Figs. 201, 202 and 203. These may be described as _mill_ or _file cutters_.

=408.= =To Make a Single Cutter.= The form shown at A, Fig. 198, is roughed out to as nearly as possible the required form in good steel. Some makers, possessed of exceptional skill, make them entirely by hand, and they make very beautiful teeth by this means; but as a rule watchmakers cannot look for such success, so that it is better to complete the formation of the cutter in a specially arranged tool.

[Illustration: _Fig. 201._]

[Illustration: _Fig. 202._]

The two sides may be made in the wheel-cutting engine, with the same mill cutter, which is inclined when used to undercut the acting edge; but this operation is not as easy as it appears at first sight, and the watchmaker will find it to his advantage to make the following device:

[Illustration: _Fig. 203._]

A spindle, _b d_, Fig. 204, supported between the runners, _t_, _v_, serves as an axis for the arm _f g h_, which is bent at _g_ so as to afford a support to a conical cutter _a_, driven on the ferrule _c_. The descent of this arm is limited by an adjustable stop, fixed to the bed of the turns.

Having removed the T-rest, replace it by the rod N, to which the cutter is clamped by a screw _k_, after being roughed out so as to reduce the work required of the cutter.

Place N so that the conical cutter occupies the position indicated at _z_, and, if a slight pressure be applied at _h_ while _a_ is caused to revolve, both the straight and curved portion of the side will be formed, and the side will, at the same time, be bevelled to an angle corresponding with that of the cone. The curved portion of the side will be more or less undercut, according as the arm _h_ is depressed below the horizontal plane passing through the axis of the lathe. The opposite side is formed by inverting the piece _f g h_.

[Illustration: _Fig. 204._]

In smoothing or polishing it is only requisite to replace the cutter by a smooth conical roller, and to work as before.

=409.= The cutter is sometimes fixed in the arbor as shown in Fig. 198. The arbor itself is thick and perforated with a round hole in which the tail of the cutter accurately fits, a slight pressure applied by the screw _m_ being sufficient to make it steady.

For cutting the escape-wheels of clocks the arbor should have a velocity of about 200 turns a second.

M. Peupin, a skilful watchmaker who adopts the practice here given, having observed that with a sharp cutting edge he did not obtain a sufficiently smooth surface, succeeded in obviating the difficulty by drawing a polisher with rouge along the cutting edge, maintaining it at right angles to the plane of the cutter. This operation, if carefully executed, will serve to remove the feather-edge, to make the edge even and yet not dull, and to secure a highly polished cut surface. The sides of the teeth will present a proportionately better surface, according as the portion _c a_ (M, Fig. 198,) approximates towards the dotted line _c d_.

His escape-wheel teeth are cut in successive stages. The last stroke of the cutter is given by advancing it against the side of the wheel, so that the cutter axis remains in the plane of the wheel.

=410.= =Triangular Cutters.= When a cylindrical or conical mill is not available for finishing and sloping the sides of a cutter, it may be replaced by a triangular cutter (T or C, Fig. 205,) and when the application of much force is required there may be a pointed bearing; but this is seldom necessary.

[Illustration: _Fig. 205._]

If carefully hardened and set, such a cutter gives a clean cut; of course it will not act for as long a period as the conical form above described, but this is of comparatively little importance, since the blank cutters are always roughed out previously to nearly the requisite shape.

=411.= =To Make Several Cutters at Once.= By adopting the following method, it is possible to make several such cutters in one operation.

Turn a steel disc of the form of an ordinary mill cutter, as shown at _l p_, Fig. 200. To finish it, giving the same curvature to the two sides, take a piece of steel, C, and shape the corner _r_ to exactly correspond with the side of the point or ogive of a tooth, bevelling it so as to give a cutting edge at the upper surface; then harden and smooth it with care. Having fixed it in position in the tool that carries the arbor _a_ and the roughed out disc (whether this be the lathe, wheel or pinion-cutting engine, or a special device) in the required position, one side of the disc may be finished. The arbor _a_ is then reversed and the other side finished in the same manner, so that both sides have the same curvature in opposite directions.

Of course the tool C may be advanced against _l p_, either sideways from _r_ towards _l_, or radially in the direction _l p_, as is most convenient. Or the tool might remain fixed and the disc advance against it radially or laterally.

The traverse slide in a lathe is usually provided with a stop; it would then be very easy to form one side of the disc in such a tool, afterwards reversing the arbor and forming the other side.

If a very good cutting edge is desired, the sides should be smoothed and, when the disc is completed, it may be divided into pieces similar to B, Fig. 199, each of which will serve as a cutter. It will be noticed that the acting edge is not undercut behind; it is thus necessary to slope the cutter a little as shown at B, as otherwise the rim will choke in the spaces of the wheel, straining it without cutting.

=412.= =Composite Cutter Formed of a Succession Of Single Cutters.= By mounting a series of identical single cutters round the circumference of a disc, a circular cutter can be formed in the manner indicated in Fig. 206. The upper portion represents the arrangement of the pieces while they are being turned, and the lower portion shows their positions when the cutter is ready to be used. M. A. Croutte, to whom we are indebted for several of the details here given, was much surprised that this form of cutter is not better known, since it possesses certain special advantages; we will summarize his remarks on the subject.

[Illustration: _Fig. 206._]

The separate cutters _b_, _g_, etc., Fig. 206, are not undercut from the acting edge backward; they are merely reversed, so that this acting edge is towards the front, in other words it lies along the radius. These separate pieces possess a special advantage in that they can be used until the steel is quite worn out by the setting; in this respect differing from the undercut cutters, for they are not altered either in form or thickness by setting.

As a set-off against this important advantage, they are characterized by the inconvenience of requiring that the two sides of the blade be exactly in a plane at right angles to the axis, and that the slide carrying the cutter-arbor shall move in a direction parallel to this plane. And even when this double condition is satisfied, there will be friction of the two sides above the dotted line _i j_, Fig. 199, against the sides of the teeth; and if the above named conditions are not satisfied, the cutter, being presented edgeways, will be choked with brass, and the results will be unsatisfactory.

=413.= In order to ascertain whether such a fault exists, it is only necessary to notice whether the cutter becomes brass-colored on one side towards the point, and on the other more inwards, and the sides of the teeth exhibit striæ or scores in opposite directions, as indicated at E, Fig. 207. The white strip, 1, 1, corresponds to the bottom of a space between two teeth; 2, 2, and 3, 3, the two sides of this space, spread out like an open book.

[Illustration: _Fig. 207._]

By examining the marks with care, and noticing the direction in which they are inclined, it will be possible to ascertain both whether the separate cutters are out of place, and in which direction the arbor should be moved in order to correct any error.

We must, then, repeat that all the cutters must satisfy this condition, because if only one is wrong it will produce the scores here referred to.

The necessity of these precautions in the use of such a composite cutter, and the fact that the friction of the portion above the line _i j_, Fig. 199, renders it difficult to obtain a polished cut (which is essential for such delicate depths as those of watches), have doubtless prevented its use becoming general. For work that is somewhat larger or rough, it will be found to give satisfactory results and will last longer than a single cutter. A lubricant, such as glycerine or oil, should be applied to it.

=414.= =Composite Cutters with the Cutting Edges Undercut.= An old Paris clockmaker, Brisson, used a cutter of the form F, Fig. 200, for the teeth of his wheels. He undercut the two sides of the blades by means of a small special tool. Strictly speaking, the operation can be performed by hand.

In order to ensure that the curves that form the ogives of teeth are alike on the two sides of a cutter, he made a series of templates or standards of the form C, Fig. 206, in which were two holes, C and _c_, of equal diameter. The upper one, which might be funnel-shaped so as to give a cutting edge, was half cut away, and, after being hardened and set, could be used to give a final stroke to the circumference of two discs of equal diameter. These two discs, or one cut through a diameter would suffice, having been brought by a file to the form H, and joined as shown at _r s_, can be mounted eccentrically so as to present a cutting edge to

the roughed out cutter A; the two sides can thus be made even. The disc may then be finished by cutting away the metal so as to give the form shown at F, Fig. 200.

By the aid of the standards he could easily reproduce the same forms of teeth when required.

Fig. 200 comprises, at J, a cutter for the teeth of watch wheels of the form employed successfully by M. A. Phillippe. The figure will explain itself.

We have known a Geneva wheel cutter who employed these composite cutters with advantage in making duplex wheels. The principal difficulty he experienced arose from the distortion of the metal in hardening, because the acting portion naturally lengthened a little. This form of composite cutter certainly demands careful workmanship, but, if the construction, hardening and polishing are good, it will produce fine work and will last a long time.

=415.= =General Observations on Cutting the Teeth of Brass Wheels with a Single or Compound Cutter.= High-class English watches, the movements for which are made at Prescot, in Lancashire, have the wheel teeth made by a composite cutter after the wheels are riveted to their pinions. We have remarked that these watches make less noise when running down than those in which the teeth have been formed with a mill or continuous action cutter.

Success in forming teeth with cutters depends mainly on the securing of a good form as regards the cutting edge, and on its being maintained in good condition; on the steadiness of the entire machine, so as to avoid vibration; on the weight of the wheel, and on the velocity of the cutter being sufficient. A cutter ought never to assume a brassy color except when it requires setting; if it does so, and this is not the case, it proves that the metal is being strained or scraped with friction. The velocity must be very considerable; greater with a single cutter than with one that is composite. The velocity is limited by that point at which the heat generated would cause the oil to evaporate, soften the cutter, distort, and sometimes even displace, the wheel operated on. The engagement of the cutter with the metal must be very slight, and should never be increased suddenly.

Attempts have been made to enclose the arbor bearings in horn, but it is liable to be distorted by the heat.

Before dividing the disc into cutters it is essential that the two edges be carefully smoothed, and this without their being distorted. This can easily be done in an old depthing tool, using an arrangement like that shown in Fig. 208. The lap must be of hard wood, and its right-hand corner rounded off so as to resemble the side of a tooth; it is set to engage with one side of the cutter. We say the right-hand corner, because a lateral pressure can then be applied. It is important that the surface as left by the graver be clean cut, because if the smoothing is too much prolonged, it will deform the cutter.

[Illustration: _Fig. 208._]

=416.= In some factories it is usual to use discs about 2½ inches in diameter, for cutting the teeth of brass wheels in timepieces. The single cutters are arranged round the circumference as follows: One forms a space between two teeth; the one immediately preceding forms the right-hand side of the ogive, and that which follows forms the left-hand side. By adopting such an arrangement of separate cutters, if their side that lies against the disc is slightly inclined backwards it is no longer necessary to bevel off the cutting edge.

MILL CUTTERS FOR STEEL.

=417.= =Pinions, Keyless Wheels, Etc.= The cutters that last for the longest period when used for cutting steel are those formed like a file; but a watchmaker is not always in a position to make them himself; we will, therefore, here only speak of those he can make, the description of the first few being taken from a work by M. A. Phillippe, of Geneva, _Les montres sans clefs_ (keyless watches).

=418.= =Cutter for Forming the Inclined Teeth of Winding Pinions.= Fig. 201 shows at S a section along the axis of such a cutter, and at P a side view. When it is believed to be of the required form, rest a piece of lead on the T-rest of the lathe and press it against the rotating disc. The impression made in the lead will afford a means of ascertaining both whether the form is correct, and whether the surfaces are smooth enough. This last point is important.

The cutting edges are formed by merely making a number of notches around the circumference with a tool for cutting ratchet teeth. Then advance this ratchet cutter so that it may engage with the convex edge of the cutter operated upon, and against the back of

the teeth of this cutter; the ratchet cutter is then in a position to form a second face, _o i_, by which the teeth of the cutter are undercut at the back, but in such a manner that a small flat surface _o a_ is left in order to retain the form. When a cutter made in this way will no longer bite, it may be set by passing a hard slip of whetstone over the faces of the teeth.

The ratchet cutter employed for making this cutter should never be pressed against it heavily.

=419.= =Cutter for Ordinary Wheel Teeth.= We will now pass to the consideration of cutters for forming teeth of the usual shape, of intermediate steel wheels, set-hands wheels, pinions, etc. They may be made as follows:

The rim is indented with small fine ratchet teeth, _b d_, Fig. 202. Any burr produced on the sides is then carefully removed, and the cutter is placed in the wheel-cutting engine, and notches, _c_, _c′_, _c″_, _c‴_, etc., are formed on either side with a flat square-edged cutter of such a thickness that the circumference is about equally divided into hollows and prominences. It is important to note that the right side of the teeth must be but slightly roughed, not more than is required in order to raise a slight burr, all that is necessary to form the cutting edge of this portion of the disc. In roughing these sides, at least one out of every two of the small ratchet teeth on the circumference should be left untouched, so as to ensure the required thickness being maintained.

The cutter shown in section and elevation at S and P, Fig. 201, might be cut on the side _n_ in the manner here explained, and the convex portion _k_ might be indented with a fine ratchet-toothed cutter, carried in the hinged cutter-frame of the wheel-cutting engine. The degree of penetration may be determined by fixing an ivory disc against the cutter and concentric with it, the two differing in diameter by the depth the cuts are to be made. The teeth will be rather too square towards the circumference, but their form can be carefully corrected by hand. It is obvious that the very greatest caution is necessary in hardening cutters.

=420.= =Rose-Cutters or Forming Pinion Cutters.= As the edges of pinion cutters are rounded, they can be made in the manner suggested by Thevenin. Supporting the roughed out cutter in the cutter-frame of a wheel-cutting engine, he fitted in the axis of the division-plate a kind of rose-cutter, N, Fig. 205. Its extremity, _n_, instead of being flat, is hollowed out as indicated by the dotted line, and, by presenting the cutting edge thus obtained endwise to the grooved edge of the cutter, the correct form can be given to it. With a mushroom-headed piece of steel and oilstone dust, the cutting edge of the rose-cutter can be made more or less acute by modifying the angle of this steel lap.

=421.= =Other Forms of Pinion Cutter.= When a cutter is merely required for a special piece of work, and not for continuous use, it will often be sufficient to make it as shown at A, Fig. 203; this is made by grooving the disc (_c_), or forming its edges as at _d_, after which a series of teeth are cut on the periphery with a revolving cutter, taking care to leave no more burr on one side than on the other. Then pass a smooth worn file (or a worn flat cutter) over the faces of the teeth, applying oil at the same time, so as to produce a slight burr on the edges; if the file is not allowed to bite too much and is well managed, these minute ridges will be uniform. After hardening, the cutter is ready for use.

If the faces were smoothed without subsequently applying the file, the cutter would not bite; for its action depends on the slight projection of metal that corresponds to the file-cuts. The cutter is nothing more than a circular file, with two cuts per tooth. If the corners are turned over evenly by means of a very hard burnisher the same effect will be produced; but this operation is delicate, as the amount of metal turned over must be the same in every case.

When a cutter does not bite, it must be softened and restored to its initial condition.

=422.= Or the following method may be adopted when it is required to make a cutter for a special purpose.

Proceed at first in the manner just described, but the periphery is divided into a greater number of teeth with a flat cutter, and to a rather greater depth, as at E, Fig. 203. Bend backward each tooth to a distance equal to about half a space by any convenient method; for example, by a lever resting at the bottom of each space and pressing against the corner of the tooth, etc. Before bending the first tooth introduce a piece of brass into the space behind it, of a thickness equal to about half this space, so as to avoid bending too far; for succeeding teeth the thickness must be about equal to a space; thus E will become E′. An inspection of Fig. 203 will suffice to make the operation evident; it amounts to bending back a series of separate cutters. The disc is then hardened, and the faces of the teeth are smoothed when they do not cut well; or merely smooth those that are the first to become dull.

It is important to employ soft steel that has previously been well annealed.

=423.= =Cutter for Making Square Spaces.= The teeth of such a cutter can be easily formed with a file, as shown at L, Fig. 209, the edge of the cutter, _f_, being passed backwards and forwards in the direction of the arrows, applying considerable pressure and at the same time slowly rolling _f_ around. Or the cutter may be set up on a short arbor between the centers of the lathe; then pass the file backwards and forwards across the edge until the cuts are formed, slowly advancing the file in the meanwhile, so as to form the cuts around the circumference without once raising the file. The cutter must then, of course, be hardened.

[Illustration: _Fig. 209._]

=424.= =Forming Cutters with a Milling Tool.= The roughing of a round-edged, or even of a square cutter, can also be effected with the aid of a milling or "nurling" tool, proceeding in the same manner as when milling the heads of screws, etc. The tool must be in good condition, well provided with oil, and applied with considerable pressure against very soft steel.

If necessary, the workman can make the mill for himself; it is shown at M, Fig. 210. F shows the method of applying it to the cutter, and by partly turning the mill (of course carried in a strong holder) around its point of contact with the cutter, as indicated by the dotted lines, the rim of F will be evenly roughed all around.

[Illustration: _Fig. 210._]

With good steel fairly satisfactory results are obtained in this manner, but it is needless to observe that such cutters never bite as well as those made in the usual manner.

=425.= =General Observations.= When cutters are used with steel they must be driven at a less velocity than when cutting brass, and, as M. A. Phillippe has observed, it is best to make the cutters for steel of small diameter (about half an inch). They are more easily made and are less distorted in the hardening. The velocity should diminish as the diameter increases; for too great a velocity, especially when the diameter is great, will dull the cutter and soften it, owing to the heat produced.

Cutters must be turned very true: it is advisable to give them a last stroke with the graver after they are fitted to the cutter-arbor that will subsequently carry them.

When operating on steel it is best that the cutter frame of the wheel-cutting engine be advanced by a screw so as to give it a slow and easy motion; the results obtained are more satisfactory than when it is advanced by hand or with a lever.

The following practice is not uncommon in factories when it is desired to reproduce the exact form of a cutter. A notch is made with the cutter in the edge of a piece of steel, X, Fig. 211, or a series of notches _o o′_, etc., can be made by several cutters in the circumference of a disc Z (same figure). After being hardened and sharpened at the cutting edge, this disc is fixed at the center of the division-plate of a wheel-cutting engine, and can then be used to complete the grooving of any cutter that is set in position on the cutter-arbor before hardening. The positions opposite to which the notches were cut should be marked on the chuck, so that they may always be set-square to the cutter.

[Illustration: _Fig. 211._]

=426.= Besides the forms of cutter above described for operating on steel, we may mention that circular cutters may be used in which all the notches around the circumference have been polished, thus removing the burr, and preventing them from acting in the manner of a file. But while, with the former kind, a somewhat rapid rotation is necessary (although not so rapid as when cutting brass), with this latter class the movement must be comparatively slow, and produced by means of a hand-wheel; otherwise they will not cut, since the action depends rather on the application of pressure, and resembles that of a slide-rest cutter. The distance apart and width of the teeth of the cutter, as well as their inclination, are of importance; if too far apart they occasion a waste of time; if too large the machine will act in a jerky manner, and when too narrow, an excessive pressure will be needed in order to make the cutter bite the steel, which, it is to be observed, must always be thoroughly annealed. The edge must be well supplied with oil or soapy water when in action.

It is generally found best to advance the cutter against the edge of the steel rather than across it.

TOOL FOR MAKING CUTTERS.

[Illustration: _Fig. 212._]

=427.= The instruments usually employed for making cutters for the teeth of wheels and pinions are complicated and expensive, but the author has designed one for his own use that is comparatively simple, and can be made by any watchmaker. When the reader has grasped the principle on which it acts he will be able, without difficulty, to modify it so as to suit his requirements.

[Illustration: _Fig. 213._]

The frame B B _b_, Figs. 212 and 213, consists of the body of the tool, B B, and a bar _b b_, which is attached to it by screws. Between the two the division-plate P rotates on an axis E R. The end E of this axis is formed as a chuck to receive the cutter _f_, which is clamped by a screw _t_.

The support S _s_ J is held with friction in the lower part of this frame, to carry the cutter-holder A L M. This cutter-holder is hinged at _n_, so that it can receive a double motion, revolving about a horizontal axis J, and about an inclined axis _n_.

The portion A L of the cutter-holder carries a perforated arbor _a c_, with a ferrule _c_ that receives the tail of the small rose-cutter, which will presently be described.

The end M rests against a guide G, held by a vane _o z_, which is pivoted on a pillar _z_, and can be clamped in either of the directions _z y_, _z x_, or by one of the screws _o_, _o_.

=428.= We will now consider the mode of action of the machine. Having set the little arbor _c a_ in rotation, rest the end M of the arm against the guide, and gradually advance the rose-cutter towards _f_; the edge of _d_ will form the first notch in the grooved rim of the cutter, and then will be raised from contact with it, owing to the influence of the guide G. After moving the tool-holder back to its initial position, advance the wheel P by a tooth, repeat the operation, and so on.

=429.= If the cutter _f_ has to be notched on both sides, it must be reversed on the chuck; turn the guide so as to point in the direction _z x_, corresponding exactly to _z y_; then having set the cutter-holder in the line _z h_, recommence operations. The two grooves of the cutter will then necessarily be of similar form.

Teeth can be cut on the rim of _f_ by using a cutter of the form F, Fig. 214, and holding M against a straight vertical guide.

With a given divided wheel, P, the teeth can be brought nearer together by reducing the diameter of the cutter, and _vice versa_. It is well to have some change wheels, but a better plan is to advance the division plate by the aid of a tangent screw.

[Illustration: _Fig. 214._]

=430.= =To Make the Several Accessories.= _Form of the rose or star-cutter._ The rose-cutter is formed of a mushroom-headed piece of steel. Such a conical cutter is shown at C and R, Fig. 215, and at F, Fig. 214. F and C are cut in the same way that conical cutters are always made, and R is a small triangular prism that only cuts by its three corners, _a_, _a_, _a_. As it is necessarily very small when employed in making the cutters for watch pinions, it must, in such a case, be supported at the neck by a little fork. Moreover, it must be brought gradually against the steel to be operated upon, so as only to engage a very little at a time. With a view to this, it is advisable that the cutter-holder be advanced by a screw.

[Illustration: _Fig. 215._]

The star-cutter, shown at E, Fig. 216, is at times substituted for the rose-cutter. It cuts with the corners _e_, _e_, etc., whether it be going to the right or left indifferently. Or a triangular cutter like T, Fig. 216, can be used in its place; but its angles are fewer and less acute, so that they become dull more rapidly.

A few trials will be needed in order to determine the most convenient rate of movement of the several parts; and the edge of the cutter _f_ must always be liberally supplied with oil. A little can may be so arranged as to allow oil to fall drop by drop on to the cutter _d_, Fig. 213.

[Illustration: _Fig. 216._]

=431.= _To make the guide._ Having mounted a plate, G, on the vane _o z_, trace out the approximate form of the cutter with the point of M; then cut off the superfluous metal, leaving a slight margin. This excess is necessary because the curvature of the guide is not the same as that of the cutter, for the indentations as they spread out from the center (_t_) become gradually deeper. The guide should be tested from time to time by operating on a blank brass disc fixed in place of the cutter _f_ and the guide must be

modified as experience shows to be requisite. Its edge must be saddle-shaped so that the middle may correspond exactly with the two dotted lines _z x_, _z y_, Fig. 213.

The position of the disc on the chuck _t_ must be brought to correspond with the guide by carefully turned washers placed behind it.

=432.= _Driving attachment._ Fig. 217 shows one system that may be adopted for connecting the ferrule C with a driving wheel. All that is required is that the instrument be set in such a position that this ferrule is placed as indicated in the figure with reference to the distributor.

[Illustration: _Fig. 217._]

=433.= _Cutters of uneven thickness at the circumference._ It is well-known that the edges of the cutters of rounding-up tools (=435=) are made to taper off around the periphery. In order to indent such a cutter, the guide must be mounted on a slide, so that it may be gradually displaced while the operation is in progress, by an amount previously determined upon.

The desired result can be obtained with sufficient accuracy by moving the guide backwards by successive stages with a screw. The end _k_ of the arm M, Fig. 213, is slightly tapered, so that a gradual depression of M occurs, and each cut is deeper than that which preceded it.

[Illustration: _Fig. 218._]

=434.= _Modification in the construction._ This instrument may be modified as follows: The disc to be operated upon is fitted to the chuck of the division-plate D, Fig. 218, which is vertical, and the entire system is capable of a movement of rotation round the axis of the base P. Having set the disc in the plane _a b_, as shown in the figure, clamp P; then, by traversing the cutter-holder, the teeth on the side of the cutter towards _a b_ are made. This cutter frame having now been removed, the base P is turned until the cutter is in the plane _c n_, such that it is equally inclined on the opposite side of the axis of the cutter frame; the teeth on that side may then be made, the star-cutter being rotated in an opposite direction.

It is unnecessary to prolong our explanations of the instrument, as the details already given will suffice for any intelligent workman.

TOOLS FOR CORRECTING THE FORM OF TEETH.

=435.= =Rounding-up Tools.= In Europe it is the practice, in making watch wheels, to first notch the circumference by means of a flat circular cutter in a wheel cutting engine, thus forming a number of square teeth. They are subsequently rounded off to the usual form, after the wheels are riveted to their pinions, in a special tool.

The apparatus employed for this purpose is termed a rounding up tool, and its principal feature is a mill cutter F, Fig. 219, the portion _a b_ of whose circumference is cut away and replaced by a guide _g f_ made of steel spring, and so fixed as to coincide with the edge of the cutter at _f_, and incline at _g_ in order to compel the cutter to pass, at each rotation, into consecutive spaces of the wheel. Two screws are provided, the one _f_ for setting the guide opposite the edge of the cutter, and _g_ for placing the free end of the guide opposite to a space.

This tool acts with great rapidity, a fact which has led to its being very extensively used in the factories of France and Switzerland, although the ordinary system of wheel cutting is preferred in England for all the better class of work. For it should be noted that the rounding up tool does not correct any errors that are due to bad dividing; for example, if a wheel is found to have some of its teeth larger than others, the tool can not be relied upon to correct them; on the other hand, if a wheel is exactly divided it is improbable that the employment of this tool will occasion irregularity.

[Illustration: _Fig. 219._]

The instrument we are discussing is, however, not much used by watch repairers, although they are frequently called upon to touch up the teeth of wheels, or to slightly reduce the diameters of their pitch circles, operations which cannot be done by hand with much chance of success. The limited use to which rounding-up tools have been put is owing, in great part, to their high price, but cheaper tools on this principle are now coming into use.

=436.= One of these is shown in Fig. 220. The wheel to be operated upon is held against a small table at D between two vertical runners with guard-pivot centers, and a cutter of the form shown at Fig. 219, is fixed at C to a suitable chuck of a small lathe-head B; this is caused to revolve by the hand-wheel A, a supplementary pulley K taking all strain off the axis. The three milled-headed nuts seen at E, F, and G are for adjusting the instrument; E for moving the lathe-head, so that the cutter is in the same plane as the axis of the runners, a position which is determined by the pointer I; F for advancing the wheel against this cutter; and G for setting the plane of the wheel to pass through the axis of the lathe-head as indicated by the index H. The instrument is accompanied by a number of cutters to suit the various sizes of teeth ordinarily met with, as well as of tables to support wheels of different dimensions.

[Illustration: _Fig. 220._]

=437.= =Ingold Fraise or Cutter.= =Rounding-up Cones.= Either the cutters devised by M. Ingold, or the rounding-up cones of M. Berlioz, may be used for correcting the form of wheel teeth.

The Ingold fraise is a small steel cylinder perforated through the axis so as to be mounted on an arbor, and having a number of longitudinal notches on its circumference which makes it resemble a pinion, the points of whose leaves have been ground off. The spaces of the fraise are of the exact form required to be given to the teeth of the wheel, and their surfaces are covered with fine file cuts so as to enable them to remove metal from the wheel operated on.

Having mounted the arbor that carries it between two centers of a depthing tool (made especially strong for the purpose), the wheel is supported by its axis between the second pair of centers (with guard-pivot points). If now the fraise be advanced by the screw until its teeth engage with those of the wheel, and either be caused to rotate, it will drive the other, and the fraise will thus shape the teeth to a pre-determined form, the faces of each notch acting the part of a minute file introduced between the teeth.

It will be observed that such an instrument is preferable to the ordinary rounding-up tool, in that it may be relied upon to bring all the teeth to the same shape, but, on the other hand, the latter tool has an advantage in being available for slightly reducing the diameter of a wheel when a depth is found to be too strong.

=438.= An objection has been urged against the Ingold fraises on the ground of expense, as each dimension of tooth evidently requires a cylinder specially adapted to it. This fact has led to the introduction of “rounding-up cones” the invention of M. Berlioz, which act on precisely the same principle, but are conical instead of cylindrical, so that each fraise evidently takes the place of a number of Ingold fraises. The total number being proportionately reduced. But great dexterity is required in their use, so that they cannot be successfully employed until after numerous trials.

=439.= =Exact Rounding-up Tool.= The author has devised an instrument for giving to the teeth of wheels the exact form determined upon by theory, but as it is of too elaborate a nature to come into general use, we shall not do more than here refer to it. It is rather of a nature to be used for scientific work, but might be found of considerable value for accurately forming the blades of cutters that are used in grooving the circular cutters employed for cutting the teeth of wheels.

=440.= =To Round Up Teeth By Hand.= We have seen a country watchmaker proceed somewhat as follows: His method was only effective, however, for ensuring the verticality of the file, and did not maintain it straight, nor could the curvature of all the teeth be relied upon to be the same; these two conditions are satisfied by the system here explained.

Formerly watchmakers possessed very considerable skill in this kind of work, as the teeth were always formed by hand; but at the present day, for want of practice, there is not one to be found in a hundred competent to round up a wheel properly by hand alone. Recourse may be had to the following expedient in an emergency; it necessitates the construction of a small special tool, but this is so simple that it can be made in a few hours by an apprentice.

=441.= Take a bar of metal or hard wood, made smooth on its faces and square at the corners (R, Fig. 221), and adapt to it a slide, _c c_, through the center of which a slot is cut to receive a clamping screw; it slides between the four pins indicated in the figure. An arbor _a_ is supported by _c c_, parallel to R, having a plate at its end on which a wheel to be operated on can be fixed by three screws and a loose plate. It is centered by the circumference before clamping these screws, rotating _a_ with a bow, and it may be well to place a piece of tissue paper under and over the wheel in order to avoid scratches. V is a tongue that can be introduced into the space between two teeth in order to prevent the wheel from moving.

[Illustration: _Fig. 221._]

Two arms, _p p_, screwed to the bar R R, support the handle of the rounding-up file _l_, which consists of a large cylinder _t_, _t_, that slides in the arms _p_, _p_. The cylinder T must be exactly parallel to the arbor _a_, and the longer it is the better. The file-holder _s_, also shown detached at Y, Fig. 222, is merely driven onto the rod _t_. The distance between the center of the axis _t_ and the face of the file (_b b′_, Fig. 222) is equal to the radius of the circle that embraces the external curves of two or more teeth, as will be explained.

[Illustration: _Fig. 222._]

The several parts being arranged as shown in Fig. 221, and the bar clamped in a vise at E, it will be obvious that, if the wheel is held in two fingers of the left-hand so as to prevent it from being displaced, while the rod T is moved up and down, at the same time rotating it with the right-hand, the curves of two teeth will be adjusted to correspond with the arc _o o o_ (Z, Fig. 223), and, by transferring the tongue V to the next succeeding space, the curve _i i i_ can be struck.

[Illustration: _Fig. 223._]

=442.= _Observations._ The curvature of the point of a tooth coincides very closely with a circular arc described from a certain definite center, and comprising either two or three teeth. In order to realize these conditions in practice, the slide _c c_ is so adjusted that the axis of T passes just within the circle that passes through _o_, _o_, _o_, etc. (Z, Fig. 223), at which the points of the teeth commence; by making trials with two or three file-holders that differ in regard to the distance _b b′_ (Y, Fig. 223), it will be easy to select the most suitable for producing the required curve. After operating on all the teeth in succession, advance the wheel by means of the screw D, and again work around the circumference, and so on. The progress of the work should be frequently examined with the glass.

It is possible to dispense with the tongue V, and to merely steady the wheel by hand; the work is thus done more rapidly, but must be examined with very great care.

We would insist that the lengths of the two axes are an element of success. In operating on watch wheels T should not be less than six inches long.

By suppressing the tongue the motion of the two axes may be co-ordinated so as to form any theoretical curve; This is the case in the exact rounding-up tool already referred to, but it of course renders the instrument more complicated.

=443.= =To Ease a Train of Wheels.= In very many of the cheaper watches and timepieces now met with in commerce the teeth are rough and badly cut, and the pinions but little polished, so that watchmakers are constantly complaining of the difficulty of securing even a moderately good depth. In such cases they have a simple method to adopt in addition to those already referred to, namely, to polish the teeth with a piece of charcoal.

A piece of smooth, even charcoal, with regular fibre, is moistened with oil or water, and passed across the teeth individually; first with the fibres lying in the direction of motion, and afterwards with them at right angles to that direction.

If the charcoal is carefully selected and lightly applied for a sufficient length of time and no more, the ogives will be found to be nicely smoothed, and the depth will run far more easily than it did previously. It is dangerous to use quick-cutting charcoal, as it is apt to deform the teeth.

Smoothing with a brush charged with charcoal powder cannot be regarded as anything more than cleaning; if the action is too much prolonged the form of the teeth will be spoilt.

TO TEST THE ACCURACY OF CERTAIN TOOLS.

=444.= =Drilling Tool.= First center the runner in the lathe, and ascertain that it is straight, cylindrical, and exactly centered; then fit a ring to it so as to slide with friction to (temporarily) limit the descent of this runner in the vertical stock of the tool.

After placing it in position, adapt to its lower end a collar, provided with a long index of soft brass, which is bent so as almost to touch the plate at its circumference. Rotate the runner and it will be shown to be perpendicular to the plate if the point of the index remains at the same distance from the plate.

As a confirmatory test the runner may be drawn up in the stock, and the trial repeated after bending the index nearly to touch the plate.

=445.= =Uprighting Tool.= If the two stocks or tubes that receive the runners are exactly in line, a runner should move easily through the two at once.

Setting the points in contact in various positions in a vertical line, observe whether they coincide, both when at rest and when rotated together or independently.

First ascertain that the table is at right angles to the axis in the manner already explained for the drilling tool, making the necessary tests with the two runners independently. Then support between their points a short arbor carrying a soft brass index. The position of the lower runner being maintained constant by means of a collar as above explained, rotate the upper one by hand; its friction will carry the index and arbor around, the point of this latter being set close to the plate. Repeat the operation by raising the pair of runners and bending the index down to the same amount.

If in these various positions the point remains at the same distance from the table, it affords evidence that the tool is accurate.

An uprighting tool consists of two parts: the table carrying the lower stock, and the bridge that forms the upper stock. The base of this latter is a ring turned flat and co-axial with the stock, and is fitted accurately into a square groove surrounding the table, where it is fixed by screws.

Any watchmaker understanding this mode of construction will easily perceive when he has tested the tool in the manner above indicated, both what are its faults and how far he can correct them.

=446.= The English uprighting and drilling tools, and some of foreign construction, are combined on the same stand, and a good arrangement, made by Boley, is shown in Fig. 224. It will be seen that the drill can be set in motion by a hand or foot-wheel; the table is fixed in a vise and provided with two dogs for clamping the object. The drilling spindle is perforated throughout its length so that the drill can be held by an American split chuck.

[Illustration: _Fig. 224._]

=447.= =Depthing Tool.= As the value of a depth depends essentially on the overlapping of the teeth being the exact amount required by theory, it is specially important that the tool used for determining the distance between the centers of the wheels and pinions should be of the utmost attainable accuracy.

First ascertain that the spindle which serves as an axis for the two halves of the tool does not change position when they have been several times separated and brought together. For, if this were to happen, and a runner were uneven or the hinge not smoothed within, the parallelism of the two pairs of runners would be impaired.

The runners must be of equal thickness throughout, and should pass with ease from one head to that opposite. Their points and center holes must be seen to be in good condition, and, on placing them in their turns, they must be found to be both true and cylindrical. Having restored them to their places with the points together, move the pair lengthwise from one head to the other, examining the points in successive positions to ascertain that they coincide accurately, both when the runners are loose and when clamped. When the adjustment has been carelessly done the runners will be found to bend under pressure, causing the points to be displaced.

Having set two runners side by side and level, describe with them circular arcs on a smooth piece of brass from centers previously marked, first with the points just projecting from the heads and then projecting more and more. These tests may be made both within and without the tool; so that there will be four sets of tests in all.

It is very important in making the last-named trials, that the tool be maintained at right angles to the plate on which the circular arcs are traced; this condition can easily be satisfied by a special device, or by merely causing the compass to slide along a set-square. It may be added that the series of arcs should be drawn end to end, in order that it may be easier to observe their agreement or difference when examining with the glass.

=448.= When this series of tests has been gone through, and the points have been examined so as to make sure that there is no burr which bends over while tracing the arcs, it is possible to determine the value of the tool; we know whether it is perfect or not,

and what corrections are required. As a rule there are two points mainly at fault; the holes in the heads are not exactly continuations the one of the other, so that they need to be broached out afresh and new runners have to be made. A careful and intelligent workman who is provided with suitable tools will be able, from the information given in this work, to correct, or at least improve, a defective depthing tool; but, as a rule, it will be better done by the maker.

PART V.

REPAIRING AND EXAMINING WATCHES.

METHOD.

=449.= Expedition and certainty in watchmaking and repairing are primarily secured by proceeding on a definite system, both in details of construction or repairing.

The best watchmakers, and practical men generally, take their work in a certain order, from which any departure is exceptional. By this means they avoid the necessity of doing work twice over and of frequently taking up the same piece; a circumstance that often occurs with young watchmakers, owing to forgetfulness or to a want of sequence in their ideas.

They should from the first exercise themselves in working methodically on a definite system.

It must, however, be understood that no method can be inflexible, nor can it be equally advantageous for different individuals, because men differ in regard to manual dexterity, goodness of eyesight and of memory, power of associating their ideas, etc. A system that is suitable to a person of unexcitable temperament will have to be modified by one is oppositely disposed. Everyone will be able to decide for himself as to the best system to adopt and the order in which to take his daily work.

These preliminary observations appear necessary because the method explained below of examining a Geneva watch has been regarded by some as too long and minute. We would urge any young watchmaker that hears such ideas advanced to assure himself that it is a mistake, because the system here explained is only put forward subject to the modifications that experience suggests; and it is to be observed that many of the operations given can be performed more rapidly than they are described.

When a watchmaker experiences a great loss of time, does it not usually arise from the fact that he is obliged to take a watch to pieces, or nearly so, after its repairing and examination were thought to have been completed; or when a watch that has been repaired is brought back to be examined before the ordinary period of cleaning has elapsed?

Let him add together the numerous hours spent in this kind of thankless work, let him sum up the worries experienced, and the discredit, etc., to which he has been subjected, and he will see that systematic work would have saved him both loss of money and loss of credit.

EXTERNAL EXAMINATION OF THE WATCH.

=450.= In the following paragraphs, when the manner in which a given fault manifests itself is not indicated at once, it should be sought in the index of this volume, either under the name of the operation or under that of the object to which it relates. The reader will see for himself which passages refer exclusively to the English or American and which to the Geneva watch.

=451.= =Case, Glass, Dial, Dome.= Glance at the case in order to ascertain that it has not received a blow or been subjected to pressure; that the joints and fly springs work well; and that the hands in rotating touch neither the glass nor dial. By laying the nail on the surface of the glass, it will be easy to see whether there is sufficient freedom between the socket of the hand and the glass. In case of doubt, place a small piece of paper on the hand, close the bezel and tap the glass with the finger while the watch is in an inclined position. If free, the paper will be displaced.

The set-hands square should be rounded at the end and a trifle below the level of any accidental bending of the back of the watch, and the dome must not press on the balance-cock wing or the central dust cap (if present). The above remark also applies to the winding square of a fusee watch.

There must also be sufficient freedom between the going-barrel teeth and the banking-pin of the balance on the one hand, and the internal rim of the case, the fly-springs, and the joints on the other. Otherwise there is danger of contacts when the case is closed which occasion irregularity and stoppage often difficult to detect.

=452.= The dome must be at a sufficient distance from all parts of the movement, more especially the balance-cock. If there is any occasion for doubt on this point put a thin layer of rouge on the parts that are most prominent. Close the case and holding it in one hand to the ear, apply a pressure at all parts of the back with a finger of the other hand, listening attentively in order to ascertain whether the vibrations are interfered with. If the interval is insufficient, a trace of rouge will be found on the inside of the dome. In such a case, if the dome cannot be raised nor hollowed slightly in the lathe (when formed of metal), lower as far as possible the index work and the balance-cock wing and fix in the plate, close to the balance, one or two screws with mushroom heads that will serve to raise the dome.

Ascertain that the hands stand sufficiently far apart; that the hour hand does not rub against the hole in the dial; and that the minute hand does not come nearer to the dial in one place than in another, a fault which may arise either from the dial not being flat or from the center-wheel being badly planted.

Remove the movement from its case, after making sure that it is held steadily by the locking screws; take off the hands, and see that the hour wheel has the right amount of play; this freedom may be diminished if required by laying on the wheel small discs of tinsel cut out with a punch. If the dial presses against any part of the movement, or is not flat or comes so near to any of the pivot-holes as to draw off the oil, it must be ground away until a sufficient amount of freedom is obtained.

TO EXAMINE A GENEVA MOVEMENT.

=453.= Although the following remarks refer in the main to foreign watches with a Lepine movement, very many are also applicable to the English and American watches; further observations specially bearing on them will be found in articles =477-80=.

=454.= =The Motion Work and Hands.= Rotate the wheels connecting the hour and minute-hands by the aid of a key and a glance will suffice to show whether the several depths, which should be light, are satisfactory. The wheels should not rub against one another, the plate, barrel, or stopwork. The barrel should have been previously examined to ascertain that it is not inclined to one side, as if it were, an error would probably be made in estimating the degree of freedom.

The set-hands arbor (the square of which should be a trifle smaller than that of the barrel-arbor) must turn rather stiffly in the center pinion, and the cannon pinion must be held on the arbor sufficiently tight to avoid all chance of its rising and so becoming loose; for this would alter the play of the hands and motion work. If any fault is found in the adjustment correct it at once, so as to avoid doing so after the movement has been cleaned.

If it has not been already done, slightly round the lower end of cannon pinion and the steel shield, care being taken to avoid forming a burr on the pinion leaves. These two pieces ought to rest on the ends of the center pinion pivots, and at the same time be some distance removed from the plate and bar respectively.

=455.= =Freedom and Endshake.= Observe that there is sufficient clearance between the plate and barrel; the barrel and center-wheel; the several wheels in succession both between themselves, their cocks, and sinks; between the balance on the one hand and its cock, the center-wheel, fourth wheel cock, the balance-spring coils and stud on the other. The fourth wheel is frequently found to pass too near to the jewel forming the lower pivot-hole of the escape-wheel.

The end-shake of the wheels may be tested by taking hold of an arm of each with tweezers and lifting it. This may also be done in the case of the escape-wheel, but, when the cock is slight, it will be sufficient to press gently upon it with a pegwood stick, then releasing it, and observing the apparent increase in the length of pivot. At the same time ascertain that the width and height of the passage in the cock is enough to allow the teeth, when carrying oil, to pass with the requisite freedom.

Holding the watch on a level with the eyes, lightly raise the balance with a pegwood point several times, each time allowing it to fall. The variation observed in the space between the collet and cock will indicate the end-shake of the balance-staff.

=456.= =Action of the Escapement.= The side play of the balance pivots in their holes can be easily estimated by touch, or this may be done by the eye, attentively watching the upper pivot through the end-stone with a powerful glass, while the watch lies flat and the lower pivot in the same manner with the watch inverted. If the end-stones are not clear enough, although such a case is rare, remove first one end-stone and examine the pivot; then replace it and remove the other.

It should be possible to rotate the balance until the banking pin comes against its stop, without causing the escape wheel to recoil at all, or allowing a tooth to catch outside the cylinder behind the small lip. The banking-pin sometimes passes too near to the fourth wheel staff. The =U=-arms should rest nearly in the middle of the banking slot of the cylinder: they should be as far from the upper as from the under edge of this slot, so that the end-shakes may have free play in all positions of the watch.

Ascertain that the balance-spring is flat; that it coils and uncoils regularly without constraint; that it does not touch the center wheel, the stud, or the inner curb-pin (with its second coil). The rapid examination of the escapement may now be regarded as completed if the watch in hand is merely being cleaned after having previously gone well.

But if engaged on a watch that has not gone well previously, or if examining a new one, the action of the escapement must be thoroughly tested.

=457.= =Visible Depths.= While the train is in motion through the force of the mainspring or the pressure of a finger against the barrel teeth, examine with a glass all the depths that are visible. That of the escapement, for example, can be easily seen through the jeweled pivot-hole when this is flat, the watch being laid horizontal and a powerful glass used. When the action cannot be seen in this manner with sufficient distinctness, hold the watch up against the light and look through it. Depths that cannot be clearly seen, or about which any doubt exists, must be subsequently verified by touch. (=458.=)

If examining a new watch, it may be found necessary to form inclined notches at the edge of the cocks or near the center hole of the plate so to see the action of the depths. But it is important that the settings of the jewels are not disturbed, and indeed that enough metal is left around these holes to admit of their being re-bushed if necessary.

=458.= =Invisible and Doubtful Depths.= These must be tested by touch, and the requisite corrections applied after having re-polished the pivots, etc., as may be necessary. We would observe that holes a trifle large are less inconvenient than those which afford too little play; providing the depths are in good condition.

=459.= =Length of Balance Pivots: Centering the Balance-Spring.= Remove the end-stone from the chariot and see that the pivot projects enough beyond the pivot-hole when the plate is inverted. Then remove the cock and detach it from the balance. Take off the balance-spring with its collet from this latter and place it on the cock inverted, so as to see whether the collet is central when the outer coil is midway between the curb-pins. Remove the cock end-stone and end-stone cap, place the top balance pivot in its hole and see that it projects a little beyond the pivot-hole.

Place the balance in the figure-of-=8= calliper to test its truth, and, at the same time, to see that it is sufficiently in poise; it must be remembered, however, that the balance is sometimes put out of poise intentionally.

=460.= =Play of Train-Wheel Pivots.= Allow the train to run down: if it does so noisily or by jerks, it may be assumed that some of the depths are bad in consequence either of the teeth being badly formed, or the holes too large, etc. To test the latter point, cause the wheels to revolve alternately in opposite directions by applying a finger to the barrel or center-wheel teeth, at the same time noting the movement of each pivot in turn in its hole; a little practice, comparing several watches together, will soon enable the workman to judge whether the play is correct. The running down of the train will also indicate whether any pivots are bent. Now remove the barrel-bar with its several attachments.

=461.= =Center-Wheel: Bad Uprighting.= Remove the third wheel, and, if necessary, test the uprighting of the center-wheel by passing a round broach or taper arbor through it, and setting the plate in rotation about this axis, holding a card near the edge while doing so. This will indicate at once whether the axis of the wheel is at right angles to the plate.

When a marked deviation is detected, or the holes are found to be too large, they must be re-bushed and uprighted again. When, however, the error is but slight the axes may be set vertical by bending the steady pins a little, in doing which proceed as follows:

Set the bar in its place alone, the screw or screws being a little unscrewed, and rest the side of the bar opposite to that towards which it is to be bent against a piece of brass held in the vise, and strike the farther edge of the plate one or two sharp blows with a small wooden mallet. Experience alone can teach the workman to proportion the blow so as to obtain a given amount of deviation, and must enable him to ascertain whether it is desirable or not to pass a broach through the steady-pin holes before operating as above explained. Some discretion is essential in practising the method.

It is important that the center pivots project beyond the holes in the plate and bar. A circular recess is turned around the outer end of each of these holes so as to form reservoirs for oil. Owing to the neglect of these simple precautions, which are so easy to take, many watches, especially those that are thin, come back for repair with their center pivots in a bad state, because the oil could not be applied in sufficient quantity, and has been drawn away by the cannon pinion or the steel shield.

If the watch has a seconds hand, ascertain by means of the calliper that its wheel is upright. Finally, examine each jewel to see that it is neither cracked nor rough at the edges of the hole.

=462.= =The Barrel: to Take Down and Repair.= The side spring, which must not be too strong, should reach with certainty to the bottom of the spaces between the teeth of the ratchet, and this latter should be held steadily in position by the cap. It is a good plan after making the extensive repairs here spoken of to again test the barrel and center pinion depth, either by touch of by drilling a hole for observation.

The screw of the star-wheel must not project within the cover nor rub against the dial; it must be reduced if either case presents itself. The action of the stopwork must be well assured, especially when the actual stop occurs. It is a good plan to, as it were, "round-up" the star-wheel and finger-piece, with an emery stick, supporting them on arbors. There must be no possibility of friction between the finger and the bottom of its sink.

[Illustration: _Fig. 225._]

=463.= =To Test the Stopwork.= Take up the winding square of an arbor, with the barrel, etc., in position, in a pair of sliding tongs or a Birch key; hold the tongs between the last three fingers and the palm of the left hand, the first finger and thumb being applied to the circumference of the barrel so as to rotate it, first in one direction and then in the other. During this movement, take a pegwood point in the right-hand, and try to turn the star-wheel _against_ the direction in which it would be impelled by the finger; the position is indicated by B in Fig. 225. The tooth that is just going to engage with the finger will thus be caused to take up the worst possible position for being turned, and thus, if the action proves to be satisfactory for each tooth, we may rest content as to the future; providing, of course, that the engagement takes place square, and there is no tendency to cause distortion of the metal. When the corner of C is stopped against the convex tooth of the star-wheel, the finger should be free in a space, and directed towards the center of A. By holding the sliding tongs in a vise both hands can be kept at liberty.

For details in regard to the examination and repair of keyless mechanism, see article =481=.

ACCESSORIES FOR BEGINNERS.

=464.= To facilitate the work by securing order in taking to pieces and cleaning, preventing the screws from being mixed, etc., it is a good practice to prepare beforehand one or more boards, in which grooves and holes are made in positions to correspond with those of the several pieces on the plate of the watch, as indicated by Fig. 226.

[Illustration: _Fig. 226._]

The round holes receive the cock and bar screws, which may be cleaned while the other parts are in the benzine solution. (Two holes are shown side by side for each bar and cock, so that the same plate will serve for a large and small watch). The oval or circular hollows at _a_ and around _m_ receive the cap screws, and _m_ the shield; _c_, _c_, _c_, hold the screws of the side spring and star-wheel and the finger-piece pin; _j_ is for the screws of the top end-stone, and _n_ for those of the bottom end-stone, etc.

It may be well here to mention the very convenient divided boxes for holding the several parts of a watch when taken to pieces that are in general use by watchmakers. They measure about six inches by four, and one inch in depth, thus being large enough to contain all the parts of any ordinary watch.

At first every young watchmaker will find the advantage of noting on paper, bearing the number of the watch, the successive operations that have to be done. He will then merely have to strike them out one by one as the work progresses. As he becomes more practiced he can dispense with this auxiliary.

CLEANING THE WATCH.

=465.= Whatever system of cleaning is adopted it is essential that it be concluded by passing a pegwood point into each of the holes.

Brilliancy is given to the surfaces of cleaned pieces by passing a carefully kept fine brush over them. A brush that is greasy can only be cleaned by soap and water, and a new brush is prepared for use by passing an inclined cutting edge over the ends of its bristles so as to taper them off to fine points, and to remove knots due either to hard parts or to bristles becoming united. This preliminary treatment is completed by charging the brush with French chalk, and rubbing it vigorously on a dry crust of bread until the brush can be passed over a gilded surface without scratching it. The bristles are maintained in good condition by the same treatment. Billiard chalk is also very effective for this purpose, and the greater number of cavities there are in the crust the better it will act. A burnt bone is an excellent substitute for the crust, and has the advantage of causing the brush to impart a very brilliant appearance to objects to which it is applied.

=466.= =To Clean with a Brush.= This method is less used now than formerly, as it can be adopted with safety with the old-fashioned gilding, but is too severe for the thin galvanic coats that are applied at the present day. It may, however, be resorted to for getting up the surface of polished brass wheels, for example.

Put some French chalk or powdered sal-ammoniac (which can be bought at a chemist's) in pure alcohol. Shake the mixture, and with a fine paint brush coat the object with a small quantity of it, subsequently brushing the surface with a brush that is in very good condition. Polished wheels may be made to present a very brilliant appearance by this means, but their teeth and the leaves of pinions must be afterwards carefully cleaned.

The French chalk and sal-ammoniac are all the more effective according as they have remained a longer time in the alcohol; doubtless owing to the fact that the hard grains met with in them are then more completely dissolved.

=467.= =Soaping.= It is advisable to use a soap that quickly produces a good lather; and the object is held in the hand and cleaned by rubbing with a soft brush charged with this lather; then immerse first in clean water, and subsequently in alcohol, moving it about in each: it may be left for a few seconds in this latter, and, on being removed, is dried with a fine linen rag or soft muslin. A stroke with a soft brush in good condition will give brilliancy to the surface. As water sometimes dissolves the soap very slowly, it is desirable that it be employed warm. If about to soap polished wheels, the surface must be first got up with a buffstick and rouge, or by brushing with sal-ammoniac.

The balance spring may be cleaned by laying it on a linen rag doubled, and tapping it gently with a brush charged with lather; then dipping in water and alcohol in succession.

The alcohol may be used hot or cold; its action is, however, more rapid and effective in the former case. But there is no occasion to use hot alcohol except when dealing with substances such as wax, that resist its action.

=468.= =Essences and Benzine.= The employment of essences in cleaning watches is becoming more general every day. They are to be obtained at all material dealers, together with full instructions in regard to their use. A few observations may nevertheless not be out of place here.

The objects are left in the solution for a few minutes in order to allow all adhering matter to dissolve, but they must not remain too long, as certain qualities of benzine, etc., are apt to leave stains. Dry the pieces on removing them, and finish by passing over a fine brush that has been charged with chalk and subsequently been rubbed on a hard crust or burnt bone; as has already been observed, this will produce a brilliant surface on either gilding or polished brass.

The following composition, the ingredients of which can be obtained at any chemist's, has been strongly recommended to us by a clever watchmaker:

90 parts by weight of refined petroleum. 25 " " sulphuric ether.

The objects are immersed for several minutes; indeed, they may remain for a longer period without danger, and on removal from the bath are found to be clean and bright. It must not be forgotten that many of these essences are liable to ignite with the mere proximity of a lamp.

PUTTING THE WATCH TOGETHER.

=469.= The three following rules must be observed in arranging a system of putting the watch together: (1) avoid taking up the same piece two or more times; (2) hold it lightly, as any pressure will produce a mark; (3) keep it as short a time as possible in the fingers. Any linen rags used must be free from fluff, but rags of all kinds should as far as possible be replaced by certain kinds of tissue paper. The best kind will be that which, while securing a given degree of pliability, will best prevent heat and moisture from passing through. Blue-shaded tissue paper should be avoided, as it is often found to encourage the formation of rust on steel work.

=470.= The following order is adopted by some excellent watchmakers in putting together the ordinary form of Geneva watch; it may be adopted exactly or modified as experience dictates.

Commence by putting the several parts of the barrel together, attaching it to the bar and observing the directions given farther on (=474=) in regard to the distribution of oil. Owing to the position of the stop-finger, it is sometimes found that the mainspring must be set up either one-quarter or three-quarters of a turn. Very often one-quarter is not sufficient, and in such cases it is necessary, before putting together, to ascertain that the spring admits of at least 5 or 5¼ turns in the barrel. If it will not allow this amount, and yet has to be set up three-quarters of a turn, too great a strain will come upon the eye of the spring in winding. Fix the chariot with its end-stone on the under side of the plate.

Replace the fourth wheel, making sure that it is free and has no more than the requisite end-shake and is upright. Then the escape-wheel, testing it in a similar manner. See that the teeth have sufficient freedom on both sides of the cock passage, then make the two wheels run together with a pair of tweezers of pegwood, in all positions of the plate, to make sure of everything being free.

=471.= After attaching the index and end-stone to the balance-cock and the balance-spring to the balance (observing that the center of the stud is against the dot on the balance rim), place some oil in both the balance pivot-holes (=476=); adjust the balance to the cock after placing a drop of oil in the cylinder (though a much better plan is that given in article =476=), and set in position on the plate. Some workmen apply a drop of oil to the top of the escape-wheel pivot-hole before setting the balance-cock in its place, but others prefer only to add the oil after the escapement has been tested.

Placing a small piece of paper first between the balance and cock, and then between the balance and plate, ascertain whether the escape-wheel occupies its correct position in reference to the cylinder, in order that the escapement may act properly. This test is especially necessary in dealing with very thin watches or those in which the cylinder banking slot is exceptionally narrow. The barrel bar is now fixed to the plate.

=472.= Set the third wheel in its place, and lastly the center wheel, after putting a little oil on the shoulder of its bottom pivot. Before putting the bar over it, apply oil to the top pivot in a similar manner; then screw it down. After this is done screw on the third wheel cock.

Now apply a small quantity of oil to the two center pivots, and very lightly to the others that have not already been oiled; give a turn to the key and listen to the tick of the watch in all positions. This should always be done before replacing it in the case.

After passing the slightly-oiled set-hands arbor through the center pinion, and adapting the cannon pinion to its end, reverse the watch, passing the end of the center arbor through a hole in the riveting stake, so that the watch is supported on the end of the cannon pinion; a light blow of the hammer on the square end of this arbor will then suffice to drive the cannon pinion home. Some do this before replacing the movement in its case, and some after.

Add a little oil to such pivots as have not already received enough, and fix in their places the remaining parts of the motion work, the dial and hands: the watch then only requires to be timed.

=473.= =Precautions to be Observed in Applying Oil.= The method of distributing and applying the oil is of more importance than might be thought, and has a very marked influence on both the time of going and the rate.

Oil that is very fluid may be used for the escapement and fine pivots, where only a small quantity is needed and the pressure is slight; but it is not suitable in other places on account of its tendency to spread, and thus leave the rubbing surfaces.

If too much oil is applied the effect is the same as if there had been too little; it runs away, and only a minute quantity is left where it is wanted.

=474.= _Barrel._ It is not enough to apply oil to the coils of the spring; some must also be placed on the bottom of the barrel. Before putting on the cover, moisten the shoulder of the arbor-nut that comes in contact with it with oil; by doing so, when oil is applied to the pivot, after the cover is in its place, this oil will be retained at the center of the boss in the cover. Moreover, it will not then be drawn away by the finger-piece, passing from this to the star-wheel.

The oil applied to the upper surface of the ratchet to reduce its friction against the cap must not be in such quantity as to spread on to the winding square. It is a good plan to round off the lower corner of this cover.

=475.= _Center-wheel._ The observation made above in reference to the oil applied to the barrel-cover may be repeated here. By proceeding as explained in article =472=, and adopting the precautions mentioned at the end of article =461=, it is possible to make sure of the pivots lasting for a long period.

=476.= _Escapement pivots: Cylinder._ When the drop of oil is introduced into the oil-cup of the balance pivot-hole, insert a very fine pegwood point, so as to cause the descent of the oil; a small additional quantity may then be applied. When this precaution is not taken, it frequently happens that in inserting the balance pivot its conical shoulder draws away some of the oil, and there is a deficiency both in the hole and on the end-stone.

As has been already noticed (=471=), some workmen place a single drop of oil within the cylinder, and when the escape-wheel advances each tooth takes some up. This method is unsatisfactory, because the earlier teeth receive such a quantity of oil that it runs down the pillars, where it is useless and merely tends to increase the weight of the wheel. A much better plan is to put a very small quantity in the cylinder, and on the flat of each tooth or every second or third tooth. It will thus be evenly distributed, and will not tend to flow away.

The escape-wheel pivots require but a small quantity of oil. It often happens, however, that, owing to carelessness, the workman applies too much, and it runs down to the pinion. The leaves will thus become greasy and stick, while the pivots are running dry.

TO EXAMINE ENGLISH OR AMERICAN MOVEMENTS.

=477.= As has been already observed in article =453=, many of the remarks made in speaking of the Geneva movement are equally applicable to that of English or American construction, and any intelligent watchmaker, on reading articles =450-463=, will be able to select for himself whatever has a bearing on the English watch, without difficulty. It will be well, however, to supplement it by the special directions contained in the four following articles:

=478.= =Case, Glass, Dial, Cap, Dome.= In addition to the points specified in articles =451-452=, the following require attention. See that the position of dial is not altered by closing down the bezel, that the fuzee dust cap does not touch the dome or cap, and that the diamond end-stone or other jeweling of the balance-cock is free of the case. In ¾-plate watches the chain is occasionally found to rub against the edge of the case, or the top-plate to press against the bottom edge of the same, causing the train to bind. See that the balance and chain and the fuzee great wheel are free of the cap, where one exists; the chain is especially liable to rub after the breaking of a strong spring, which may cause the barrel to bulge, when it may also rub against the potence. Ascertain that none of the dial-plate feet or pins touch the train, that the hour wheel is clear of the third and fourth wheel bar, and the minute wheel out of contact with the dial-plate and not pressed by the dial. See that the third wheel is free in its hollow, and that the balance, more especially in oversprung watches, is clear of the barrel.

=479.= =Movement.= The regulator or index must be tested, especially in watches that are undersprung, at several points between "fast" and "slow," to see that it nowhere approaches too near to the spring, is held with sufficient firmness, and that it never comes near enough to the guard pin for contact to occur. See that the potence screw and steady-pins do not project, and that the barrel does not touch the name-plate, balance-cock, top-plate hollowing or great wheel.

Before taking off the top-plate, notice the position of the detent in the steel wheel, and the amount of its end-shake; the wear of the holes, and freedom of the train wheels; the position of the third pinion with respect to the center wheel, and that of the escape wheel to the lever; see that the banking pins are not loose or bent; that the guard pin, which protects the balance staff when the chain breaks, is near enough to the barrel and the potence. When the watch is taken to pieces, any loose pillars or joints must be secured, pivots examined to see whether worn or bent, and those working on end-stones that they come through the holes. The fourth wheel pinion must be free in the hollow of the pillar plate and the center wheel in its hollow; a similar examination also must

be made of the collet and pin which secure the great wheel to the fusee. If a chain is broken near the barrel end, the stopwork is probably defective or the spring too strong.

The following faults may be met with in the English stopwork. The stop may come opposite the fusee snail too soon or too late, allowing one turn too few or too many of the fusee; or the back of the snail may butt against the stop, and thus stop the watch after going for a few hours. Overwinding sometimes occurs in consequence of the stop-spring being locked between the shoulder of the stop and its brass stud; and the blade of the snail or the end of the stop may be worn or bent in cleaning.

In ¾-plate fusee watches, see that the balance does not come too near to the fusee, fourth wheel, center wheel, and sometimes the escape-wheel. It is to be observed that the breaking of a mainspring sometimes causes certain teeth of the great wheel to be strained.

=480.= =Escapement.= It may be well to note the few following particulars that should always be attended to. See that ruby-pin and pallet stones are firmly set, that neither pallets nor roller is loose on its staff, and that the lever and pallets are rigidly fixed together. The guard pin must be firm, the balance well riveted to its collet, the spring collet sufficiently tight and the curb pins firm. If there is a compensation balance, ascertain that each screws tight. The precautions to be observed in regard to the balance-spring are given in article =456=.

=481.= =Keyless Work.= So great a variety of arrangements of the mechanism for winding watches at the pendant is met with at the present day that it would be impossible to give detailed directions in regard to their examination; the following general remarks, however, mainly taken from the work of M. A. Philippe on Keyless Watches,[6] will be found of value in directing attention to the points which most require it, and will suffice for any intelligent workman. Is should be observed at the outset, however, that the adjustment of keyless work is almost entirely a question of depths, and the workman who has thoroughly mastered this subject will rarely experience any difficulty in dealing with keyless mechanism.

Carefully observe each depth, etc., in succession, to make sure that no prejudicial friction occurs either between teeth or by contiguous parts coming in contact. All springs should act solely in the direction in which pressure is required of them. Special attention should be given to the intermediate steel wheel for communicating motion to the cannon pinion, when this exists, as it is permanently in gear with the train, so that any unevenness of the depth will effect the rate: if the minute wheel have too much end-shake or play on its stud, it is apt to ride on the intermediate steel wheel. The friction of the cannon pinion on the set-hands arbor must not be excessive, since it would involve too great a strain on the teeth of the minute wheel, nor too slight, since the hands would be liable to be displaced on releasing the set-hands stud. If the intermediate wheel has too much end-shake, limit this by an eccentric screw overlapping its edge.

Test the spring of the set-hands stud, to see that it is not too strong nor too weak and that it moves parallel with the plate. Failure in this latter particular might lead to its rising on to the rocking-bar or other pieces on which its acts.

The winding pinion depth must be examined to see that it is neither too deep nor shallow.

The set-hands stud-spring must be strong enough to resist any accidental pressure on the stud, but, on the other hand, the strength must not be excessive, as the spring will then be all the more liable to break, besides causing inconvenience when setting the hands. The course of the spring should be banked at the point which gives a good depth between the winding and intermediate wheels. The minute-wheel stud must be firm in the plate, as any accidental binding might otherwise unscrew it, occasioning the breakage of the dial. When the minute hand is carried by the set-hands arbor, and not by the cannon pinion, care is necessary in fitting this latter, for if too loose it will rotate in setting the hands without carrying the minute hand round, and the minute and hour hand will cease to agree.

It is important that attention be paid to the application of oil to keyless work, as, in its absence, rust rapidly forms, and the mechanism becomes bound. Of course, all bearing surfaces, such as the interior of the pendant, intermediate and minute wheel studs, studs or screws of the rocking bar or other surfaces on which wheels rotate, must be lubricated; an equally important point is to liberally oil the teeth of the winding pinion and the bevel or crown wheel that engages with it. The application of a little oil inside and outside the cannon pinion must not be forgotten.

TO RAPIDLY TIME A WATCH OR CLOCK.

=482.= It seems desirable to supplement the information here given by a few details, since we have observed that, either from want of patience or method, many watchmakers are not always successful in counting the vibrations.

=483.= =To Practice Counting Vibrations.= At the outset it is to be observed that to each vibration to the right there is a corresponding one to the left, so that it is only necessary to observe those in one direction, or else to count one for each two impacts of the escapement, in a minute (or half-minute), in order to ascertain the number of vibrations.

14,400 vibrations per hour correspond to 4 per second; that is 240 per minute, or 120 per half-minute, and the half of this number is 60.

Similarly, a 16,200 train would give 4½ vibrations per second; or 270 in a minute, the half of which number is 135.

An 18,000 train giving 5 vibrations per second, or 150 per half-minute, would count 75 in this interval of time.

This being understood, the required number of vibrations is to be ascertained as follows:

The movement is placed in such a position that the light is reflected from an arm of the balance, so that, by reference to some fixed point, (such as the side of the balance-cock, the stud, etc.), each return of the balance can be noted and counted. A very little practice will remove any difficulty that may be experienced in doing this. When the requisite skill has been acquired, one can listen to the impacts of the escapement while continuing to count, and in order to determine with greater facility the correspondence of the position of the balance with successive pairs of vibrations, close the eyes from time to time while still counting. On opening them, the accuracy of the coincidence can be at once tested by the sight, and, with a little patience, it is possible to count the double vibrations with certainty in this manner, both by the eye and ear; it is only necessary when nearing the end of the minute or half-minute to continue counting aloud, while keeping the eye on the regulator: for the ear will guide the voice, which will thus accurately reflect the motions of the watch.

The above explanations will be sufficient to enable any watchmaker of average intelligence to acquire the power of counting vibrations, either in the manner here recommended, or by modifying it in any manner that may suit his temperament. This power, when once acquired, will be of very great assistance in his daily work, for before taking a watch to pieces that requires repair, he can in one or two minutes ascertain the number of vibrations it should make; he will thus be enabled to regulate the watch almost instantaneously when the necessary repairs have been completed. We would again observe that the main point is to educate the ear to ignore each alternate vibration, and thus to count only the intervals of the balance being in the same position and the same phase of its motion.

=484.= =Vibration Counter.= Leclerre's Vibration Counter is shown in Fig. 227. R is a ratchet wheel with 30 teeth, mounted on a vertical plate, so that it can rotate freely. A pawl, _v_, prevents its movement except when forced forward one tooth at a time by depressing the spring gathering-click, _p_, a finger being applied to the button, _o_, each time the word "ten" is uttered. The number of teeth advanced thus affords a record of the vibrations without there being any necessity to go into higher figures.

[Illustration: _Fig. 227._]

=485.= =To Regulate a Watch.= Place the movement near to a regulator or watch indicating seconds, in such a position that the eye can easily observe the periodical return of an arm of the balance, as already explained, and commence to count, always starting from the instant at which the seconds hand points to zero. Then count steadily 1, 2, 3, 4, etc., until this hand reaches 30 seconds.

Assume, as is very commonly the case, that the balance should make 18,000 vibrations in an hour, or 150 in a half-minute, and that, on counting its vibrations, we find 65 double vibrations, or 130 beats, whereas it should give 150. It is thus 20 beats slow. Advance the index, and repeat the operation; and so on till the regulation is effected.

A greater degree of accuracy will be secured by counting for a longer period, say one, two, or three minutes; but when this is done, it is advisable, in order to avoid confusion, to recommence at one after each 30 or 50 have been counted, because all that is required is the final deviation.

Remarks. 1. All men are not equally quick of perception, so that, in counting and uttering the word _one_, it will be found to correspond with the end of the first beat in the case of some observers, and its commencement with others. By practicing on a well regulated watch, a watchmaker can determine to which of these classes he belongs. If to the second, he should double the _one_

at starting; in other words, he should count thus:

1, 1, 2, 3, 4, 5, etc.

2. Advantage may be taken of the principle of the sounding-board by placing the watch on a sonorous body which will make the vibrations louder, or by placing between the plate of the watch and the ear a rod that is a good conductor of sound. By either or both of these means, the operation is rendered very easy, especially if the vibration counter recording the tens is employed.

=486.= =Another Method of Regulating a Watch.= When the movement is in going order, arrest the balance and make a mark with rouge on one arm of the escape-wheel. Release the balance when the seconds hand of the regulator crosses 60. Observing the number of revolutions that should be made by the escape-wheel in a given time (it would be six turns per minute with an ordinary 18,000 train), count its revolutions while the fourth wheel makes one complete turn; indeed, even this counting may be avoided by making a rouge mark on its edge where it corresponds with the mark already made on the escape-wheel. If after two or three minutes these two marks are found to occupy similar positions at the instant the seconds hand of the regulator crosses 60, the watch is to time. If there is any difference it is easy to ascertain whether this indicates a gain or a loss, and the index is moved accordingly.

=487.= =To Regulate a Clock.= The timing of timepieces by counting vibrations is much more easy than that of watches.

Before removing the pendulum count the number of its vibrations during two or three minutes. This time will be sufficient to afford a guide in regulating the clock after it has been repaired.

In most modern timepieces the escape wheel makes 120 revolutions in an hour, or two in a minute. Hence we have two modes of timing.

(1). Having made a light mark on the circumference of this wheel opposite to a fixed point, observe if the coincidence is maintained after intervals of two or three.

(2). Multiply the number of the escape-wheel teeth by 2, and the product by 120. This gives the number of oscillations the pendulum should make in an hour. Thence deduce the number it should make in two minutes, or the number per minutes can be obtained by multiplying the first product by 2, and it only remains to count the number actually performed in any definite interval.

=488.= =Guilmet's Synchrometer.= When a clock is to time, its pendulum makes a certain definite number of oscillations per minute, dependent on the train. If, therefore, before taking it to pieces a comparison pendulum be set to make the same number of oscillations as that of the clock, or if the former be set to make the number which the train shows that the clock pendulum should perform, it can be used as a term of comparison for setting the clock to time after it has been cleaned. This is the principle on which the synchrometer is based. A pendulum is lightly supported on a frame, and has an adjustable rod sliding in a tube, and graduated so that it can be firmly set without difficulty to give the various periods of oscillation commonly met with in timepieces. The pendulum is hung freely without any train to drive it, and continues to oscillate for two or three minutes, quite long enough to ascertain whether agreement is maintained between the two pendulums.

=489.= =Other Methods of Regulating a Clock.= Various plans have been recently proposed for rapidly timing a clock, all based upon one idea: namely, the temporary addition of a seconds hand for purposes of observation. That suggested by M. Jacomin is recommended by its simplicity.

Having removed the pin and washer that maintain the minute hand in position in an ordinary timepiece, replace them by a light brass cap that can be fixed by a screw or in any convenient manner, so that a fine steel pin projecting from it shall be accurately in the axis of the minute wheel. Part of a watch movement, comprising only the center, third and fourth wheels with seconds hand attached, is supported in front of the clock dial, so that this pin can be inserted in place of the set-hands arbor, and it is evident that, if the clock is to time, the seconds hand should perform one revolution per minute as it will form part of the clock train. The length of pendulum must then be varied until this condition is found to be satisfied.

TIMING IN POSITIONS.

HORIZONTAL AND VERTICAL.

=490.= To adjust a watch so that it has the same rate when first placed in a horizontal and then in a vertical position is a delicate and often difficult operation; thus it is seldom found to be properly done in ordinary watches.

The rates in a vertical and horizontal position are made identical or nearly so by equalizing the resistances that interfere with the motion of the balance in the two cases, and by taking advantage of the displacement of the center of gravity of the balance spring.

Satisfactory results will be obtained in most cases by employing the following methods, either separately, or two or more together, according to the results of experiments or the rates, the experience and the judgment of the workman:

1. Flatten slightly the ends of the balance pivots so as to increase their radii of friction; when the watch is lying flat the friction will thus become greater.

2. Let the thickness of the jewel-holes be no more than is absolutely necessary. It is sometimes thought sufficient to chamfer the jewel hole so as to reduce the surface on which friction occurs; but this does not quite meet the case, since an appreciable column of oil is maintained against the pivot.

3. Reduce the diameters of the pivots, of course changing the jewel-holes. The resistance due to friction, when the watch is vertical, increases rapidly with any increase in the diameters of pivots.

4. Let the balance spring be accurately centered, or it must usually be so placed that the lateral pull tends to lift the balance when the watch is hanging vertical. In this and the next succeeding case it would sometimes be advantageous to be able to change the point at which it is fixed; but this is seldom possible.

5. Replace the balance spring by one that is longer or shorter but of the same strength; this is with a view to increase or diminish the lateral pressure in accordance with the explanation given in the last paragraph.

6. Set the escapement so that the strongest impulse corresponds with the greatest resistance of the balance.

7. Replace the balance. A balance that is much too heavy renders the timing for position impossible.

8. Lastly, when these methods are inapplicable or insufficient, there only remains the very common practice of setting the balance "out of poise."

If there is a gain in the vertical hanging position of the watch, slightly reduce the _lower_ side of the balance; the oscillation will increase somewhat in extent, and there will be a losing rate in this position.

The converse must be done in the opposite case.

When the vibration exceeds a whole turn, the changes will be the reverse of those above indicated. This fact must not be forgotten, especially in regard to the duplex and lever escapements, which may at first make a vibration of more than a turn, and subsequently less, according to the state of the oil.

We would again observe that the timing of a watch for position presents some difficulty, and it will only be after making a number of trials that the watchmaker will be able to accomplish it with certainty.

NOTE ON THE PROPORTIONS OF BALANCES.

=491.= Two very important elements in the timing are the weight and dimensions of the balance; it is, then, necessary that a watchmaker should practice himself in observing their relative values, and the effect of increasing one at the expense of the other on timing, and more especially on timing for positions.

The _sensibility_ of a balance to variations in the motive force, and the time that elapses between the initial short vibration and the first that is of normal extent, a time that is approximately constant will serve as criteria. A balance that is very sensitive to variations in the motive force is generally too small; and one that attains to the normal arc of vibration almost instantaneously is, as a rule, too light. The converse effects would indicate that the size and weight were excessive.

In order that he may be able to practically apply these remarks, the workman should gain experience by making observations on several watches whose rate is known to be good, in the following manner.

In regard to _weight_: Stop the balance at the position of rest of its spring, then release it and count the number of vibrations up to the point at which the normal arc is attained; the extent of this must have been previously recorded on the plate with rouge marks.

Record the number thus obtained in a table opposite to the dimensions of the balance, and, by comparing these dimensions with those of another balance of equal size, the weight can be ascertained and also recorded.

In regard to _size_: Pass through the center pinion a kind of short screw arbor carrying a large thin ferrule, on which a cord supporting a weight is coiled. Fixing the movement in a movement holder, set it in a vertical plane and observe the extent of the vibrations of the balance with different weights attached to the cord.

These arcs should also be recorded in the table opposite to the dimensions of the balance. With sufficient practice the watchmaker will be enabled to judge at a glance whether the weight and size are well proportioned.

DEMAGNETIZING.

=492.= The following method of removing the magnetism from a watch that has been accidentally brought under the influence of a powerful magnet is proposed by Professor A. L. Mayer. We shall not here enter more fully into the subject than is necessary to indicate the manner in which a watchmaker may restore the steel work to its original condition.

Take a delicately suspended magnetic needle, say a mariner's compass, the length of which is about equal to the diameter of the watch, and lay it on a table. Now place the watch to be operated on, which should not be going, on the table close to the needle and on either the east or west side of it, having previously turned the box around until the needle points to zero. Taking care not to vary the distance between the centers of the watch and compass, observe the number of graduations to which the north end of the needle is deflected with each figure on the dial brought in succession nearest to the compass; it is also necessary to note whether the deflection is towards the east or west.

For example, assume that the watch is on the east side, and that, with noon nearest to the compass, the north end of the needle is turned 12° to the east, that is, towards the watch. This shows that some point in the watch in the neighborhood of the number XII on the dial possesses what is known as "north polarity," and if the deflection had been to the west the polarity would have been "south."

=493.= To take an example. Let the results of a series of trials with the several hours in succession towards the compass be as given in the following table:

========== Hour nearest to the } | I | II | III | IV | V | VI Compass } | | | | | ----------+----+-----+-----+-----+-----+---- Angle of Deflection | 5° | 18° | 72° | 56° | 22° | 5°
----------+----+-----+-----+-----+-----+---- Direction of Deflection | E | W | W | W | W | E
----------+----+-----+-----+-----+-----+---- Hence Polarity is | N | S | S | S | S | N
==========

========== Hour nearest to the } | VII | VIII | IX | X | XI | XII Compass } | | | | | | ----------+-----+------+-----+-----+-----+---- Angle of Deflection | 17° | 16° | 16° | 20° | 24° | 20°
----------+-----+------+-----+-----+-----+---- Direction of Deflection | E | E | E | E | E | E
----------+-----+------+-----+-----+-----+---- Hence Polarity is | N | N | N | N | N | N
==========

[Illustration: _Fig. 228._]

It will be seen that the greatest deflection westward corresponds to three o'clock, and, in the easterly direction, to eleven o'clock. This shows that the strongest south and north polarity are respectively in these directions. The first thing to be done is, then, to eliminate this particular magnetism. Placing a bar magnet in a horizontal direction, approach the watch to its south-seeking end in such a manner that a line X X′, Fig. 228, through the axis of the magnet, will pass through the center C of the watch, the figure XI, which marks the point of extreme north polarity, being nearest to the bar magnet. Now cause the watch to oscillate so that it alternately takes up the two positions A and B, and, when this has been several times repeated, bring III in a similar manner near the north-seeking pole of the bar magnet, oscillating the watch in the same way. Again try the watch with the compass, repeating the above operations if necessary until the readings are somewhat as follows:

========== Hour nearest to the } | I | II | III | IV | V | VI | Compass } | | | | | | ----------+----+----+-----+----+----+----+ Angle of Deflection | 5° | 4° | 0° | 5° | 8° | 2° | ----------+----+----+-----+----+----+----+ Direction of Deflection | E | E | | W | W | W | ----------+----+----+-----+----+----+----+ Hence Polarity is | N | N | | S | S | S | ==========

========== Hour nearest to the } | VII | VIII | IX | X | XI | XII Compass } | | | | | | ----------+-----+------+----+----+----+---- Angle of Deflection | 4° | 4° | 2° | 1° | 0° | 2° ----------+-----+------+----+----+----+---- Direction of Deflection | E | E | E | E | | E ----------+-----+------+----+----+----+---- Hence Polarity is | N | N | N | N | | N ==========

These figures show that, in counteracting the polarity at III and XI, the magnetic action of the watch in all other positions has, as might indeed have been anticipated, materially diminished. Such a condition of things will, of course, not be attained at once, and it may even happen that the polarity at the two points III and XI is reversed; in such a case it is only necessary to oscillate the III in front of the south-seeking pole instead of the north.

The last table shows that a maximum south polarity is now at V, and north at I. These points must therefore be operated upon in the same manner, and, by proceeding in this manner, and successively eliminating the worst points, the magnetism may be effectually removed.

As proving the efficiency of the above method, Prof. Mayer mentions a case in which a watch lost one hour in six in consequence of magnetism, and yet after the above treatment, it resumed its original rate of about a second per day.

=494.= =Another Method.= A second method of procedure has recently been described by H. S. Maxim. He employs a specially arranged apparatus, based on the principle that if a watch or other object be subjected to rapid alterations of magnetism, while gradually withdrawing it from the influence of the magnetic poles, the distance ultimately becomes so great that the reversals are inappreciable, when the watch is found to be demagnetized. A bar magnet is arranged to revolve in a horizontal plane around a vertical axis; the watch being placed in a small pocket opposite to the magnet, is caused to rotate in an ever-shifting vertical plane, while the frame supporting it rotates in a horizontal plane. While these movements continue the watch carrier is gradually moved away from the magnet by the action of a long horizontal screw, and it is stated that watches that have been completely spoiled can be rendered perfectly free from magnetism by such an apparatus.

FOOTNOTES:

[6] _Les Montres sans Clefs_ (Geneva).

PART VI.

PRACTICAL RECIPES.

=495.= The practical operations of the watchmaker are numerous and of a very varied character. Detailed instructions in regard to the proper conduct of a large number of them will be given in this part of the work, and frequent references will be made to former parts of this volume, whenever by so doing repetition can be avoided.

The operations herein discussed are often of so dissimilar a nature that it has been found impossible to classify them in such a manner that will always ensure the reader finding the information he requires without waste of time; and any risk of this would seriously impair the value of such a hand-book as the present. A very full index has therefore been added, and when seeking for details concerning any particular operation, this should in all cases be first consulted.

THE PLATE.

=496.= =To Make a Plate.= The sheet of brass having been prepared in the manner explained in article =103=, roughly rounded and smoothed on one face, is cemented to the chuck of a lathe. Turn out the other face of the plate very flat, and make the circumference square.

When using a lathe the face must first be roughed out, and then the plate is to be cemented to a perforated plate, so that it can be centered and finished. Smooth the exposed face with a well-set cutter and turn the inside and outside of the edge; then make sure that the whole is concentric by a light cut with a cylindrical drill in the center hole. After removing and cleaning the plate it is set up in the dogs, and the face that has hitherto been untouched is gently dressed with the graver.

There will thus be left a narrow ring at the edge that is not touched by the graver: this may be levelled with a smooth-cut file, and the whole surface then smoothed as explained in article =171=.

[Illustration: _Fig. 229._]

If a lathe is not available, the plate must be cemented to an arbor of the form shown at Y, Fig. 229. The heel of this is received in a runner of the turns, while the point of the opposite runner is received by the hole in the center of the plate, which is thereby held in close contact with the plate of Y, the revolution being, of course, produced by a bow. While the cement is still hot, a stick resting on the T-rest will serve to ensure the concentricity of the plate until it is set. This setting may be rendered more rapid by the application of cold water.

Turn out the plate with a hooked graver made of a worn out file, and, if the upper or under side does not run true, turn the portion that projects beyond the chuck with a graver, and, when the plate is removed, face the surface, taking the flat ring produced by the graver as a guide, and taking care to avoid altering any portion of it.

The smaller sinks can also be made in the same primitive manner, to which we have only drawn attention for the sake of watchmakers who are ill-provided with tools. But we would at the same time point out that, at the present day, there should not be a single one who does not know how to extemporize a lathe-head.

=497.= =Cocks and Bars.= If it is required to make all the cocks and bars of a watch, prepare a _false plate_, the thickness of which is a trifle greater than that of the highest cock or bar; then turn on the under side a series of sinks to correspond with the thin portions of the cocks and bars. Cut the several parts out of this plate with a fine saw, and it only remains to shape their contours with a file.

The same method may be adopted if a number of identical cocks have to be made at a time.

THE BARREL.

INCLUDING ARBOR, STOPWORK, MAINSPRING, ETC.

=498.= =To Make a Barrel.= Having trued both faces of the brass, and drilled a central hole rather less than that finally required and exactly perpendicular to the faces, turn away the brass from the inside (leaving a considerable excess of metal at the center to form the shoulder), and form the ring on which the teeth are to be cut, if it is a going-barrel, in the ordinary lathe on a wax chuck. Then fasten the plane surface, which must be quite true, to a smooth plate that is of uniform thickness and has a hole in the center to permit the passage of the pump-center. Having fixed the plate by the mandrel dogs, finish with well-set gravers: 1 the inside; 2 the external cylindrical surface both of the barrel and of the ring left for the teeth; 3 the barrel-cover groove; and 4 with a fine-pointed cutter slightly enlarge the central hole. By this means it is possible to ensure that the barrel will turn true and in the flat. Smooth the inside, more especially the groove, the corner of which must always be carefully smoothed and polished.

The cutting of the recess in the barrel-cover (of a Swiss or French watch) that gives freedom to the motion work, as well as the recesses for the stopwork, will not present any difficulty when the workman is provided with a lathe with or without a slide-rest.

[Illustration: _Fig. 230._]

When there is no slide-rest, the tool shown at D, Fig. 230, can be used for making the groove. A strip of metal of rectangular section has a small cutter clamped in a slot in its surface at a slight inclination. By releasing the two screws of the clamp, this cutter can be advanced to any required extent, and in the strip of metal are two or three slots having different degrees of inclination, so that the one can be selected that corresponds with the depth of the groove.

=499.= =To Make the Star-Wheel Sink.= This is easy on the lathe, the requisite degree of eccentricity being given to the barrel-cover by means of the pump-center.

=500.= =The Cover: Form of the Groove.= As in making the barrel, a thick ring must be left at the middle of the cover to be afterwards removed.

[Illustration: _Fig. 231._]

Fig. 231 is an enlarged figure to show the mode in which a cover is held in its groove. The two are so formed that the cover shall pass into the recess with the least possible resistance, and yet be held firmly without a risk of rotation. It is, nevertheless, a good precaution to fix a pin in the rim so that it shall prevent such an accident.

=501.= =Barrel Hook.= It is necessary to observe that a certain amount of caution must be exercised in regard to the barrel hook, for at least three-quarters of those met with are badly made. A large hook, projecting far into the barrel, as often occurs, occupies a needless amount of space, and at times occasions the breaking of the spring. One that is badly formed or does not project sufficiently allows the spring to escape. A hook should project rather beyond the thickness of the spring; if too thick the spring will be weakened at its eye; if too thin, it is liable to give when the pull of the mainspring is exerted on it.

The circumference of the barrel must be drilled through exactly midway between the bottom and the groove, in a direction that is slightly inclined, so as to resist the pull of the mainspring. A thread is cut in this hole with a conical tap, arresting its advance just before the full threads are reached, in order to make sure that the brass screw to be subsequently inserted shall hold firmly. Then tap the brass wire from which a hook is to be made. Allowing a length to project beyond the screw-plate equal to about one and a half times the thickness of the mainspring, file the two sides flat, round off the point, inclining it slightly backwards, and form the hook with a fine screw-head slitting or other suitable file; then remove the wire from the screw-plate and hold it in a pin vise.

[Illustration: _Fig. 232._]

The angle _a_ (C′, Fig. 232) is now filed down so as not to project within the barrel; any burr that might interfere with its introduction is also removed and the hook is then screwed into its place. It will be easy to ascertain whether the various heights, etc., are correct before screwing it tight home. Then screw the hook into position so that it requires the application of some force in doing so and cut off the external portion level with the surface of the barrel, employing a sharp cutting file. But if it appears necessary to withdraw the hook to make any alteration, this should be done before bringing it to the final position.

Some watchmakers do not take such precautions; they fit a piece of hard brass wire to the hole, beveling off the end that is to form the hook, then cut off the wire nearly flush with the outer surface of the drum and, resting the back of the hook against a piece of steel, give a blow with the hammer so as to bend the point of the hook. But this method, although expeditious, is not the best and it does not always succeed.

=502.= =To Repair a Barrel.= When the play or the end shake of the pivots is considerable, bush the holes with bushings turned on a smooth taper arbor. They must not be riveted roughly, as there is a danger of distorting the bushing or of causing the bottom of the barrel to “cockle.”

If there is any fear that the bushing will be thus distorted or that the barrel will not run true after the operation, it will be well to employ large bushings in which the hole is less than that ultimately required. Then center from the circumference and enlarge the hole, at the same time truing it.

Some practical watchmakers, if the bottom of the barrel is thin, or if special solidity is requisite, fear that the bushing may become loose; they, therefore, enlarge the barrel-hole and make it square; then bush it with a piece of plain brass, and having centered the barrel by its circumference in the lathe, drill a central hole.

It is hardly necessary to observe that, when the holes in both barrel and cover require to be operated upon, a pin should be fixed so as to prevent the latter from rotating in its groove; so that before finally removing the barrel from the lathe, the cover can be put in position to have its center accurately adjusted with a long pointed graver.

=503.= =A Barrel That Does Not Run True.= The remedy for this has just been indicated: enlarge the holes and rivet in them bushings that are either plain or have only very small holes. The two holes can then be accurately centered with a slide-rest and cutter of the requisite form.

[Illustration: _Fig. 233._]

It is a very simple process, and yet there are some workmen who, either from not possessing a lathe or ignorance as to how it should be used, set the barrel on a screw arbor, and, after having topped the teeth, round by hand those teeth which have been touched. This method of procedure is longer than the former and gives results that are worse; moreover, since the screw-arbors are rarely themselves true, especially in regard to the cones, which will be found to have a play on the axis, it is far better to set the barrel in cement on an arbor of the form C, Fig. 233, on the center pin of which the barrel-hole fits without play; the middle of plate C must not be too thickly coated with cement.

=504.= =Barrel Out of Upright.= Several methods may be resorted to for adjusting a barrel that does not turn flat on its axis. Assume that the holes are not too large, for it has just been shown that by bushing the holes and truing them on the lathe, it is always possible to ensure that a barrel shall be true on its axis.

To true it without renewing the holes, first try turning the cover round in its groove by successive short stages, and test its truth each time; the arbor being clamped in a pair of sliding tongs and a card held close to the teeth. If, after the entire circumference has been tested, no point is found that satisfies the requisite conditions, the edge of the cover must be gently hammered (a piece of silver paper being first laid on the anvil so as to avoid marking the gilding) on the side at which the teeth pass farthest from the card and the effect of the operation must be tested. This hammering should be done very carefully and little at a time, and if too great a strain is put on the cover to force it into the groove, some metal must be removed from the side opposite to that at which the hammering occurred. Hence, if the one side is too much extended in the first instance, so that a large amount of metal has to be removed from the opposite side, the operation is liable to be unnecessarily long and difficult. It is hardly necessary to observe that we are here referring to the modern form of going-barrel, in which the cover is on the opposite side to the teeth; in the older form, where the reverse is the case, the opposite edge of the cover must be hammered.

Sometimes a barrel that runs true on its arbor is found to incline when mounted on the plate: such a fault is due either to the barrel holes being too large or to the sink that receives the ratchet not being parallel to the plate. This sink must be trued in the lathe while in position, screwed to the plate of the watch.

[Illustration: _Fig. 234._]

=505.= =To Adjust a Post or Curb in Position.= Make a small punch, a front and side elevation of which are shown at _p p_, Fig. 234; harden it and let it down to a yellow temper at the point. Now fix a flattened ball of lead in the vise, the upper surface of which is so formed that the portion of the barrel that is to receive the hole for the post may rest securely. There is no necessity for the entire barrel to rest on the lead. Place a small piece of mainspring, _q_, within the barrel against the circumference, where it will be maintained by the punch _p_, which will also hold the barrel steady on the lead block. Then give a moderate blow with a heavy hammer on the head of the punch, forcing its point through the barrel.

A burr will be produced outside the barrel, while there will be a corresponding depression within, especially in front of the hole. To secure clean edges, pass a file over the external projection, but only sufficiently to remove its crest, and, resting the inside of the barrel on a lead block, drive inwards the metal that projects; then pass the punch through in a direction opposite to the first and of course with less force. Remove the burrs and repeat the operation first on one side and then on the other with gentle blows of the hammer, removing the punch by hand. Finish with a very fine file, which will entirely remove any external burr round the hole, and one cut with a slide-rest cutter in the inside, followed by charcoal and oil.

A watchmaker that has never performed this operation will do well to experiment with the punch on a small plate of brass, or, still better, on a worn-out barrel.

To insert the post, coil up the mainspring in the winder so as to be able to introduce a slightly conical piece of steel or brass between the two last turns of the spring and near to the hole. Place the post in position and hold it and the spring while the wedge that keeps the coils apart is removed. If the opening thus secured was found to be insufficient, it might be increased by introducing a screwdriver, which is held down until the post is inserted. The making of this curb, shown at _b_, Fig. 234, will offer no difficulty.

[Illustration: _Fig. 235._]

=506.= =Stopwork.= If the pitch circles of the finger-piece and star-wheel of several Geneva stops be measured, it will be seen that three different proportions may exist (Fig. 235), in which the former is less than, equal to, and greater than the latter respectively.

When the finger-piece has a greater diameter, as at _d_, it will oppose an increased resistance to the hand in winding, but the direction of its pressure against the stop will be much below the center of rotation of the star-wheel, because the finger is necessarily very short.

When the finger-piece is very small, as at _a_, there will be less resistance opposed owing to any want of freedom of the star-wheel, and the pressure against the stop will be more nearly tangential, the finger being relatively long; but more care will be required in the construction and, for a given force applied to the key in winding, there will be a proportionately increased pressure against the star-wheel axis.

Inconveniences thus increase in proportion as either piece is enlarged as compared with the other, and the best proportion is secured by making the two diameters equal, as shown at _c b_.

The stud on which the star-wheel rotates should be cut square or, preferably, slightly conical downwards.

=507.= =To True a Star-Wheel.= The form of a star-wheel can be adjusted on the lathe, on the tool shown in Fig. 208, using a cylindrical mill-cutter and adding a stop so that the branches of the tool are always brought to the same distance apart.

Star-wheels can be bought of the material dealers, but they are not always equally divided; indeed, some exist that have been merely punched in the punching press. Hence it follows that many of them are characterized by at least one of the following faults: teeth of unequal length, or with their concavities of unequal form.

[Illustration: _Fig. 236._]

When the teeth are well formed and finished at their ends, but of unequal length, this arises from the star-wheel having been badly centered during the operation of cutting; it must then be re-centered. Take a small brass plate H, Fig. 236, and drill a hole at its center, with a notch at the edge, _a_, to receive the convex tooth without shake. Now place the plate in the lathe and turn out a sink to receive the star-wheel and hold it firmly. The convex tooth will then drop into the notch and the wheel should project a little above the face of the plate. Now release one dog, and, having gripped with it one tooth of the wheel, take a fine-pointed graver and true the central hole and the sink that receives the screw head, taking care only to remove a small quantity of metal at a time.

If the workman has not considerable experience in using the lathe and fears a derangement in releasing and again tightening the dog, he had better remove the plate, cement the star-wheel in position and replace it, when it can be re-centered with the pump-center.

=508.= =To Make a Finger-Piece.= After having drifted the square hole in the center of a steel disc of suitable dimensions, and traced out a line to mark the circumference of the disc and the end of the finger, drill two holes a little beyond this line, leaving such a space between them as to ensure that the base of the finger shall possess sufficient strength; but these holes should be drilled so far in towards the center of the disc that freedom is left for the corners of the star-wheel teeth during its rotation. The head of the finger is at first left so as to exactly fit the spaces of the wheel without play, this being subsequently given with a fine file and in the smoothing.

File the circumference all round so as just not to touch the line traced out; then, putting the disc on an arbor, hold a fine _barrette_ file against the edge, and cause the arbor to oscillate backwards and forwards, the file coming in contact alternately with each side of the finger. This smoothing of the rim will materially facilitate and abridge the final work with the graver. The corner of the rim on one side of the finger having been finished off with the graver edge, reverse the arbor between its centers to treat the other corner in a similar manner. A finger-piece made as here explained will be found to be very true.

Some watchmakers, when it is possible, finish the circumference after it has been adjusted on the barrel-arbor itself; but as a rule this is not necessary.

The slit that receives the pin may be cut as follows: File a square piece of brass to fit the hole in the finger-piece, cut a notch across the end with a screw-head file, and insert it in the square hole. Having centered a flat cutter, the thickness of which is equal to that of the slit to be cut, on a taper arbor, place this in the lathe; resting the brass horizontally on the T-rest (which had better be at the back of the lathe, so that the progress of the operation may be more easily observed) and present the notch to the cutter.

=509.= It will be understood that the foregoing details relate to the method to be adopted in making the finger-piece by hand, but it is very easy to arrange an addition to the ordinary lathe, with or without a throw, for rounding or truing the circumference with great

rapidity.

Having mounted a circular mill-cutter on an arbor in a chuck, as seen at R, Fig. 233, replace the =T=-rest by an upright that has a shoulder, and is truly cylindrical, and of a diameter to fit the support without shake; the finger-piece, D, is fixed to its upper end by a cone and nut, as in the screw-arbor, or by any other means. A lever _I_ is adapted to the vertical rod, so that it can be rotated between two stops on the lathe-bed; such stops are, however, not always needed, because by employing a thick cutter that is smooth on the face there is no danger of damage to the finger. At the same time, if there are no stops, considerable care is requisite in the smoothing and polishing to prevent the sides of the lap touching the finger. This can be polished afterwards in a very short time by using a lap that has been turned on the edge to fit the notch. It is useless to enter into further particulars, as the little appliance or one of an analogous description can be easily made.

The apparatus shown in Fig. 195, and described in article =402=, could be employed for such a purpose.

=510.= =To Make a Clock Barrel.= A strip of soft brass, thicker than the circumference of the drum is intended to be, is coiled into a circle rather less in diameter than the required barrel, on a cylinder of hard wood, either by pressure between the jaws of a vise, or with a mallet or hammer. The two edges, after being carefully cleaned, are soldered with silver solder or brazed, while they are held in position by a piece of binding wire wound round the drum.

Placing this ring on the nose of a beak-iron, harden it by gentle blows, so as not only to harden the brass, but also to increase the diameter and make a true cylinder.

Chuck it on a cylinder of hard wood in order to turn the two ends square, and form the edge that is received in a groove cut in the bottom of the barrel; the bottom is then soft soldered in position. In the older barrels that contained very strong springs, it was often the practice to leave tongues projecting round the drum that entered holes in the bottom and were riveted on the other side.

The barrel may be cemented to a large wax chuck that has as its center a short arbor tapped and provided with a washer and nut, or it may be gripped by its base in the universal head, and the surfaces, etc., finished.

Some of the details given in regard to a watch barrel are applicable here.

The drum is now no longer made by bending a strip of brass, except in country towns, because brass tubing is always to be obtained in cities at metal warehouses, which only needs to be cut into rings of the requisite length.

=511.= =To Make a Barrel-Arbor.= If the metal is in the rough and has the scale on, it must be cleaned either on the stone or with acid. The following method of procedure has been proved in practice to be expeditious:

When the arbor has been turned to shape with the graver, smoothed, and almost polished, it is placed in the barrel and should rotate when in position, but with considerable friction. Then make the two squares as explained below (=513=); and, after smoothing that which receives the finger-piece, set this latter in position on the arbor and see that it does not descend quite to the shoulder. Then replace it by a worn out finger-piece, or by a copper disc that is cut so as to allow of the insertion of the pin in exactly the same position as is required by the finger-piece to be definitively used. It is then easy to drill the pin-hole from either side of the square and to smooth it with a fine broach. Each time that the arbor has to be inserted in the barrel, great care must be taken to remove any burr, as it might damage the barrel holes.

Before hardening the arbor, cut in it two grooves of moderate depth at the points at which the ends must be broken off. Such a practice has two advantages: 1. The two waste points of the arbor can be removed and each end partly formed without employing a file, an arrangement whereby it is possible to maintain in the arbor a maximum of hardness, at least at the winding end. 2. If the arbor is distorted, it will not be in the body, but from the points at which these cuts are made. If any distortion occurs, the blow-pipe jet can be directed on the points, which are then removed with a file before the final polishing.

=512.= To harden the arbor, place it in an iron tube and surround it with powdered charcoal which is pressed down, having previously been well dried. When the whole has been heated to the requisite temperature, throw it into water, and, if the precautions already explained under hardening are adopted, the arbor will be found to be smooth and clean and without either scales or blisters on its surface. Clean and polish it; this latter operation will give the proper freedom to the pivots, although it often happens that a touch with a broach is required in the two holes.

[Illustration: _Fig. 237._]

The bevelled groove within the ratchet teeth is polished by rotating the arbor while a small steel plate, perforated at its center and of the form shown in plan and section at Z, Fig. 237, is held by the hand against the groove. The shoulders can be easily and rapidly polished in the tool represented in Fig. 44.

[Illustration: _Fig. 238._]

=513.= =To Make the Squares. To Make Drifts.= The tool shown in Fig. 238 is used. On the plate P, which is at right angles to the foot S, is fixed a frame that carries two hard steel rollers, _c_ and _d_, the edges of which are extended to form a guide.

A bent finger _b_ is hinged on a screw on the side of the plate, and has a hole _j_ drilled in it, which is continued for a short distance into the plate P.

The following is the method of using the appliance: Fix to the arbor a disc, indicated by dotted lines, in the circumference of which are four equidistant notches to receive the nose of the finger _b_. The rod S takes the place of the =T=-rest and the arbor is placed between the centers of the lathe. As S can be raised or lowered to any position and the runners can be moved laterally, it is easy to bring the point at which the square should commence to correspond with the line _n n_. The finger _b_ having been inserted in one of the notches of the division-plate, reduce the arbor with the file L. Move _b_ to the next notch, and repeat the operation, and so on with the other two sides.

If there is any danger of the finger not maintaining a sufficiently firm hold of the plate, a tight-fitting pin can be inserted in the hole _j_.

At first the arbor should be filed away less than is actually required, and the only adjustment necessary to ensure this is the raising of S to a suitable height. No difficulty need be experienced in this, but, if any doubt is entertained, a screw may be supported from the bed of the lathe, terminating in a rod that passes through the plate P, as indicated at _t_ for example, thus securing perfect regularity in the upward and downward motion of the system.

If a tapered square is required, it will be sufficient to slightly incline the frame by means of two screws _v i_, placed near its left-hand edge with their ends resting on the plate P.

=514.= =To Drill Exactly Through the Center of the Arbor.= Of course, if the old arbor-nut is available, it will afford the best guide for performing this operation, and, if the arbor is tapped, such a hole will not be required. But when neither of these conditions is satisfied, the workman will have two slight difficulties to overcome: the drilling of the arbor and its nut exactly in the center and parallel to the plane of the ratchet. By adopting the following method, he can easily satisfy these conditions:

[Illustration: _Fig. 239._]

=515.= Take a brass disc D, Fig. 239, turned smooth on its two faces. Enlarge its central hole until the barrel-arbor enters it to such a distance that a blow of a mallet will drive it up against the ratchet where it should hold firmly. This disc is chucked on the lathe and a groove is formed that passes exactly through the center. Ascertain by means of a douzieme or a thickness gauge whether the thickness of the disc, measuring from the bottom of the groove to the under side, is equal to the space between the shoulder of the arbor that corresponds to the outside edge of the barrel hole, and the point at which the hole should be drilled. If the thickness is excessive, diminish it from the under side; if, on the other hand, it is not sufficient, fit some thin discs on the arbor, and then force the brass disc to the position thus determined upon. It is hardly necessary to add that when this is done, holes must be drilled to some depth on either side of the arbor, using a drill that does not shake about in the groove although quite free and inclining slightly downwards so that the hole shall not be above the point determined upon, namely, the bottom of the groove. Continue the drilling until the two holes meet, the drill being maintained, during this part of the operation, parallel to the face of the ratchet.

[Illustration: _Fig. 240._]

=516.= If the workman is not provided with a tool for cutting the groove exactly in the axis of the disc, the accuracy that is so essential can be ensured as follows: A brass rod G, Fig. 240, is divided into four at the end as near the center as possible by means of a fine saw or a file that only cuts with its edge, which will be used to form the groove. Set the rod G in the lathe, a center of the form _f_ being inserted at _b_ where the slits cross, and turn down the rod G _b_, although only a little metal should need to be removed, until it enters the hole in the brass disc and projects a short distance on the other side. It then only remains to insert in one of the notches of G _b_ the cutting file or the saw previously used, to form a groove on the surface of the disc that passes

exactly through its center; it is to be remembered that the saw, etc., must only cut with its edge, and should enter the notch with a very slight friction, sufficient to indicate that it fits without play.

=517.= =The Arbor-Nut.= The usual practice is to make the diameter of the nut equal to one-third that of the inside of the barrel. With thick springs of but slight flexibility it must be larger so as to avoid overstraining the innermost coil, and, conversely, with a very thin spring it is diminished, rendering the employment of a longer spring possible. When the nut is too small the spring must be made long, and, by setting up the stopwork, a coil of the spring can be maintained always on the nut.

=518.= _To drill the nut along a diameter._ By means of the rod G, Fig. 240, draw a straight line to indicate a diameter of the nut. This line will serve as a guide for marking two points opposite to one another on the circumference, round which a circle has previously been traced with a graver. The points should be marked so deeply as to ensure that the drill does not displace itself in the initial stages of the drilling; with a little caution, and using a glass, very little difficulty will be experienced in ensuring that the points are in a right line. One of the two following methods may be employed for drilling the nut:

[Illustration: _Fig. 241._]

1. Prepare a brass block of the form shown at _f p f′_, Fig. 241, the space A being cut away, and the end _p_ provided with large-headed screws, shown at _v_, _v_, in the plan. The two faces, _f_, _f′_, must be parallel to each other, and at right angles with the face _p_, a condition which can be easily satisfied by means of the lathe, the face _f′_, for example, being turned towards the headstock, and the dogs introduced into the space A; the opposite face _f_ is then trued with the slide rest. In the vertical face _a a_ make a round hole, through which a pointed center passes, being pressed forward by a spiral or other spring, and the point corresponding exactly with the line _a a_ traced on the face of the brass; of course the axis of this center must be at right angles to the same line. A small block may be inserted within the space A to prevent any flexure of the arms.

An inspection of the figure will make clear the manner in which this little tool is to be used. Having fixed the nut on the face _p_ by the screws _v v_, so that the two points on its circumference coincide with the line _a a_, the whole is placed in the drilling tool with the dogs pressing either on the upper external face or in the space A. After the block is fixed, ascertain by rotating the uprighting spindle that its point coincides in all positions with the top mark on the edge of the nut, and drill as usual. Drill one side, invert the block, and proceed in a similar manner to drill the other.

The little appliance above described might be simplified by being made of the form shown at E, which would require to be reversed when the second hole is about to be drilled.

=519.= =To Polish the Inclined Faces of Ratchet Teeth.= Set the ratchet in slow rotation by means of the foot-wheel, and bring a strip of spring covered with coarse rouge and oil against it from the side, resting the strip on the =T=-rest. In a very short time the teeth will be rounded and polished. This process is similar to that adopted at the present day for polishing the inclines of cylinder escape wheels in the lathe. The position of the polishing spring and its inclination must be determined upon by trial, so as to make sure that the entire surface of the tooth is acted on.

[Illustration: _Fig. 242._]

=520.= Another method is to make a small boxwood lap, and arrange it as shown at M, Fig. 242, so that, when caused to revolve on its axis, which may be more or less inclined, it is brought into contact with the ratchet wheel with its axis, as indicated by the figure. The teeth will cut into the wood, and trace out a helix, as seen at M′, and the lap, passing successively into the ratchet teeth, will cause it to revolve rapidly. When the groove is deep enough, apply some coarse polishing rouge to the surface of the drum; after a few rotations the faces will be found to be polished.

The arbor and lap may be arranged in either of two ways.

Mount the lap between the centers that carry the cutter in a wheel-cutting engine and support the barrel-arbor opposite to it in a vertical direction between the chuck and the bent arm or “gallows” used to fix a wheel while cutting its teeth.

A watchmaker who is not provided with this tool must chuck the lap in the lathe, then mount the barrel-arbor in such a carrier as is shown at _p p_, Fig. 242, and, resting its base on the =T=-rest, hold the ratchet against the lap, determining the most suitable height and inclination by trial; this, he will find, can be easily done.

=521.= =To Polish the Circular Groove in the Ratchet.= It takes a long time to accomplish this by using first, an iron polisher with oilstone dust, then one of copper with rouge and oil. The operation can be performed more expeditiously by using an iron runner, as shown at B, Fig. 243. The end is rounded to correspond with the groove; and the hole, which is indicated by dotted lines, should be large and funnel-shaped, so as to avoid contact with the corners of the winding square when a see-saw motion is given to B in the polishing.

[Illustration: _Fig. 243._]

The arbor being cemented to a chuck in a lathe, hold the end _o_, charged with oilstone dust or rouge, in the groove, and, while the arbor revolves, rotate the spindle B in the hand, at the same time giving it a see-saw motion as above mentioned. A very little practice will be required to do this.

=522.= =Repairing a Barrel-Arbor.= Cement the arbor _a a_, Fig. 244, to the lathe chuck, turn down the ratchet, removing its teeth and thus diminishing its diameter by about a third, as shown at _n n_; then reduce the thickness to a half, turning it down on the side next to the winding square, and continue this square down to the flat disc that remains, taking care that no shoulder is left at the angle between the two. The arbor is now in a condition to receive the new ratchet which has to be fitted.

[Illustration: _Fig. 244._]

Adjust a flat ratchet _r r_ like those used on the barrel-arbor of a fusee watch, which must be of the thickness and diameter of the original ratchet, so that it exactly fits the winding square; turn a sink in it, as shown by the dotted line, to receive the disc already formed; and, if the hole fits the winding square freely but without play, and this square is carried down to the disc, the dust cap _c c_ will maintain the ratchet in its position as effectually as though it formed one with the arbor.

By adopting the above method, which does not occupy much time, it is often possible to avoid making a new arbor when all but the ratchet is sound; and if this portion should again wear out, the necessary repair is still further simplified.

We are assured that arbors repaired in the above manner showed no signs of wear after fifteen years, except that the square in the ratchet was a trifle enlarged, though not sufficiently to interfere in any way with the efficiency; moreover, in modern watches, the winding square is generally long, so that the ratchet can be left somewhat thicker at the center and a corresponding sink cut in the under side of the dust cap to receive it.

=523.= =To True a Barrel-Arbor that is Coned Inwards or too Large.= Cement the arbor firmly to a chuck as shown at C, Fig. 245. With care it will be easy to make the part _e_ run true. As a rule, but very little metal requires to be removed to make _e_ cylindrical or conical in any desired direction, and it will generally be sufficient to finish by polishing with an iron polisher and oilstone dust or coarse rouge and oil. Use a narrow polisher that only bears on the end of _e_, giving it a double movement, straight forward and in a half circle towards one side; or else use a broader polisher, supporting it on the =T=-rest. By inclining this, the iron can be prevented from touching _e_, except near its extremity. It is unnecessary to add that when the arbor has been made cylindrical or coned in a given direction a suitable polisher, bearing on the entire length of _e_, can be used.

[Illustration: _Fig. 245._]

Either of the two following methods can be adopted in the place of that above explained: Support the winding square end of the barrel-arbor in an eccentric runner; let the opposite end run in a small coned hole in the end of a steel runner, which must be polished and hardened so as to prevent the corners of the square that receives the stop-finger from wearing it away; now apply coarse rouge until the fault no longer exists and follow with fine rouge to complete the polishing.

If not provided with an eccentric runner, it will be sufficient to take a tight-fitting key, drive it on with a blow of a hammer and file a point at the tapped end so as to be in the axis of the barrel-arbor. Having attached a ferrule to this key, place the whole between the runners and proceed as explained above.

=524.= =To Renew a Worn Winding Square.= The best plan is to make an entirely new arbor; but when this cannot be done, as, for example, on the ground of expense, the following method of repair may be attempted: Direct the blow-pipe flame on to the square while holding the body of the arbor in a pair of pliers, so as to prevent its being over-heated; and round off the corners of the square, leaving the diameter no greater than is necessary for strength, and tap it with a screw-plate. Now drill a hole at the end of a piece of round steel of somewhat greater diameter than the original square, and form an internal screw by means of a tap made in

the same hole of the screw-plate as was used for the arbor; the end of the tap should be tapered and with good cutting edges.

If the arbor is the full length allowed by the case, reduce the length slightly and screw on the small steel spindle, tapped to the right depth. It must not be screwed quite down to the ratchet, although intended ultimately to come into actual contact. After having thus tested it, form the square, which will naturally be rather larger than the original, and cut a deep groove with the graver at the point where the square is to be broken off, but, before breaking it, harden and let down to a blue or violet temper; then smooth, polish, and screw finally on to the arbor. If this last operation does not result in the square breaking away, grip the spindle in a vise, and, taking the square in a pair of long-nosed pliers, break it with a sharp blow. It only remains to finish off the end in a screw-head tool.

THE MAINSPRING.

=525.= A free and uniform action of the mainspring is one of the primary conditions that have to be satisfied for ensuring a continuously good rate.

=526.= _To make the eye in a Mainspring._ Every watchmaker knows that this is commonly done by means of a mainspring punch; but in its absence a hole can be made by hammering a pointed punch one or more times through the end of the spring after it has been softened, and, after filing away the projecting metal, the hole is broached out or enlarged with the point of a graver and finished with a rat-tail file, taking care that the corners are rounded off so as to avoid the risk of cracks.

=527.= _To reduce the height of a Mainspring._ This and the following method are only to be resorted to when a new spring cannot be obtained.

Introduce the spring into a barrel of less height than itself and wear the steel away by rubbing it on a hard surface charged with oilstone dust, keeping it constantly rotated between the fingers. When the reduction is sufficient remove the spring and draw-file it, so as to round off the two edges; then clean the entire surface.

=528.= _Selecting a Mainspring: Adapting it to a Fusee._ The spring that is characterized by the most uniform uncoiling and the least difference between the force exerted when fully and only partially wound up will generally secure the most constant rate. In selecting one for a going-barrel watch, or in adapting to a fusee, the adjusting rod, shown in Fig. 246, and described in article =530=, is used.

THE FUSEE.

=529.= At the outset, we would state the three characteristic properties of a fusee that have led to its adoption and retention in high-class watches and marine chronometers: 1, it equalizes the motive force; 2, it enables us to use a _tapered_ mainspring, in which the uncoiling takes place in the most advantageous manner possible; and, 3, it secures a longer period of going.

[Illustration: _Fig. 246._]

=530.= =To Adjust a Fusee to Its Mainspring.= Set the barrel and fusee in position in the frame, with the mainspring and chain carefully hooked in their places, and the former set up about half a turn, and grip the fusee square in the clamp, _d n_, of the adjusting rod, shown in Fig. 246; then wind up the mainspring by rotating this lever with the hand until arrested by the stopwork. Now slide the weight _m_, which is held by friction and a light spring, along the rod until a point is reached at which the lever just neutralizes the force of the mainspring, so that the whole rests in equilibrium when left to itself. Rotate the rod backwards by half turns at a time. If equilibrium is maintained to the end, the fusee is well adjusted. But when this is not the case, it will be found that the weight of the lever is too great or too small; showing that the radius of the fusee is either too small or too great. Adjust the lever so that it balances with the radius of the fusee, which is thus shown to be most deficient, and at all other points along the thread of the fusee more metal must be removed to an extent indicated by the experiment.

When not provided with a fusee engine, it is a common practice to use the ordinary lathe, and an equaling file smoothed on its two faces; or a templet might be adapted to the =T=-rest of such lathe.

If the irregularity observed is but slight, it is advisable not to touch the fusee; because, in the great majority of cases, an equipoise can be arrived at by altering the degree to which the spring is set up. Thus, if the weight is too heavy for the lower coils of the spring, set it up more, so as to increase its tension; in the converse case, of course, it must be let down. By trying several springs,

especially if they are of different manufacture, it will very often be found possible to secure a sufficient degree of uniformity without there being any occasion to re-cut the fusee.

CHAIN.

=531.= =To Ease a Chain.= When the links are rusty or not sufficiently supple, the chain should be placed in oil and left there for some hours at least. Round off the edge of a boxwood block, cut a groove across this edge, and clamp the block in a vise; then place the chain like a saddle in the groove, so that it hangs down on either side. Applying oil liberally to the wood, take an end of the chain in each hand, and pull it backwards and forwards in the groove, renewing the supply of oil at intervals. When perfectly flexible, the chain must be cleaned with benzine, or, after soaping, wash it in water and leave for some minutes in alcohol. After being dried, it is dipped in fine oil and dried in a clean linen rag free from fluff, pressing the rag against the edge. A chain treated in this manner will be found to remain supple for a long time, and it will not be liable to rust.

=532.= =Riveting a Hook, Etc.= When riveting either a hook or link to a chain, it is very necessary that the end of the rivet be cut or filed quite square; for, otherwise, the blow of the hammer will bend the rivet, so that the chain will not be square on the barrel, neither will the riveting be firm.

WHEELS.

=533.= =To Rough Out a Wheel.= The sheet brass having been prepared in the manner indicated in article =103=, one face is smoothed with a file, followed by oilstone dust; the plate is then set up in the lathe, to true the other face with the slide rest. On the smoothed face trace out the rim and the crossings. These latter can best be marked out on the dividing plate, or _grammaire_, already explained in article =343=.

[Illustration: _Fig. 247._]

After drilling the small holes, _a_, _c_, etc., Fig. 247, at the corners, cement the wheel to a plate that is perforated to permit the use of the pump center, and remove the metal between the crossings by first turning the sinks indicated by the shaded disc _s_ with the slide rest, and subsequently cut the groove _i i_. Now center the wheel in the lathe, and trace the arcs _a c_ with a fine graver, moving the face-plate backwards and forwards in the manner referred to in article =364=.

Remove the wheel from the plate, and finish off the spaces with a file. Two files will be needed for forming the angles; one a flat barrette file, with the corner beveled off and smoothed to nearly a right angle, to go against the rim of the wheel; and the other a taper file, with faces of the same curvature as the inside of the rim, its two edges being inclined at rather more than a right angle and smoothed carefully. If these simple precautions are not taken, there is a risk of cutting through the arms or making them too narrow.

Many of the details in the following article, although specially relating to a balance, will be found applicable to the construction of other wheels.

=534.= =To Make a Plain Balance.= The round plate of which the balance is to be made must be hammered with the greatest possible care, and of a thickness but little greater than that of the finished balance (=103=). Smooth one face and cement it either to a perforated plate through which the pump center can reach the balance (if the universal head is to be used), or on the chuck of an ordinary lathe, or on the wax chuck C, Fig. 233. Hollow the middle portion with the slide rest cutter or hook tool, according to the kind of lathe used; but, whichever it be, it must be very well set, and only remove a small portion at a time. The application of an excessive pressure will produce a kind of rolling action, which will induce a tendency in the arms to bend. Remove the metal between the rim and boss until its thickness is diminished by about a third; smooth this surface carefully, finishing with a piece of charcoal. The disc is now ready for crossing out.

Place it on the dividing plate (see article =343=) to mark out the three arms, and remove the metal between them, either in the lathe, as explained above, or by drilling a series of holes parallel to the arms and rim. These holes should be so arranged that they can be enlarged with a fine-pointed graver (while the balance rests on a flat wooden block or is cemented to it), and a turn with a sharp edged broach, or the passage of a thin rat-tail file should be sufficient to separate the useless metal. As a rule, the series of holes is drilled with the disc held against a wooden block, but the burrs produced on the under side by the drill prevent it from being maintained flat, unless they are removed after each hole is drilled, and this might occasion a distortion of the disc. It would,

perhaps, be better to cement the rough balance to a sheet of zinc; the color of the shavings would suffice to indicate whether the hole was through.

The arms and rim must be made smooth and even with nicely formed crossing files, the edges of which are smoothed to the most convenient angle, as already indicated.

In filing the crossings the balance should rest against a small block in the vise, and they are rounded while resting in a groove at the edge of a similar block, specially shaped for the purpose. This block is also useful as a support in finishing the angles between crossings and rim.

The under face of the balance is smoothed with oilstone dust; and the arms by drawing the polisher along them while the balance rests on a flat block; it is then cleaned and fitted on a very true arbor, as A, Fig. 233. This should pass through the center hole of the balance without play after a broach has slightly enlarged it, and the balance is clamped by a cap and three screws, _j_. It only remains to set the arbor in the lathe and polish the rim, first turning it to a half oval if desired. In the latter case the rim, after being smoothed, is polished first with coarse rouge on hard pith, and subsequently with fine rouge on softer pith.

=535.= If the arms of a balance are found to be too long, so that they curve, the rim must be lengthened by hammering with the greatest possible care; the inside and outside of it must then be trued on an arbor of the form A.

The boss at the center will be found thicker than is desirable; its height can be reduced with the balance merely adjusted on a smooth taper arbor, but it is necessary to observe that the balance and arbor must not be adjusted to each other by pressing or by rotating the balance with the rim held in the fingers. It must be pushed on or off the arbor by applying pressure at the center of the boss on one side or the other with a piece of hard wood resting firmly against the =T=-rest, while you cause the arbor to rotate.

Instead of the form of arbor shown at A, a screw arbor might be used, with its cone pressing against a cap, but the balance must always be carefully adjusted on the arbor, and this latter must run perfectly true.

=536.= =To Make a Number of Identical Wheels.= If it is desired to make a number of brass wheels of the same size and shape, the workman will find it much to his advantage to employ the punching machine. By adopting the following method he can make his own punches and bed-plates.

[Illustration: _Fig. 248._]

With a view to secure same length in the matrices that are used for forming the crossings, without augmenting the difficulty of construction, proceed thus: Each of the pieces V, V, Fig. 248, consists of two parts: 1. The star-piece, _a c b d_, of three, four, five or six arms, according to the number of crossings of the wheel. 2. The collar, V. The star-piece is of the same length as the collar, and is made in the wheel-cutting engine in the same manner as the leaves of a pinion. The punches, of which one is shown at P, are fitted by hand to the recesses of the star-piece, and then cemented in position; the whole is then chucked in the lathe and turned as one piece, so that its diameter is slightly greater than the interior of the collar. Now harden the star-piece, and temper it to a blue color. When cold harden the collar V _v_, and temper it to the same degree, but, while expanded by the heat in tempering, introduce the cold star-piece and drive it home. By proceeding in this manner, no subsequent hand fitting will be required. V _n_ must not be hardened.

Tools for punching the crossings of wheels are sometimes made on this system in which the disc of brass is fixed to a support that can be made to revolve by quarters of a revolution at a time, and a single punch serves to remove the metal by four separate operations. But as a rule it is better to use four punches together.

=537.= =To Repair Wheels.= When the teeth of a wheel are damaged, the only possible remedy is to provide a new one. If, however, a single tooth is broken, the following method can be adopted, on an emergency, for inserting a new one:

[Illustration: _Fig. 249._]

=538.= _To insert a new tooth in a wheel._ Cut a small notch in the rim of the wheel, shown at _a_, Fig. 249, which should be dovetailed if possible, and the two sides spread out slightly from the upper towards the under side, as indicated at _c c_. Cut a small piece of well-hammered brass, of the form B, so that the part _d d_ fits exactly into the notch in the rim. Now invert the wheel and grip it near to _a_ in a pair of long-nosed pliers, which must be held in the vise. Moisten the inner faces of the notch with

soldering fluid and, placing B in position, put particles of solder round its edge; holding the lamp beneath the nose of the pliers, the solder will presently melt, and a drop of the fluid should be added to facilitate its running into the joint. Cool the wheel and wash thoroughly, first with water and subsequently with alcohol.

It only remains to file both faces smooth and level with the rim of the wheel; then shape the tooth carefully.

By introducing B from the side opposite to that which is visible in the watch, and sloping the faces _d d_, to a less degree than _a_, the inverted wheel will present a recess to receive the solder; so that, on looking at the upper surface, at which the edges fit very closely, the joint will be scarcely visible.

=539.= _To true a wheel._ When the teeth are found to be in good condition, but the wheel does not run true, or one or more of its arms are strained, the fault can be corrected, in a case of absolute necessity, as follows:

Remove the pinion from its wheel. Enlarge the central hole in the lathe and rivet or solder in it a brass ring that is slightly thicker than the wheel, and perforated with a smaller hole than that required for the riveting. Now center the wheel from its circumference; increase the central hole with the slide-rest cutter, and turn down the two faces of the ring level with the wheel. Rivet the pinion in its place, after testing the truth of its riveting neck, when the wheel should be found to turn both true and flat.

If the wheel under repair is likely to be subjected to much force, at least two small notches should be left in the enlarged hole in the wheel to receive corresponding projections in the brass ring.

=540.= If the _crossings of a wheel are broken_ and the wheel cannot be replaced, it must be chucked in the lathe and the arms turned out with a graver, the inner edge of the rim being at the same time turned circular, and a step turned on this edge where the metal is to be left of half its original thickness.

Take another wheel of the same size and thickness, or a plain disc, and turn it of the same diameter as the outer ridge of the step; reduce its thickness at the edge by one-half and a disc will thus be obtained with a ridge round the edge corresponding exactly with that of the wheel, and the one will fit in the other. They are, of course, soldered in this position, care being taken to prevent the solder from reaching the teeth, and the old wheel will thus be provided with a new interior.

If the disc is made to fit closely on the upper side, a wedge-shaped ring being left to receive the solder in the manner explained in article =537=, the joint will be scarcely perceptible on the exposed face, even with a glass.

In repairing delicate wheels in any way it is a good precaution to cement the rim to the edge of a hole in a brass plate, so that only the arms or other part to be operated upon is exposed.

=541.= =To Make a Stem-Wind Wheel.= We will suppose that the old wheel is available as a pattern; if it is not, the several dimensions must be ascertained by calculation in accordance with the laws of depths.

[Illustration: _Fig. 250._]

Prepare a thick plate, and drill a central hole, fitting a steel pin into it as shown at _o d_, Fig. 250. The diameter of _d_ must be exactly the same as that of the pump-center in the universal head. Fit the wheel-blank R to the pin _o_ without play, and cement it to the plate. Remove the pump-center and insert _d_ in its place, clamping the plate P firmly against the face-plate by the dogs. By using well-sharpened gravers or cutters, the wheel may be rapidly shaped.

The pin might be forced in from the under side to the level of that face of the plate; and if it were perforated as shown by the dotted lines, it might be centered by means of the pump. Or the plate P might be made circular and centered from its circumference.

=542.= To cut the teeth on the circumference the wheel need only be fixed on the chuck of the wheel-cutting engine as usual by means of the steel cone. The crown teeth are cut while the wheel is firmly cemented to a pin-chuck like that used in turning it.

Other keyless wheels can be made on the same principle, and such modifications as may be necessary experience will suggest. Sufficient information in regard to wheel-cutting has already been given in =397= and following articles.

PINIONS.

=543.= =To Make a Pinion.= At the present day pinions of all sizes can be obtained of the material dealers, so that it is very seldom that a watchmaker is obliged to make one for himself.

In an emergency, however, he can adopt the following method for making one out of the ordinary drawn steel; but it should be added that, in all probability, some practice will be needed before success is arrived at. Cut a length of steel wire of suitable diameter about two-thirds as long as the files that are to be used for shaping the teeth. Turn it down to form the axis, leaving a block near each end equal in length to the required pinion, as if three pinions were to be made on the same staff. Then cut and round leaves on all, keeping the file always in contact with a leaf of each pinion. By proceeding thus the sides and roundings of the leaves will be maintained parallel to the axis, and there will be no risk of the pinion being barrel-shaped, as is nearly always the case when a short pinion is held in the fingers or rested on a block in the vise.

Proceed in the same manner in smoothing and polishing, using pieces of some close-grained wood, such as walnut.

It is much easier to make the pinion of the required form by means of a revolving cutter in the lathe, if the workman is not provided with a special tool for the purpose: the arrangement of the lathe is described in article =402=.

In some factories the leaves are cut in two operations: a cutter with plain fine saw teeth divides the circumference into the requisite number of equal parts, the leaves being subsequently made of the correct shape by a special cutter, the method of making which has already been very fully explained in articles =417-435=.

=544.= =To Determine the Size of a Pinion.= The following table is usually employed for this purpose. See also =562= and the following articles.

To give the approximate diameter of a pinion, the pinion caliper should include:

For 16 leaves, 6 full teeth; that is to say, measuring the distance between the two external faces; " 15 " rather less than 6 teeth, or 5 teeth, and just beyond the point of the sixth; " 14 " 6 teeth, measuring at the points. " 12 " 5 teeth, measuring at the points (or rather 4½ teeth); for a clock-wheel, 5 full teeth; " 10 " 4 full teeth; for a clock-wheel, 4 _squared_ teeth; For 9 leaves rather less than 4 full teeth, or 3 full teeth to the point of the fourth; " 8 " 4 teeth, measured at the points, minus a quarter of a space; " 7 " rather less than 3 full teeth; for a clock-wheel, 3 full teeth, plus a quarter of a space; " 6 " 3 teeth, measured at the points, or rather more; for a clock-wheel, 3 full teeth.

It is important to notice that these measures can only be regarded as a first approximation, and it is only by actual trial in a depth-tool that we can be certain that a pinion is correctly sized. By taking the measures in a micrometer, or other accurately divided gauge provided with a vernier, the work of selecting will be much abridged; but how long will it be before the generality of watchmakers will make use of these convenient appliances? The well-known wheel and pinion sector, although convenient, is not equal to them in point of accuracy, and is affected by an error in measuring a chord, not a true diameter of the wheel or pinion.

=545.= =To Increase or Decrease a Pinion.= The pitch circle of a pinion may be increased by reducing the thickness of the leaves in such a manner that their flat faces are continued further on to the rounding; conversely, a pinion may be decreased by carrying this rounding farther down towards the base of the leaf.

=546.= =To Decrease a Pinion Without Removing the Wheel.= Some watchmakers recommend that the wheel be removed from the pinion, and, after the necessary reduction has been effected and the leaves re-polished, again riveted on the pinion-neck. Very few workmen, however, can do this well, so that after the operation the wheel is seldom found to run true. If a new pinion cannot be procured, the old one must be reduced.

When a pinion that is too large is replaced by one that is smaller, it is necessary to take care that the hole in the wheel is well centered and not too large; in either of these cases it must be enlarged and bushed after being centered by the circumference.

=547.= =To Polish Pinion Leaves Mechanically.= It was formerly the custom to polish the leaves of a pinion, holding it on a block or between two fingers and traversing a strip of metal with oilstone dust backwards and forwards in each space for the smoothing, and a similar strip of walnut wood (with rouge) for polishing.

This method has long been abandoned in factories, where all pinions are polished in a machine.

We will proceed to explain a simple arrangement for polishing pinions in the ordinary lathe, but it is advisable first to describe one form of tool that is actually in use on the large scale for this purpose. The two only differ in their dimensions.

=548.= _Pinion-polishing Machine._ A frame B B, Fig. 251, supports at its upper end an =H=-shaped piece, of the same form as the cutter-holder in an ordinary wheel-cutting engine; but the arbor, instead of carrying a cutter, is provided with a wooden drum R. On the base of the frame is a plate P, which can be fixed by the screw E, and carries a second plate _p_ to serve as a bed for the slide, which supports the pinion to be polished freely between two brackets _a_, _a_. The plate _p_ can be set a little oblique and clamped by the screw _v_.

[Illustration: _Fig. 251._]

The machine acts as follows: Present a corner of a pinion-leaf to the circumference of R (which is caused to revolve by a cord passing round the pulley _n n_), the axis of the pinion being not quite at right angles with that of the drum, in order that the groove formed in the soft wood may resemble the thread of a screw, and so cause the pinion to revolve. When the groove is of sufficient depth, apply rouge if operating on a small pinion, and emery for a large one: after a few turns of R, the slide carrying the pinion being at the same time moved backwards and forwards, the pinion will be found to be polished. A better surface can be obtained by using flour emery.

The steel wheels of keyless work can be polished in the same manner.

=549.= The spindle of the screw E passes through a rectangular slot in B in order that the slide and its support can be moved parallel to the axis of R.

The grain of the wood must be at right angles to the axis of rotation of the drum, and a wood that is non-fibrous is preferable. It must evidently not be too hard, and, if too soft, the thread formed on its circumference will get rough, and often will suddenly change position. When the entire surface has been worn it must be re-turned smooth and cylindrical. The larger a roller is, the quicker it will polish and the less it will wear. Moreover, it will render a proportionately less amount of motion of the slide necessary. The root of the walnut tree is especially sought after, but, when this cannot be obtained, other woods can be used.

In factories where clock pinions are made, thin discs are employed in place of the drums. They are at least a decimetre (4 inches) in diameter, and very narrow at the edge, and can be re-turned with a graver when worn without being removed from the tool, if a =T=-rest be fixed in some convenient position.

The screw _d_ is for limiting the descent of the drum, but some workmen prefer to dispense with it, and, instead, hold the frame C C in the hand, pressing it gently against the pinion. They urge that the wood is never of the same degree of hardness round its circumference, and therefore must of necessity wear irregularly; by holding C C in the hand the pressure on the pinion can be more evenly adjusted, as it is possible to feel at once whether the drum is polishing or scratching.

The inclination of the slide to a plane at right angles to the axis of R is measured by the pitch of the screw formed on the drum. But in practice no special precautions are taken, and it is only necessary to incline the slide slightly to the right or left, until the pinion is found to revolve freely.

The drum may be from two to three inches in diameter, and, in order to ensure the same degree of hardness throughout the entire circumference, it is a good plan to make the drum of a series of wedges cut so that the grain in all radiates from the center. Beautiful polished surfaces are obtained in this manner.

[Illustration: _Fig. 252._]

=550.= _To polish a pinion in the ordinary lathe._ Various methods may be adopted, but the following is one of the commonest:

Support the pinion between the two centers _b_, _d_, of the pinion-carrier shown in Fig. 252, the form of which will be evident without explanation. Rest this carrier by the portion M against the =T=-rest, pressing it against the drum at the same time with one finger. Rotating the drum first by hand, make the pinion cut a groove varying the inclination until it is found to be correct, and, when sufficiently deep, charge with polishing material, and rotate it with wheel, at the same time moving the pinion-carrier backwards and forwards endwise. A little experience will give the requisite skill.

If the pinion is not held at a sufficient inclination it will scrape and will not revolve. If too much inclined, only the roundings of the leaves will be polished, the sides being left untouched. A well-formed groove will last for a long time.

=551.= =To Tighten a Cannon Pinion.= If it is simply slack it will be sufficient to increase the diameter of the set-hands arbor as described in article =336=. But if the cannon pinion is in the habit of working off this arbor when setting the hands, the arbor can be tapered a little downwards; or proceed as follows:

[Illustration: _Fig. 253._]

Drill a hole in the square that receives the minute hand in the position shown at _a_, Fig. 253, and also indicated by dotted lines at _c s_; now turn a groove round the arbor, also shown by dotted lines, at the point _n_, to correspond with the hole _a_. Insert a pin in this hole, filing it off smooth with the surface at the side at which it enters, and nearly level at the other side, to be hammered over just sufficiently to prevent the pin from working its way out. The cannon pinion will now be found to turn with the requisite degree of friction, and without any tendency to work up. It will last all the longer if both the pin and the groove in which it works are polished.

SET-HANDS SQUARE.

=552.= =To Make a Set-Hands Nut.= This is a small square nut pinned to the pivot of a solid cannon pinion that projects beyond the top-plate in some watches after passing through a hollow center pinion. This construction has been latterly discontinued, but it may be well to explain the mode in which such a nut can be renewed when necessary.

[Illustration: _Fig. 254._]

Take a rod of soft steel of a diameter half as large again as that of the square to be made. Drill a hole along its axis rather less in diameter than the set-hands arbor and cut off the ends a little longer than the square is required to be. Put this nut on an arbor and turn it flat on each end (although still a little long) and truly cylindrical. Having inserted a loose fitting coned brass wire of oval section into the nut, hold it on its side on an anvil. With a sharp blow of the hammer cause the cylinder to assume an oval form, so that the round hole is as seen at A, Fig. 254, this being the section of the end of the set-hands arbor itself. If the work has been carefully performed up to this point, the steel nut should now pass a short distance on to the arbor on applying a moderate pressure, and it will suffice to slightly alter the form of this latter in order to ensure a perfect fit. As there should be no shake, it is advisable that this adjustment be made after the nut is hardened.

File the two faces _d_ and _f_ parallel to each other and to the axis of the oval, reducing the total thickness very nearly to the amount ultimately required, then holding the nut in the pincers by these two faces firmly, but without scratching them (or it may be held by a rod fitted to the oval hole), form the square, removing all the metal that is beyond the two vertical lines in the figure. Then set it on an oval arbor and turn the corners down to the exact diameter required; pass the graver over the two ends so as to adjust the length. It will then be easy to finish off the square and round the lower end, holding the nut on a steel rod in a pin-vise. Drill the hole for a pin after marking its two ends on the nut as explained in article =518=, then, holding the nut so that it rests on its lower face, form a recess with a chamfering tool held in its axis; the form of this can be modified if required with the rounded end of a rod and oilstone dust.

Harden the square and temper it to a blue color; then smooth its faces and ends, and fit the square to the set-hands arbor. The hole for the pin must now be made through this arbor, taking care not to allow the square to rise out of its place during the operation. It only remains to polish the recess formed in the nut with a rod rounded at one end and rotated with a ferrule, and finish off the corners with a burnisher and rouge; the lower end is finished in the same manner as the head of a screw.

=553.= We have here considered the case of a new arbor, but, if fitting a nut to one that is already drilled, proceed as follows: Make the nut rather longer than necessary and drill a hole higher than the point at which measurement shows it ought to be; then remove metal from the lower face until the two holes coincide. The work is simplified if the nut be made of the correct height at once and, instead of drilling a hole, a slit be formed as in the head of a screw, the bottom of which must correspond with the lower edge of the hole in the arbor.

=554.= =To fit the Set-hands Arbor to the Center or cannon pinion.= We have pointed out in article =364=, the objections to hammering the set-hands arbor so as to secure sufficient friction to make it hold in either of the pinions through which it passes in the ordinary form of watch. Tracing a spiral line on its surface is not much better, as the metal thus caused to project soon wears

off. A better method is explained in article =337=, but, when only a slight increase of diameter is needed, the following will suffice:

Roll the arbor on a hard flat wood surface with a file of medium cut, applying considerable pressure so that the arbor is forced against the file. If the pressure is sufficient and maintained long enough, a dead rough surface will be formed on it which will increase its diameter so that it will retain a small quantity of oil. It is well to roughen the surface rather more than necessary, subsequently passing a burnisher lightly over it until the arbor fits the pinion with sufficient friction.

As to the making of a set-hands arbor, it will present no difficulty to a watchmaker of even average skill in turning and filing.

PIVOTS.

=555.= =The Play Of Pivots.= It may be accepted as an approximate rule that the play of escapement pivots in their holes should be as follows:

In the cylinder escapement, about one-sixth the diameter of pivot.

In the duplex escapement, about one-tenth the diameter of pivot.

In the lever escapement, about one-eighth the diameter of pivot.

A large hole causes the pitching of the depths to vary with position, and a deficient play renders the escapement more sensitive to thickening of the oil.

The depth of a pivot-hole or the length of its cylindrical acting surface may be taken to vary inversely with its hardness. Thus a ruby hole is made less deep than one of brass.

=556.= =To Replace the Pivot of a Hollow Pinion.= It often happens that the pivot of a hollow center pinion is so deeply cut that it cannot be re-polished, in consequence of the careless manner in which too many examiners finish the center holes (=461=). If the pinion itself is found to be still in good condition, it can be made serviceable as follows:

Cement the pinion, with its wheel attached, firmly to the chuck of a lathe after having removed the two worn pivots, and, when it is accurately centered, increase the hole by means of a drill that is a trifle larger than the original pivots (see article =282=); in the hole thus enlarged and carefully smoothed insert a close fitting steel tube that has been hardened and tempered to a blue color, which must be smoothed and run true. The portion of this tube that projects on either side is then adjusted to the proper length, and it only remains to polish the pivots.

If only one pivot requires renewal, ascertain whether there would be sufficient hold with the hole enlarged through half its length, and proceed as already explained.

We have assumed that the shoulders of the original pivots can be made to serve again, but it often happens that the shoulders do not possess sufficient substance, in consequence of the hollows being cut too deep. In such a case it is hardly necessary to observe that the hole must be drilled larger, so that, after the tube has been adjusted, new shoulders can be turned on it.

=557.= =To Redress a Bent Pivot.= For this purpose some workmen merely use a pair of pliers or tweezers; others place the pivot in a slot of the Jacot tool, and press on it with a burnisher that has little or no cut, at the same time causing the staff to rotate. Either of the two following methods may be adopted:

Drill a number of straight holes in a plate exactly at right angles to its surface. Now introduce the pivot into a hole that it fits with very little play, and redress it by causing the staff to rotate, at the same time holding the plate in the hand. Caution is necessary since there is some risk of bending the pivot too far.

=558.= =Pivoting a Cylinder, etc.= This operation will not present any difficulty if the several heights are properly taken. See also the articles on Beaupuy files (=240=), and on compasses for measuring heights, etc. (=243=).

=559.= =Polishing Pivots in the Lathe.= Pivots are as a rule polished by metal polishers provided with suitable materials, and held in the hand; in Fig. 255, however, is given the design of a machine by which this work can be accomplished when the pivoting is done in the chuck-lathe, the pivot itself being free and unsupported by a runner.

[Illustration: _Fig. 255._]

The bed P of the instrument carries a wheel R which engages with a pinion on the axis of the polishing lap _m_. The wheel R is mounted on a clock stud passing through a slot and fixed by a nut, so that the pitching of the two mobiles may be modified; motion is communicated to the lap by simply placing the finger against the teeth of R. The bed can move in a vertical plane, being pivoted on two screws, _v_, _v_, and the block that receives the points of these is riveted to the disc _d d_, which can be made to rotate, with friction, on the second disc _n n_. This latter is riveted to a plate _e_ fixed at the end of a cylindrical rod F.

It will be evident that if the rod F is inserted in the =T=-rest support, the plate P extending towards the back of the lathe, this plate can be raised or lowered, and moved towards the right and left, so that the flat face of the lap can always be brought in contact with the pivot that is to be polished. This latter is caused to rotate by a foot-wheel while one hand holds the raised plate by the button _a_, and a finger of the other hand is applied to the teeth of R, causing the lap to rotate.

The upward motion of P may be limited by the edge of the top _s_ of the button _s k_, which is tapped so as to rotate with stiff friction on the pillar H. The stop _l_ is to prevent the polisher from traveling too far towards the left and thus removing too much from the shoulder that is to be polished. The screw _x_, giving motion to the slide _y_, is for securing parallelism between the pivot and the surface of the lap, according as the former is cylindrical or conical in shape.

For fine pivots it is advisable to introduce an additional wheel and pinion. The finger will then be better able to appreciate the degree of resistance opposed, and, owing to the increased velocity, it will be useless to use oilstone dust, but rouge can be applied directly after the turning. At _e_ is a steady-pin for maintaining the position of the instrument.

BUSHING PIVOT HOLES, ETC.

=560.= Every watchmaker knows how to proceed in adjusting an ordinary perforated bushing or stopping. We would make a few remarks on the subject of bushings generally.

The tapped bushing is very firm, but, in order that it may be well centered, it is essential that its thread fits exactly the tube of the tool (=322=), and that the pointed rod is exactly central. A turned bushing, especially when a broach can be passed into it after it is in position, is more easily made central (see article =342=).

When bushing holes that are rather large with solid bushings, after the hole has been marked with the pointer it must be drilled with a small drill, a larger one being subsequently passed through, so as to increase it. Otherwise there is great danger of the hole turning to one side.

If a hole, such as that of the center wheel, is bushed with a perforated bushing, it will often be found to incline towards the barrel or fusee, so that the hole is displaced. Such an inconvenience may be avoided by using a bushing with a hole smaller than is ultimately required, afterwards enlarging it with the plate centered in the lathe.

=561.= =Riveting of Bushings.= Some watchmakers have found considerable advantage in replacing the sudden and irregular impacts of a hammer by gradual pressure, without shock, obtained by a small press worked by hand on the principle of a punching machine. With a well made bushing, the flat end of which is slightly rounded, and the inside of the hole in the plate finished with a rat-tail rather than with a cross file, it is found that the riveting is always perfect. Others employ an ordinary pair of sliding tongs, the noses of which are drilled to receive two punches, one flat and the other rounded, as in the mainspring punch. Three pairs of punches suffice for all sizes of bushings, and the same tool can be used for closing up screw-holes, etc.

[Illustration: _Fig. 256._]

=562.= =Movable Bushings.= These are for use in regulator clocks and others of large dimensions, and a few words must suffice for their description. They are the invention of M. Alleaume, and will be understood from Fig. 256. It is always desirable, with a view to prevent wear, that when metal pivot-holes are used, the pivot should bear on a length equal to about three times its diameter; but for such a condition to be satisfied, it is essential that the axes of both holes and pivots be absolutely parallel. The figures will at once show in what manner such parallelism is secured. C C is the plate, in section, in which a hole is made of the form indicated by the lines that bound the cross-hatchings. The movable bushing A is held against a shoulder, and prevented from rotating by a screw, the point of which enters a small hole in the bushing. The pivot of B passes into A, and this latter is capable of such slight motion as will insure contact between the surfaces throughout their length.

DEPTHS.

=563.= =To Secure a Good Depth.= The least skillful of watchmakers can, without much difficulty, place a wheel in the depthing tool in conjunction with a pinion, and change this latter until the two are found to run easily together. But there are comparatively few that are sufficiently acquainted with the subject of depths to be able to select a pinion whose proportions are such as to satisfy the greatest number of the conditions to be fulfilled by a good depth.

This unsatisfactory state of things is due in great measure to the employment, without any correction, of tables of the sizes of pinions (=544=), according to which these sizes are determined by a measurement on the teeth of the wheel, taken with a pinion caliper. This method, although sufficient for ascertaining the size approximately, and even for securing a depth that runs more or less easily, cannot be accepted as an unvarying rule.

Far from resting on any mathematical law, as ignorant men urge in their attempt to instruct others, it is only true for a particular number and form of tooth in regard to the wheel, and a definite thickness of leaf and shape of the rounding in regard to the pinion. It ceases to be true if applied to other numbers of teeth, or to pinions that have their leaves thicker or thinner, or the roundings different from those of the pinion first determined upon.

=564.= _Theoretical and practical depths._ The fundamental principle of every depth is as follows: To determine what curvature should be given to the teeth of the wheel which drives, in order that the tooth that follows (whether its side be straight or formed according to a pre-determined curve) shall be driven in such a manner as to secure the best transmission of force, a transmission which is in part influenced by the uses to be made of the machine.

=565.= Teeth formed like the involute of a circle have very marked advantages, but they cannot be adopted in practice, especially in the case of the leaves of pinions. The epicycloid can be realized very approximately in the teeth of wheels in horology, and such teeth can be used in conjunction with pinion leaves having straight faces, the construction of which does not present any difficulty. This explains why the epicycloidal form has been adopted by watchmakers; but, although it is more easily drawn than the majority of other curves, there are still some obstacles in the way of its general application, mainly dependent on industrial requirements. The difficulty is usually got over by forming the tooth according to a circular arc, nearly identical with the epicycloidal curve, see articles (=440-42=).

=566.= When two mobiles are of the _same diameter_, the theoretical depth will be characterized by having teeth and spaces of equal width; but, since in practice the friction with such an arrangement would be excessive, owing to its taking place on both sides of the tooth, the teeth of the wheel that are driven are so far reduced in thickness as to secure the necessary freedom.

=567.= When the two mobiles are very highly numbered, the lead is short, so that the tooth of the wheel may be a trifle broader or narrower than the space without inconvenience.

But when using pinions of low number (from 6 to 10 leaves), this is not the case. In proportion as the width of the wheel tooth is reduced, its ogive becomes shorter, and the most advantageous portion of the lead (that beyond the line of centers) becomes less. And, besides this, account must be taken of the slipping towards the end of the lead, and the reduction in the difference between the geometrical and the total diameters of the wheel.

=568.= To secure a good depth with low numbered pinions, the leaves should not be more than half the thickness of the space. If they are thicker than this, it may be found necessary to reduce the width of the wheel teeth, when the pitching is insufficient; but the most serious objection lies in the fact that the pitch circle of the pinion will be diminished in diameter. Let there be two pinions with circular roundings and of the same total diameter, but having leaves of different thicknesses—that with the leaves thick will be found to be too small, etc.

=569.= =To Calculate the Vibrations of a Pendulum or Balance.= Multiply together the numbers of teeth of the wheels, starting with the one that carries the minute hand (which therefore makes one revolution in an hour), but exclude the escape-wheel.

Multiply together the numbers of leaves of the pinions, commencing with the one that engages with the center-wheel.

If the first product be divided by the second, the number obtained gives the _number of revolutions_ of the escape-wheel in an hour.

Multiply this figure by _twice the number_ of teeth of the escape-wheel, and the product is the _number of single vibrations performed by the balance or pendulum in one hour_.

ON THE APPLICATION OF THE GEOMETRICAL LAWS OF DEPTHS TO PRACTICE.

=570.= It has been urged that when the geometrical forms of the leaves and teeth, as given in scientific treatise, are accurately carried out in practice, the depths are found to be unsatisfactory and liable to cause occasional stoppage; and these facts are brought forward as evidence that theory and practice are at variance.

On the contrary, theory and practice are in perfect accord: the apparent disagreement arises from an error in the application of the geometrical laws.

In copying the theoretical forms of the teeth of wheels and leaves of pinions, it would be necessary to ascertain that they were mathematically exact, and this is impracticable. Two conditions must be borne in mind:

1. Theory shows that the mobile which drives should be made a trifle larger than the geometrical size, so as to counteract imperfections in the workmanship.

2. A pinion is _never_ made of the exact mathematical proportions, in consequence of the processes that have to be adopted for cutting, polishing, centering, etc. If a number of pinions be taken, and if the several dimensions of each be determined by means of a micrometer measuring to hundredths of a millimeter (or from two to three-thousandths of an inch), differences that are, comparatively speaking, large will be found in the diameters, measuring between corresponding leaves; in the thickness of leaves; in the diameters of the circles at which the roundings join the straight faces, and the general truth of the pinion will nearly always leave something to be desired. It should be added that these faults will be more marked according as the leaves have been more quickly made.

The teeth of wheels will be found to be characterized by similar faults, although they are less marked.

=571.= It follows from these facts that, in watches and timepieces, the _pinion is always a little smaller_ than theory would require; thus the epicycloid should be struck with a somewhat smaller generating circle, and the ogive of the tooth will be proportionately reduced.

The _practical conclusion_ at which we arrive, then, is as follows: As it is impossible to secure absolute perfection in the teeth of small horological mechanisms, their ogives must be slightly more rounded at the points than the designs given in scientific treatises indicate, since these latter are drawn exactly in accordance with the geometrical laws.

These remarks are of the greatest possible importance to the manufacturers of both watches and timepieces; they point to the fact that not only the ogives of all wheel teeth should be lower than theory indicates, but also that, in commoner work, they must be still lower, according as the pinions are of more inferior quality.

=572.= =To Alter a Stem Winding Pinion Depth.= The depth of the Stem Winding Wheel and Pinion often occasions considerable inconvenience, and its adjustment requires to be accurately made: when the depth is too deep, its alteration is easy, as the roundings of the pinion leaves can be reduced, or the stud or other piece that carries the winding wheel can have its base a little reduced on one side, so as to set the wheel a trifle out of upright (but so slightly as not to be perceptible to the eye, and taking care that the teeth remain on a level with those of the barrel-arbor wheel). A shallow depth is somewhat more difficult to correct. If a sufficient change cannot be made by altering the support of the winding wheel, one of the following methods must be resorted to:

1. Reset the pendant of the case.

2. Make a new winding pinion of greater diameter, increasing the number of its leaves by one, to correspond to this change.

3. Alter the position of the movement in the case.

The two first methods are more especially applicable to new work, while the third is more convenient for repairers, although of course it can only be resorted to with advantage when the pinion has a bearing in the pendant. The requisite change in the position of the movement can be produced by raising the rim of the case that supports the plate, or by soldering two thin strips of metal on this rim, producing a similar effect; one on either side of the pendant will suffice, except when a considerable change is necessary,

in which case they should be set at intervals around the rim to avoid an obvious inclination of the dial. Or four holes can be drilled at equal distances apart around the edge of the plate and in its plane, so that their edges overlap the position occupied by the rim of the case; pins are then set in these holes and filed away until they produce the requisite amount of elevation. Or, again, flat-headed screws may be fitted around the edge with their axes at right angles to the plane of the plate and their heads on the dial side.[7] The depth will then be adjusted by screwing these screws more or less into the plate.

It is advisable to ascertain that the dial is not forced too near the glass, as such is occasionally found to be the case, necessitating the bevelling of the edge of the former.

PALLETS.

=573.= =To Advance a (visible) Jewel in a Pallet.= Workmen that have had much experience of escapement making do this without any difficulty by holding the pallet arm in a pair of tweezers that have been slightly warmed, but ordinary repairers will not succeed with such a method: they can however, effect the required change as follows.

[Illustration: _Fig. 257._]

Make a small brass plate, E, fig. 257, with a piece _c_ projecting upwards, which the screw _v_ traverses with stiff friction. A saddle _b_ is fitted to the edge of the plate by screws. A glance at the figure will suffice to show the mode of using it; the pallet arm whose jewel is to be adjusted is clamped under _b_ with the jewel just opposite the screw _v_. Now turn this screw until it stands at the distance from the impulse face of _a_ through which the jewel is to be advanced; taking the plate in a pair of long-nosed pliers, hold them over a small lamp flame, and press with a small screwdriver lightly against the point _a_ so as to advance the stone by the requisite amount as soon as the shellac is sufficiently soft. A particle of shellac is placed at _a_, if any cavity forms during the process, and the plate is laid on some cool body, avoiding contact with the pallet-staff.

If the stone projects below the lower surface of the pallets, a small washer must be placed underneath before clamping the screws of _b_, of such a thickness that the stone is just on the level with the surface E.

=574.= =To Alter the Form of a Pallet Face.= Workmen that possess the requisite skill and steadiness of hand can alter the form of a pallet jewel, when it is necessary to modify the height or form of the impulse face, by simply using a copper polisher charged with diamond powder. The polishing material employed is always decanted in very pure oil, as otherwise it is apt to scratch instead of polish. The coarser quality is first used when a material change has to be effected, but if only a very slight alteration is necessary, and the adjustment has to be very exact, only the finest quality must be used, as there is a danger of making scratches that would be very difficult to erase. We would also add that this operation requires some skill and patience.

[Illustration: _Fig. 258._]

=575.= =To Measure the Lift and all other Angles, etc. of the Lever Escapement.= A very simple instrument for measuring these angles was designed by Curzon, one which any watchmaker can arrange for himself, and is quite sufficient for all practical purposes. This is shown in Fig. 258, and consists of an ordinary depth tool to which a scale is added. A hand adapted to the pallet-staff supported between one pair of runners of the depth tool gives motion to a curved rack (shown by dotted lines), and this causes a pinion carrying a second index to rotate, the radii being so related that the movement of the staff is magnified four times on a scale which can be observed while the glass is at the eye examining the pallets. The index which travels over the shorter scale to the left (divided up to 10° on either side of zero) is connected with the pallet-staff by a fork and a short arm passing through the circular groove; it affords a convenient means of moving the pallets while testing them, and gives a measure, in degrees, of their motion. The graduated arc shown at the top is for measuring the lever and roller.

=576.= =Verge Pallets: to Measure their Opening.= The little instrument shown in Fig. 259 may be used for this purpose; its mode of action will be easily understood from an inspection of the figure.

[Illustration: _Fig. 259._]

One of the pallets being held with its flat face against the base of the graduated semicircle by the lever and spring B, so that the axis of the verge is at right angles to the plane of the instrument through the point _n_, an index previously fixed to the other pallet will show by the graduations the number of degrees of opening.

This index, shown at P, Fig. 160, must be very light. It is formed in two parts, the body _c d_, and the small spring _z z_. The pallet when held in the notch _c_, must have its face held flat against _c d_ by the spring _z z_. The face _c d_ of the index must be quite smooth and straight, so as to avoid any error in the reading of the scale.

[Illustration: _Fig. 260._]

The pressure-block C, Fig. 259 (shown in plan and elevation at C, Fig. 260), is movable on its center, and this center, which by an engraver's error is represented on the line _n r_, should be a little to the right of that line.

=577.= =To Open or Close Verge Pallets.= Some workmen cut a notch at the end of a small rod in which the verge is inserted, the two arms of the fork being then drawn together by a screw; then, holding each pallet in a pair of long-nosed pliers, one in each hand, the rod is held in the flame of a lamp and, as soon as the body of the verge becomes blue, it is gently twisted to the right or left according as the pallets require to be opened or closed.

This method is not always convenient, and the following may be recommended:

[Illustration: _Fig. 261._]

Support the verge by its shoulders between two cone-plate centers in a pair of finishing turns, as seen in Fig. 261. A carrier _b_ is screwed to the upper pallet, and prevents the verge from rotating; _c_ is a rod through which heat is conducted; _a_, shown both in plan and elevation, is another rod, which is much longer than _c_, and has a notch cut at the end, so that it can be forced on to the lower pallet. The end _d_ is free, and the =T=-rest shown dotted at _s_, must be brought nearly into contact with it, the distance between them corresponding to the angle to which it is required to alter the opening of the pallets. Now hold a lamp under the free end of _c_ and, as soon as the body of the verge changes color, _d_ will descend by its own weight until arrested by _s_, the opening will thus be increased or diminished to the requisite extent.

The operation will be accomplished more quickly by directing the blow-pipe flame against the verge body.

Of course when diminishing the opening, the verge must be held in the reverse direction to that shown in the figure.

CYLINDER.

=578.= =To Polish the Cylinder Lips Mechanically.= The polishing of the lips of a cylinder is one of the most delicate operations that can be undertaken by a watchmaker; we have, therefore, endeavored to devise an instrument by which this can be done mechanically, and which should at the same time be so simple and so easily made that any watchmaker should be able to construct it for himself.

[Illustration: _Fig. 262._]

=579.= It consists of two distinct parts which take their place in an ordinary pair of finishing turns. 1. The plate P, Fig. 262, supported on a rod T, to take the place of the =T=-rest. 2. The frame E, whose axis replaces one of the runners. This much being clearly understood from the figure, there will be but little difficulty in understanding the following details.

[Illustration: _Fig. 263._]

On the plate P is mounted a bracket, _b b b′_, held by a screw and washer. It has a slot cut lengthwise, so that on loosening the screw it can be made to slide towards the right or left. The vertical portion _b′_ supports a fork-shaped piece, _d c_, a front view of which is given in Fig. 263, pivoted on a collet-screw, _f_, and this may be fixed by a pin passing through its end like a bolt. The upper end of the fork-piece is provided with teeth for a purpose that will be presently apparent.

The long spindle, _g h_, turns between the two supports, _k_, _l_, fixed to the plate P, under the action of the handle M. This axis carries two eccentric cams, _q_ and R. When it rotates, the eccentric R causes the fork _d c_ to rise and fall, thus occasioning an oscillating movement of the rack _d_, at the same time the other eccentric _q_ presses against the back of the slide _i n_, which moves freely in the guide _s_, and is always held against the cam by a helical spring _j_; the slide thus has an oscillating motion in the direction of its length.

[Illustration: _Fig. 264._]

All the details in regard to the slide and its guide will be easily gathered from the plan in Fig. 262, and the side elevation in Fig. 264.

A small iron polisher is adapted to the slide _n i_. Being pivoted on a pin at one extremity, serving as an axis, its end _u_ is pressed downward by the light spring _v_ (Figs. 262 and 264), which might be replaced by a spiral spring below the polisher if preferred.

=580.= This being understood, we will pass to the frame E.

The rod that carries it is formed of thick drawn steel pinion wire, the diameter of which is less than that of the hole in the poppet-head of the turns. This spindle is provided with brass collars at _y_ and _z_ of such an external diameter as to be received in the poppet-head, in which the rod can rotate freely. By adopting this arrangement, not only is the frictional surface diminished, without reducing the accuracy of the adjustment, but the apparatus can be easily adapted to any pair of turns.

[Illustration: _Fig. 265._]

To the right-hand side of the frame is fixed, by two screws, the cylinder carrier _x_ shown at X, Fig. 265. It must be removed in order to set the cylinder in position by cementing its balance to the surface; care is necessary to make sure that the back of the cylinder shall be towards the side _e_ of the frame when the carrier is again screwed in position. After having thus replaced it, set the rack _d_ to engage with the pinion wire _z_, in such a manner that, when the eccentric cam R occupies the position indicated in Fig. 263, the small iron polisher rests at the middle point of the cylinder lip. Now finally clamp the screw that fixes the support T.

The mode of action of the machine will be easily understood. If, after charging the polisher with polishing rouge the handle M is rotated, the cam R will impart an oscillating angular movement to the frame E through its axis _y z_, and the cam _q_ will, at the same time, cause the polisher to move backwards and forwards, always in contact with the surface of the lip during its movement.

=581.= The work will be performed more rapidly, and the polish will be better if the iron have a slight lateral motion as well as that in the direction of its length. It is, however, more simple to communicate a longitudinal oscillating movement to the cylinder, and this answers the same purpose; it is only necessary to make two small additions, the spiral spring _o_ and the little cock _a_. The latter is fixed to _d_ in an inclined position (as indicated at A), and this inclination can be varied by merely turning the left-hand screw. It will be evident that when _d_ is ascending, the cock will push the spindle _y z_ forward; and when _d_ descends, the spindle will be brought back to its initial position by the pressure of the spring _o_, which is simply placed over the end of the opposite runner. This longitudinal movement must be but slight, and it can be made as little as desired since it depends solely on the inclination of _a_.

=582.= _Observations._ 1. The angular motion of the frame E must be sufficient to enable the polisher to act on the entire surface of the lip. The extent of this movement is determined by the size and the degree of eccentricity of the cam R. The greatest motion will occur when the spindle passes through the hole 1 (Fig. 263), and it will gradually become less as the holes 2, 3, etc., are used. The cam _q_ should also have two or three holes for varying its eccentricity. These cams may be made of hard wood, ivory, etc.

2. The iron polisher may be replaced by a piece of flexible spring fixed by a screw to the slide; but its pressure is less uniform.

3. The bent arm _w_, Figs. 262 and 265, is clamped to the plate P by a screw _d_, and the long arm _b_, Fig. 265, bears against the back of the poppet-head, and thus ensures the steadiness of P. To insure steadiness by its means, _b_ is drawn back in the direction of the arrow, then hooked behind the poppet-head and clamped by the screw _d_. The firmer the support is the better.

4. The machine may be arranged so that the two lips can be polished at the same time, but it then becomes more complicated. In the tool here described, as soon as one lip is polished the cylinder carrier is unscrewed, turned around, and screwed against the left arm of the frame E, in which are two screw-holes opposite to those in the right-hand arm. Unscrewing the slide _b b_, the =T=-rest carrier is moved along the lathe bar until the polisher is over the lip; _b b_ having been set in position is clamped, and, after seeing that _w_ has a bearing, the second lip may be polished.

5. The cylinder carrier shown at X, Fig. 265, is used when the balance is in position. For a plain cylinder without its balance another form of carrier is employed that has at the edge of its central hole a small but solid projecting shell to which the cylinder is cemented.

=583.= _Methods of Obtaining Continuous Motion._ Rapid work is not possible when a single handle, as shown at M, is used for working the apparatus; recourse may, however, be had to one of the following methods:

1. Mount a small pinion with a square hole at its center, and make it engage with a large wheel driven by a handle. This wheel, having a great number of teeth, will proportionately increase the rate of motion.

2. Take a powerful clock movement and connect up its center arbor with the axis _g h_; having wound up the main spring, allow it to run down so long as it possesses sufficient power to drive the mechanism.

3. Fix a ferule at _h_, and drive it by the aid of a foot-wheel.

BALANCE SPRING.

=584.= =To Select a Balance Spring.= Various methods are adopted for this purpose. The most common, by which the strength is ascertained from the length of cone formed by hanging the balance from the inner coil of the spring while the outer is held in a pair of tweezers. A more exact method, based on the same principle, is to employ the small gauge shown in Fig. 266.

[Illustration: _Fig 266._]

A vertical pillar _n n_ is fixed on a smooth plate B, and the slide C is held by friction in any position on _n n_. Place C so that the distance between _c′_ and B is equal to the distance between the end of the lower balance-staff pivot and the balance-spring collet. Having now fitted the spring in this collet, raise the balance, by tweezers holding the outer coil, until the lower pivot just rests on B. The graduations on C will then afford a measure of the extension of the spring, and this extension should about equal the radius of the balance measured on the same scale.

When the number of vibrations performed in an hour is known, a spring may be selected by fitting it to the balance and, while holding the outer coils in the tweezers, supporting the lower pivot on a hard smooth surface; the balance is then made to vibrate and the vibrations are counted. The spring need not be pinned into the collet, but may be attached by wax to the top pivot.

=585.= =To Fix a Balance-Spring to its Collet.= A common way of doing this is to put the collet on a wire or broach which is held in one hand while the other presents the inner end of the spring, held in tweezers, to the hole in the collet; subsequently fixing it with a pin. The following is a more convenient method:

At the middle of a brass plate is a boss tapped through a vertical hole in its center to receive a small screw with flat head. When the collet is fixed by this screw passing through it, the operation of setting the spring in position and pinning it will be much facilitated, and the plate will at the same time afford a means of testing its parallelism. Two or three screws with heads of various sizes should be provided, and, in order that they may be always available, they should be screwed into holes at a corner of the plate.

This tool might be made of further use by adding an arrangement for holding the stud while drilling it, with a view to ensure that the hole is at the proper height.

[Illustration: _Fig. 267._]

=586.= =Balance-Spring Gauge.= A back view and side elevation of this are shown in Fig. 267; it can be made without difficulty by any watchmaker.

Through the middle of the plate passes a staff _a b_ lightly pivoted between the cock _p_ and the plate, and projecting on the left-hand side as far as the point _a_. Between the cock and plate it carries the collet of the spiral spring _s_ and the stop-finger _d c_, and at the point _z_ is a light finger _y z_ that passes over the graduations on the dial.

When the stop-finger _d c_ is free it stands in the direction of the dotted line _i_; on rotating the staff, by taking hold of the pivot _a_, in the direction of the arrow _i_, the extremity _c_ of the finger will be brought round till it presses against the inclined plane _r_, which it will force back and, on coming against the stop near _c_, it will be held fast in the notch of the small bent lever that terminates at _r_. A spring maintains this lever always against a pin set in the plate. The index finger _y z_ will now be standing over the zero of the scale, and will be maintained in that position until the finger _d c_ is released by a momentary pressure of the hand on the push-piece _n_, when it will fly back to the initial position corresponding to the dotted line _i_.

=587.= The instrument is used as follows: The small sliding holder H, which is shown in section at E, (both of these figures being much enlarged since it is extremely fine and light), has a hole through its center that fits on to the axis at _a_. Having set a balance spring in the clip as indicated at E, place H on the pivot _a_, tightening the slide so that it can be used to rotate _a b_, and bring the

stop-finger round to the position _d c_. Holding the outer coil of the spring in tweezers at _v_, its inner coil being held in the clip, release the bent arm by means of the push-piece _n_. The point on the dial at which the finger _y z_ is arrested will give a measure of the force of the balance spring _v_.

It will be evident that a spring can now be easily selected of the same strength as _v_, or stronger or weaker within definite limits which will become well known when some use has been made of the instrument.

The entire mechanism is enclosed within a box that is covered by a glass, through the middle of which a hole is made for the passage of _a_. The spring _s_ is of about the strength ordinarily used for 18-line watches.

[Illustration: _Fig. 268._]

=588.= =To Set a Breguet Spring in Position.= To test the strength of a flat spiral spring that is to be formed into a Breguet spring, it must first be attached by its collet to the balance-staff. As the outer coil cannot be held in the stud owing to its being so near to the pivot hole, it must be held in the clip _b_ of the little appliance shown at S, Fig. 268. Holding the watch-plate between _a_ and _c_, the arm D can rise or fall on the rod _h_, and _b_ can be brought to such a position that it grips the spring at a point just beyond the stud, so that, when the spring is turned inward, the point held may be brought up to the stud. The springing of the watch can thus be proceeded with, and springs tried until one of the required strength is obtained. It then only remains to give the spring the double curvature, and to take care that the end of the overcoil is brought sufficiently near to the center.

Since the action of a Breguet spring is more free than that of an ordinary flat spring, the watch may be found to lose slightly; it is advisable therefore to time the watch before making the bend, so as to show a gain. A little experience will enable the watchmaker to avoid being much out, and any trifling error that there may be is corrected either by a displacement of bend or by altering the central coil. If the latter method is to be resorted to, it is better that the watch should lose rather than gain a little.

=589.= =To Flatten an Ordinary Balance Spring.= Remove the collet and stud, and clamp the spring by a central screw between two plates, which are then placed on a blueing tray and gently heated. A small piece of whitened steel is laid on the plate in order to see that the heat does not exceed what is needed to give a blue temper. Allow the plates to cool and separate them.

Ordinary springs being made of rolled steel and subsequently coiled, always open out on heating; it is therefore necessary before resorting to the above method, to coil up the spring, as otherwise the outer turn will be found to have opened beyond the stud.

=590.= =To Diminish the Strength of a Balance Spring.= Scraping the end or the entire length always renders the spring defective. Dipping in acid is very little better. It is preferable to embed the spring in cork or soft pith, and work it over a ground glass plate covered with oil stone dust that is fine and smooth. This method might be resorted to for reducing the height of a mainspring.

[Illustration: _Fig. 269._]

If the cork or pith is hard and only a little metal has to be removed, the operation is successful; but it is apt to result in more metal being removed from the edges than from the center. When much has to be removed, the spring must be cemented to the polishing plate (shown at G, Fig. 269, and described in article =345=) with fine wax, thoroughly liquid, so that on pressing the spring all its coils may come in contact with the plate; it must be held thus until cold. Now adjust the leveling screws, so that the whole surface bears flat on the glass; rub it as long as is considered necessary, and detach the spring as soon as the plate is sufficiently heated; boil in alcohol to clean its surface.

=591.= =To Harden Gold Springs.= Gold detent, thermometer, suspension and balance-springs can be obtained of a high degree of elasticity. Rolling hardens them, but renders them very brittle. They can be made supple and elastic, not by hardening, as in the case of steel, but by annealing, care being taken not to exceed a certain degree of heat. The spring may be coiled on a block and placed in a tube that has a smooth steel lid, then heat the tube in the flame of a spirit lamp, and as soon as the steel is of a blue temper, remove the flame and allow the whole to cool.

Others anneal by keeping the spring in boiling oil for a definite period.

The hardness of a gold spring increases with the proportions of alloy it contains, and, if well annealed, it will be very elastic and will break when bent too far, as in the case of steel.

=592.= =To Ease an Index on Its Endstone Cap.= It is a common but bad practice among watchmakers to scrape the inside of the ring of the index or to cut it through. A better method is as follows: Resting the index on a cork, cover the inside of its ring with oil stone dust and make the cap rotate in its seat by means of a pinion calliper, the two points of which are inserted in the screw-holes. The operation is repeated as often as may be required.

DIAL PLATE.

=593.= =To Cut the Large Hole in the Timepiece Dial Plate.= Some workmen cut the hole in the dial-plate of a timepiece by means of a strong pair of compasses, one leg of which terminates in a bullet-nose that is supported in a central hole, while the other is provided with a hardened cutting point that serves to scrape out a groove.

Others use a rule that revolves on a conical point and carries a slide with a tracing point which can be replaced by a sharp-pointed cutter. Proceed in exactly the same manner as when using the compass, but a greater force can be applied, because, while one hand steadies the center, the full force of the other is applied to the cutter.

A third and still simpler plan is adopted by some clockmakers. A rod of the diameter of the central hole, and a cutter of which only the cutting point projects, are gripped in a vise at a distance apart equal to the radius of the hole to be made. Then passing the rod through the central hole and holding the plate in both hands, rotate it, at the same time applying pressure so as to cause the cutter to form a groove. When a moderate depth has been attained, invert the plate and cut one on the opposite side. Care is necessary when the grooves are on the point of uniting; on the removal of the center, smooth the edge with a half round file. Some workmen consider it more convenient to set the cutter and rod in a thick piece of wood that is rounded at the top and made flat on its two sides towards the bottom, so as to be firmly held in the vise.

=594.= =To Drill an Enamel Dial.= Take a hard, well-sharpened graver and moisten it with turpentine or turpentine that contains camphor in solution, or in the following mixture, which is still better:

Turpentine 62 parts by weight. Oxalate of potassium 4 " " Camphor 4 " "

The two latter substances are reduced to powder and dissolved in the turpentine, and two parts by weight of sandal wood may be added.

The graver point is placed on the dial at the point at which a hole is required and the graver is rotated backwards and forwards between the fingers. Practice, acquired by drilling a few holes in broken dials, will soon indicate the degree of pressure that can be applied without fear of accident. Some workmen prefer only to apply the maximum pressure while the graver rotates in one direction, reducing it during the opposite movement; others hold the handle or tang in one hand and rotate the graver with the other, always in the same direction.

The operation is continued, frequently arresting it, however, in order to set the graver and moisten it, until the copper-plate and back enamel are perforated.

As soon as this point is reached, take an iron or steel spindle, pointed at one end. The point must be more obtuse than the hole already formed in the dial. Charge this end with emery or oilstone dust, and place in the chuck in your lathe; when the spindle is caused to revolve the enamel on the contour of the hole will be rapidly removed. When the copper disc is reached, a fine-pointed and sharp graver must be used to remove the metal that is exposed as well as that which is covered with only a thin layer of enamel; then renew the operation with the spindle, occasionally drawing a file along the surface of the acting cone. Or the cones of solid emery to be obtained at material stores can be used for this purpose. A workman must be very careless or unskilful to fail in rapidly drilling a hole in a dial by this method without accident, and he may carry on the process easily until the hole is large enough to permit the introduction of a rat-tail file.

=595.= =To Enlarge a Dial-Hole With a Rat-Tail File.= As an extra precaution the contour of the hole on either side may be coned with a spindle as explained above, so as to reduce the thickness of enamel to be acted upon by the file; but a watchmaker that has had any experience can dispense with such a preliminary, which we would at the same time recommend.

The file must enter the hole freely. If only the point can do this, the file must be held very short, so that the finger may come in contact with the dial before the larger diameter of the file locks in the hole, as this would almost certainly crack the enamel. Some workmen avoid such an accident by forcing on to the file a rather long cork of small diameter.

With a view to avoid scratching the face of the dial in case the file is drawn out of the hole in its backward movement, it is well to round off and polish its point.

During the forward movement a slight circular motion is given to the file, and in returning no pressure is to be applied; the file must merely slide over the surface. It is dipped from time to time in the liquid mentioned in the last article. When the hole is large enough, a conical spindle should be used to smooth its edges as in the earlier stages of the process.

=596.= =To Remove Enamel from the Back.= To remove portions of the enamel from the back when it touches part of the motion work, etc., various methods are adopted.

The little spindles of solid emery that may be obtained at material stores may be used for the purpose.

Some watchmakers use a flattened lead ball perforated at its center and carried on a taper arbor, forming a kind of small grindstone, rounded across its rim. The arbor is held in a chuck and the edge of the lead disc is moistened with water, and emery powder sprinkled over it; when set in rotation the surface to be removed is held against the lead, the necessary pressure being applied by the finger against the other face. Water must be frequently sprinkled on the surface so as to avoid heating, and to maintain the emery in its place, and the dial is washed occasionally to examine the progress of the work.

In place of lead, some use emery formed into a solid block with shellac or various kinds of cement; it is centered on a large taper arbor, and should be at least a quarter of an inch thick and rounded at its edge. Such a disc is very hard when cold; it is used in the manner explained in the last paragraph, but wears more rapidly than the lead disc, if the latter is well made and supplied with emery of the right degree of coarseness, in sufficient abundance and evenly distributed.

=597.= =Dials Fixed by Screws through the Edges.= The screw-holes at the edge are drilled in the manner already explained in article =594=, and the center hole is enlarged as there described, if this is found to be necessary in order to permit the free passage of the hour wheel. The diameter of a dial may be reduced if it is too large in the manner explained in article =600=. When it has been thus prepared, place it in position, the XII being exactly opposite the pendant, with the movement in the case, and close the bezel. If the dial is found to shake under the bezel it should be fixed with three or four small wedges of pegwood, care being taken that they do not subject the dial to much pressure. The accuracy of the position may be tested by holding a stretched piece of cord over the dial, and observing whether it passes at the same time through the middle of the pendant, the center hole, the XII and the VI. When the dial is thus found to be properly placed, mark one of screw-holes on the watch-plate through a dial-hole. Some care is necessary in doing this lest the hole is marked eccentrically or the dial is displaced by pressure against one side of the hole in it, which might result in the dial being cracked by the screw. Now remove the plate from its case and drill its screw hole in the drilling tool; tap it and fit the screw. Replace the plate in the case, and, after fixing the dial to it with the one screw thus fitted, carefully mark the second hole, etc.

Some workmen expedite the operation by marking and drilling the two holes at the same time; but if at first they do not succeed in making them in the required position they materially increase the time occupied, as one hole at least requires to be bushed, etc.

=598.= =Dials Held in Position by Feet.= If the dial has feet, and it is required to adapt them to the plate, they must be first carefully bent straight; then take a piece of stiff card board of moderate thickness, and laying it on a piece of lead, punch out with a sharp-edged punch, or other means, a round hole of the diameter of a foot. Having inserted one foot in this hole, and placed the card on a flat surface with the dial uppermost, apply a slight pressure to this latter so as to mark the position of the second foot. Then punch out a second similar hole at the point thus indicated. If the operation has been properly conducted the two feet will enter the holes easily, but at the same time without constraint or shake, and they should project on the opposite side.

It now only remains to cut out the cardboard to the size of the plate, and, after making a central hole and a mark to exactly correspond with noon, to place it in position in the frame and under the bezel, as though it were the actual dial. Then mark the two holes for the dial feet, using a sharp-pointed chamferer that just fits the hole, held vertical and rotated by one hand, while pressure is applied by a finger of the other hand.

Some workmen merely prick holes in the card with some sharp-pointed instrument, or even force the feet through it at all risks; hence it happens that feet are often bent out of the vertical, and, in order to be able to bend them into the required position, it becomes necessary to enlarge the holes in the plate and bend the dial feet.

[Illustration: _Fig. 270._]

=599.= =To Cut a Large Hole in a Dial. To set a Seconds Dial.= This operation is performed in the ordinary lathe. The hole is cut by a ring of thin iron or copper cut with saw-like teeth round its edge, as shown at V, Fig. 270, kept in rotation and charged with fine emery and oil or water or, what is better, turpentine. The mixture described in article =594= will secure a still more rapid action.

It is advisable that the thickness of the ring be made to gradually diminish from _e_ towards _i_, as indicated by the section at S, so as to prevent it from choking and probably cracking the dial.

The following arrangement may be adopted: Prepare a strong ring with a projecting internal ridge, shown in section at A B C; cement the dial, _g d_, to this ridge, or fix it by any convenient means, and attach this supporting ring to a chuck that rotates in a direction opposite to that of the cutter, but much less rapidly. On reaching the copper disc, reverse A B C and repeat the above process on the back enamel. The copper is thus exposed on the two sides. On filling the deeper groove with dilute nitric acid the metal will gradually be eaten away, and the acid should be renewed as often as may be needed. It then only remains to smooth the edge, beveling it on the front side, and to cement the seconds dial in position.

The use of acid may be avoided and the cutter passed through the copper, but greater care must be exercised, because the work is more difficult when operating on metal. It will, however, not be difficult after a few trials.

Willis recommends that the dial be cut straight through, commencing at the back and using emery and oil, the dial being cemented on a brass block immediately below the cutter, and rather less in diameter than the hole produced. He mounts the cutter on a stock that is provided with a pump center, the point of which is maintained throughout the operation in the small hole or point that marks the center of the hole. The great advantage of this method is that the taper of the hole is in the required direction and no filing is necessary.

=600.= =To Reduce the Diameter of a Dial.= Resting the dial in an inclined position against a block, file its edge with a smooth or half-smooth file, which must only be allowed to act while advancing, and is at the same time displaced sideways and turned so as to follow the contour of the dial. The file should be dipped occasionally in turpentine, and when sufficient enamel has been removed, pass a new emery stick over it to remove the file marks.

=601.= =To Remove a Figure or Name from a Dial.= Oil of spike lavender may be employed for erasing a letter or number.

Enamel powder made into a paste with water, oil, or turpentine, is also used for this purpose. It should be previously decanted so as to obtain several degrees of fineness. The powder used for re-polishing the surface where an impression has been removed must be extremely fine. It is applied on a piece of pegwood, although some use ivory.

The last and best system is to use diamond powder. Take a little of the powder, made into a paste with fine oil, on the end of a copper polisher, the surface of which has been freshly filed and slightly rounded. On rubbing the marks they will be seen to rapidly disappear.

The surface is left a little dull; it may be rendered bright by rubbing with the same powder mixed with a greater quantity of oil and applied with a stick of pegwood.

Watchmakers will do well to try several degrees of fineness of the diamond powder on old dials.

METAL DIALS.

=602.= =To Restore a Silver Dial.= We proceed to describe several methods of doing this, but would at once observe that when the earlier ones are adopted, the hours, if they are painted, necessarily disappear; whereas they can be retained by resorting to the last method although great caution must in that case be taken; moreover, it is much more difficult to accomplish than the others.

=603.= First Method. This is the most expeditious system, and at the same time the most certain of success.

If the hours are in enamel, there need be no fear; if engraved and filled with black composition, this will disappear, but it can be replaced without difficulty. There remains the case of painted hours to be considered.

First make thin marks with a fine point along the lines of all the figures, taking care not to pass beyond their ends: and do the same for the dots and lines that indicate the seconds. By using a glass and following the instructions given in article =619=, no difficulty will be experienced in doing this, and the fine lines and dots thus made will afford sufficient guide for re-marking the hours.

Begin by cleaning the dial with a brush and fine pumice-stone so as to remove spots and slight scratches.

=604.= _To Frost the Surface._ In order to frost the surface of the dial, take a spirit lamp with large wick, and direct a blow-pipe flame from it against the under side of the dial, which is held by one hand with a hooked support. If the flame is gently directed over the entire surface of the back, a good dead surface is obtained that resists a moderate degree of friction either in soaping with a fine sponge, or washing in a large quantity of water, or in applying soft bread and oil of spike lavender to erase irregularities or marks made in painting the figures.

The application of the flame is several times repeated, so as to obtain a decisive and even frosting; but it is necessary, with a view to avoid buckling the thin metal, to place an iron or copper washer behind the dial. The flame oxidizes the surface of the metal; that is to say, it causes the oxygen of the air to combine with the copper which is alloyed with silver.

=605.= _Pickling or Bleaching the Dial._ Introduce sufficient warm water into a suitable flat vessel to completely cover the dial, and gently pour into it a few drops of sulphuric acid (oil of vitriol), so that the two liquids are in the proportion of about 1 to 10; then lay the dial in this dilute acid for a period that varies from half to one or two minutes. The frosting will first become yellow and then of a beautiful white color. Wash it in a large quantity of water, wipe with a fine linen rag, and apply the flame momentarily to the back in order to prevent the formation of spots on the surface.

When several dials have to be operated upon, the acid is put in a porcelain dish and boiled by a lamp. Then place each dial for a moment in it, wash in an abundant suppl of water, and dry by tapping with a fine linen rag.

=606.= Second Method. For the benefit of such as care to experiment with it, we add the following method: Brush the dial with a coarse brush and pumice-stone reduced to an impalpable powder until no scratches are visible. Make it red-hot and allow to cool. Then dip for two or three seconds in a porcelain vessel containing dilute sulphuric acid; on removal it will be found to be white, but rather dull. In order to produce a clear frosted surface, place the dial in a mixture of

6 parts by weight of nitric acid of 1.22 sp. gr.[8] 21 " " sulphuric acid. 50 " " water.

Allow the metal to remain in this acid until no more globules are seen to form on its surface, then withdraw it and immediately place in cold water. The dial will be observed to be nearly black; it is then pickled as above explained (=605=), washed well, heated red-hot and, when cold, again pickled; the operation is concluded by thoroughly washing its surface.

=607.= _Third Method._[9] Cover the surface of the dial with a thin layer of soap, and brush it over, taking care to avoid touching the hours if these are not enamelled. This can best be done with a fine brush and pumice stone reduced to an impalpable powder. When the dial has been made as clean as possible by this means, wash it carefully with water and tartrate of potash (cream of tartar), then plunge it immediately in the hot solution of nitrate of silver (=608=) attaching it to the silver wire which is fastened to the zinc and copper discs =609=; in two or three minutes the surface of the metal will be perfectly frosted, and, if each operation has been cautiously performed, the hours will remain intact.

Each time the zinc and copper discs are used they should be cleaned with nitric acid, and rubbed over with pumice stone. As soon as the dial is clean, immerse it in the solution; the least delay is apt to cause the surface to become oxidized through contact with the air.

=608.= _To Prepare the Silver Solution._ Dissolve an ounce[10] of solid nitrate of silver (lunar caustic) in a small quantity of water; filter the solution and add twice its volume of liquid ammonia. In a separate vessel dissolve 6 ounces of yellow prussiate of potash and 4 ounces of crystallized carbonate of soda in 60 ounces of water, contained in a vessel of enamelled iron, which must be placed on the fire. When near the boiling point add the concentrated solution of nitrate of silver, and allow the mixture to boil for an hour, taking care to add hot water in sufficient quantity to make up for that lost by evaporation; then filter the resulting solution.

=609.= _To Prepare the Discs and to Plate._ In order to use this solution for restoring a dial or plating any other object, take two discs about the size of a half dollar, one made of zinc and the other of copper, and, after making a small hole in each, unite them

with a copper wire, or, preferably, with one of silver. After having attached the dial or other object to this connecting wire, immerse the entire system in a glass or earthenware vessel, and pour over it a sufficient quantity of the solution, previously made hot.

If the object operated upon is perfectly clean, bright and free from all greasy or oily matter, its surface will be found in two or three minutes to be covered with a firmly adherent layer of silver. When only a small piece is treated it will suffice to immerse it in the hot liquor, and rub it with the finger; a bright silvered surface will thus be obtained.

=610.= =To Clean Metal Dials of Clocks.= When the hours are neither enamelled nor engraved, it is necessary to first trace out the several lines and dots in a manner similar to that explained in article =619=.

=611.= _Ordinary Mode of Cleaning the Dial._ Very often it is possible to make a silver or plated dial of either watch or clock sufficiently clean by merely brushing with powdered cream of tartar worked into a paste with water, carefully rubbing around any painted figures with a fine stiff brush. Then wash with clean water, dry by gently tapping with a fine linen rag, and expose to a slight heat. (This is in part the same method as is described in article =607=; the two may be combined). If the dial is tarnished, it must be silvered as explained below.

=612.= =To Plate a Brass Dial.= _Preparing the Silver._ Place in a glass flask from 100 to 150 grains of pure silver made into thin strips by means of a hammer or rolling mill. Add five or six times the weight of dilute nitric acid so as to completely cover the silver, and warm the vessel, taking care to avoid breathing the fumes or admitting them to the workshop. The metal will be dissolved, and, on continuing the application of heat until all the liquid is evaporated, crystals will be found at the bottom. When cool fill the flask with warm water and, as soon as all the crystals are dissolved, pour the solution into a porcelain dish, previously half filled with water. Place in it a sheet of clean copper of about the size of three fingers, and allow it to remain for the night.

On the following day all the silver will be found attached to the plate, and it can be collected by immersing this in water. Carefully pour off the water from the fine powder thus obtained, and wash it once or twice with an abundant supply of pure water; then dry thoroughly with the application of very moderate heat. If the silver thus obtained is not required for immediate use, it should be kept in a dark blue bottle to avoid the influence of light and moisture.

=613.= _To Prepare the Surface of the Dial._ It must be quite smooth, thoroughly washed and dried. M. Robert recommends that the smoothing be accomplished by using soft water of Ayr stone, rubbing in all directions, in order remove scratches. Or pegwood charcoal can be used, sloped at one end like a whistle, and applied with water. Others employ pumice-stone powder and very fine emery paper.

=614.= _To Apply the Silver._ Take equal parts of rock-salt and cream of tartar, pound them together, and when well mixed, take about 60 or 80 grains of the mixture, and add to it 15 or 20 grains of silver, prepared as above described, and add a few drops of water to form a thick paste, which must be well mixed and worked up on a ground glass plate by means of a horn spatula to remove all grits. A glass pestle may be used for this purpose.

The dial having been prepared, take up some of the paste with a perfectly clean and rather stiff brush, and spread it over the surface of the dial, rubbing quickly and somewhat harshly. The brush should be worked about in all directions, so as to avoid scratches, until the silver is found to adhere firmly to the dial. According to M. Robert, this rubbing is to be continued until the required grain is obtained; but M. Fournier states that it should be arrested when the surface possesses a lead-grey color; the dial is then well washed, dried, and the operation re-commenced exactly as before except that the brush used is softer. A good surface will thus be formed, and it will be whiter if the proportion of silver in the paste is increased.

The result attained in great part depends on the skill of the operator, and this can only be acquired by experience.

=615.= _Observations._ If the mixture contains too much of the salt or too little silver, the latter will adhere with difficulty, and will come off in lumps or scales; moreover, it will not have so white a color.

As the proportion of silver is increased, the white becomes gradually better; but, on the other hand, if it is in excess the surface will be coarse and uneven. Too much or too little water will have nearly the same effect. The color is worse if the dial has been imperfectly smoothed, and when several days or even hours are allowed to elapse between the cleaning and silvering.

It is essential that the rock-salt and the cream of tartar be perfectly pure; if they contain any earthy matter it will scratch the surface and impair its whiteness.

As soon as the operation is completed, the dial must be washed in an abundant supply of pure water; any neglect in this particular will cause it to blacken. This washing may be performed with an ordinary watch-brush, charged with cream of tartar. Then rinse the dial, and dry, tapping gently with a fine linen rag, and finish by slightly warming it.

=616.= =Gold Dials.= It will not be necessary to say much on this subject. In order to restore the color to a gold or gilt dial, it may be dipped for a few seconds in the following mixture: Half an ounce of cyanide of potassium is dissolved in a quart of hot water, and two ounces of strong ammonia mixed with half an ounce of spirits of wine and added to the solution. On removal from this bath, the dial is immediately immersed in warm water; then brush with soap, rinse, and dry in hot boxwood dust. Or it may be simply immersed in dilute nitric acid, but in that case any painted figures will be destroyed.

=617.= _Another Receipt._ The following is the method ordinarily adopted for coloring gold dials; but it is to be observed at the outset that, although apparently characterized by extreme simplicity, a good deal of skill is needed to ascertain when the mixture is of the right consistency, and when the dial has been sufficiently exposed to its action.

Make a mixture of 4 oz. saltpetre, 2 oz. alum and 2 oz. common salt (the purest attainable), with a very little water. On placing this in a blacklead crucible over the fire it will become limpid, and must be allowed to boil until somewhat pasty and of a pale yellow color, stirring all the while with a stick. Now take two dials, back to back, that have been cleaned and blackened by annealing, and pass a platinum wire through their centers so that they hang horizontally, resting on a loop at its end; immerse the dials in the hot color crucible, and, after holding it for a short time, withdraw them and immediately immerse in a vessel of nearly boiling water standing close by. The “color” will then be washed, and the progress of the work can be observed. The dials are again dipped in the crucible if necessary, and will probably require about three minutes’ immersion in all. It is advisable that the “color” be thick rather than thin, as in the latter case the dials are apt to be clouded.

=618.= =To Re-Paint the Hours on a Dial.= The following system has reference to metallic dials, but the reader will be able to s

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Untitled

Anonymous

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Transcriber's Notes

Text printed in italics in the source document have been transcribed _between underscores_; small capitals have been replaced with ALL CAPITALS.

The language used is that of the source document; inconsistencies have not been addressed.

Table of Contents: the chapter title for chapter VI does not agree with the headings (_Suggestions_ and _Receipts_) in the text.

THE CHOCOLATE-PLANT (THEOBROMA CACAO) AND ITS PRODUCTS.

[Illustration: THE FRUITING-STEM OF A CHOCOLATE-PLANT, THE FLOWERS, YOUNG FRUIT, AND RIPENED POD ALL SPRINGING FROM THE OLDER WOOD.]

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CONTENTS.

CHAPTER PAGE

INTRODUCTORY 5

I. OUTLINE OF THE EARLY HISTORY OF THE CHOCOLATE PLANT. -- ITS PRIMITIVE CULTIVATION. -- EARLY METHODS OF UTILIZING THE SEEDS. -- INTRODUCTION OF THE BEVERAGE INTO EUROPE 7

II. THE NATURAL HISTORY OF THE CHOCOLATE PLANT. -- THE PRESENT RANGE OF THE PLANT UNDER MODERN METHODS OF CULTIVATION. -- COMMERCIAL RELATIONS 16

III. THE SEEDS OF THE CHOCOLATE PLANT, AS THEY APPEAR IN COMMERCE. -- THEIR MICROSCOPIC AND CHEMICAL CHARACTER 23

IV. MANUFACTURE OF CHOCOLATE, AND BREAKFAST COCOA 26

V. SOME PHYSIOLOGICAL ASPECTS OF CHOCOLATE SEEDS. -- VALUE OF CHOCOLATE AS AN ARTICLE OF FOOD. -- APPLICATIONS OF COCOA-BUTTER 32

VI. A FEW CULINARY RELATIONS OF CHOCOLATE AND BREAKFAST COCOA, BY MRS. ELLEN H. RICHARDS AND MISS PARLOA 35

INTRODUCTORY.

Four years ago, a convenient handbook on the production and use of various preparations of the chocolate plant was published by our firm. The present work is designed to give, with considerably more detail, some of the interesting facts relative to the early history and cultivation of the chocolate tree, as well as a fuller account of its botany and the chemistry of its products. Since this _brochure_ will doubtless fall into the hands of some who do not have access to the earlier work, we have used with freedom some of the material employed in that; but we hope that these necessary repetitions will increase instead of impair the value of the pages now before the reader.

We trust that this second treatise may be acceptable to our many friends who gave so warm a welcome to the first.

WALTER BAKER AND COMPANY.

DORCHESTER, MASSACHUSETTS, 1891.

THE CHOCOLATE-PLANT.

I.

OUTLINE OF THE EARLY HISTORY OF THE CHOCOLATE-PLANT.

At the discovery of America, the natives of the narrower portion of the continent bordering on the Caribbean Sea, were found in possession of two luxuries which have been everywhere recognized as worthy of extensive cultivation; namely, tobacco and chocolate. The former of these has made its way into climates totally unlike that of its early home; the other of these plants, since it cannot bear the low temperature occasionally experienced in our subtropics, is more restricted in its range. The chocolate-plant is confined to the warmer regions of the globe, where it finds the congenial climatic conditions which it enjoyed and still enjoys in its earliest home in America.

The first references to the chocolate-plant and its products are found in the accounts of the explorers and conquerors who followed Columbus. These first descriptions of this singular tree, of its fruits and seeds, of its uses and the methods of cultivation, are remarkably accurate in all essential particulars.

[Illustration]

One of the earliest, if not indeed the very earliest, delineations of the chocolate-tree is in a rare volume by Bontekoe. The engraving, which is here reproduced with fidelity, represents the chocolate-tree with its comparatively large fruits or pods borne on the main stem. This might be thought at first to be an error of the artist, but it is in fact a rude expression of one of the most remarkable peculiarities of the plant. As will be shown presently, when a fuller description of the plant is given, the fruits are, as a rule, formed on the older parts. Another interesting feature is shown in the engraving:[1] the chocolate-tree is sheltered by a larger tree of some other kind near it. We shall see shortly, that this practice of planting a sheltering tree to shade the young chocolate plants for a time, is still kept up wherever the plant is successfully cultivated. It is certainly interesting that this point in cultivation, which might easily have been thought to be accidental or local, was delineated more than three centuries ago. By the natives of tropical America, the seeds of the chocolate-plant, which will be more particularly described in a later chapter, were first roasted and then rudely ground. For this purpose they employed the flat or curved surface of the sort of stone used by them to grind their maize, or Indian corn. In the engraving, one of the most simple mills or flat mortars is seen with its roller. The roller was merely a short thick stone of a cylindrical shape, which could be used with one or both hands somewhat after the manner of the common rolling-pin everywhere used in kitchens. By this simple appliance, the crushed seeds were mixed with various ingredients, among which may be mentioned spices of different kinds. A modification of this was later used in Spain. See page 15.

[1] The figure in the left of the foreground is said by Bontekoe to represent the native method of procuring fire by rapidly twirling a pointed stick in a groove of a piece of wood placed on the ground.

[Illustration: FROM A PHOTOGRAPH OF A STONE MILL, OR FLAT MORTAR.]

The drinks made from this coarse chocolate were frequently very complex, but the chocolate itself was the chief constituent. It was the custom to beat the mixture into a froth or foam, by means of stirrers, of mallet-like forms; in fact, it is said by some writers that the very name chocolate, is derived from a native word indicating the noise made by the stirring of the beverage.

Thus, Thomas Gage, in his "New Survey of the West Indies," says (under date of 1648), "The name chocolatte is an Indian name, and is compounded from _atte_, as some say, or as others, _atle_, which in the Mexican language signifieth water, and from the sound which the water (wherein is put the chocolatte) makes, as _choco_, _choco_, _choco_, when it is stirred in a cup by an instrument called a 'molinet,' or 'molinillo,' until it bubble and rise unto a froath."

[Illustration: SOME OF THE FORMS OF CHOCOLATE STIRRERS ("MOLINETS").

From a treatise published in the Seventeenth Century.]

The same writer gives us an interesting account of the native method of preparing the drink. From the extract, which is copied without change of the quaint spelling, it will be seen how wide the use of chocolate was in Europe towards the middle of the seventeenth century:--

"Now, for the making or compounding of this drink, I shall set down here the method. The cacao and the other ingredients must be beaten in a morter of stone, or (as the Indians use) ground upon a broad stone, which they call _Metate_, and is only made for that use. But first the ingredients are all to be dried, except the _Achiotte_, with care that they be beaten to powder, keeping them still in stirring that they be not burnt, or become black; for if they be overdried, they will be bitter and lose their virtue. The cinnamon and the long red pepper are to be first beaten with the anniseed, and then the cacao, which must be beaten by little and little till it be all powdered, and in the beating it must be turned round that it may mix the better. Every one of these ingredients must be beaten by itself, and then all be put into the vessel where the cacao is, which you must stir together with a spoon, and then take out that paste, and put it into the morter, under which there must be a little fire, after the confection is made; but if more fire be put under than will only warm it, then the unctuous part will dry away. The _Achiotte_ also must be put in in the beating, that it may the better take the colour. All the ingredients must be searced, save only the cacao, and if from the cacao the dry shell be taken, it will be the better. When it is well beaten and incorporated (which will be known by the shortnesse of it), then with a spoon (so in the Indias is used) is taken up some of the paste, which will be almost liquid, and made into tablets, or else without a spoon put into boxes, and when it is cold it will be hard.

"Those that make it into tablets put a spoonful of the paste upon a piece of paper (the Indians put it upon the leaf of a plaintin tree), where, being put into the shade (for in the sun it melts and dissolves), it grows hard; and then bowing the paper or leaf, the tablet fals off by reason of the fatnesse of the paste. But if it be put into anything of earth or wood, it stickes fast, and will not come off but with scraping or breaking. The manner of drinking it is diverse; the one (being the way most used in Mexico) is to take it hot with Atolle, dissolving a tablet in hot water, and stirring and beating it in the cup, when it is to be drunk, with a Molinet, and when it is well stirred to a scumme, or froth, then to fill the cup with hot Atolle, and so drink it sup by sup. Another way is that the chocolate, being dissolved with cold water and stirred with the Molinet, and the scumme being taken off and put into another vessel, the remainder be set upon the fire, with as much sugar as will sweeten it, and when it is warme, then to powre it upon the scumme which was taken off before, and so to drink it. But the most ordinary way is to warme the water very hot, and then to powre out half the cup full that you mean to drink; and to put into it a tablet or two, or as much as will thicken reasonably the water, and then grinde it well with the Molinet, and when it is well ground and risen to a scumme, to fill the cup with hot water, and so drink it by sups (having sweetened it with sugar), and to eat it with a little conserve or maple bred, steeped into the chocolatte.

"Besides these ways there is another way (which is much used in the Island of Santo Domingo), which is to put the chocolatte into a pipkin with a little water, and to let it boyle well till it be dissolved, and then to put in sufficient water and sugar according to the quantity of the chocolatte, and then to boyle it again untill there comes an oily scumme upon it, and then to drink it.

"There is another way yet to drink chocolatte, which is cold, which the Indians use at feasts to refresh themselves, and it is made after this manner: The chocolatte (which is made with none, or very few, ingredients) being dissolved in cold water with the Molinet, they take off the scumme or crassy part, which riseth in great quantity, especially when the cacao is older and more putrefied. The scumme they lay aside in a little dish by itself, and then put sugar into that part from whence was taken the scumme, and then powre it from on high into the scumme, and so drink it cold. And this drink is so cold that it agreeth not with all men's stomachs; for by experience it hath been found that it doth hurt by causing pains in the stomach, especially to women.

"The third way of taking it is the most used, and thus certainly it doth no hurt, neither know I why it may not be used as well in England as in other parts, both hot and cold; for where it is so much used, the most, if not all, as well in the Indias as in Spain, Italy, Flanders (which is a cold countrey), find that it agreeth well with them. True it is, it is used more in the Indias than in the European parts, because there the stomachs are more apt to faint than here, and a cup of chocolatte well confectioned comforts and strengthens the stomach. For myself I must say, I used it twelve years constantly, drinking one cup in the morning, another yet before dinner between nine or ten of the clock; another within an hour or two after dinner, and another between four and five in the afternoon; and when I was purposed to sit up late to study, I would take another cup about seven or eight at night, which would keep me waking till about midnight. And if by chance I did neglect any of these accustomed houres, I presently found my stomach fainty. And with this custome I lived twelve years in those parts healthy, without any obstructions, or oppilations, not knowing what either ague or feaver was."

After its introduction into Europe from America, chocolate was used at first only as a luxury, but it has steadily advanced in popular esteem until it is now recognized as one of the necessaries of life.

[Illustration: FRONTISPIECE OF ONE OF THE EARLIEST WORKS ON CHOCOLATE.]

It would be interesting to speculate as to the accidents which led to the original use of such beverages as coffee, tea, and chocolate. The earliest employment of the two former is veiled in as deep a mystery as that which surrounds the chocolate-plant. All were used at the outset by what we have been accustomed to call the uncultivated races of mankind, but we cannot surmise what first attracted their attention to these plants. One can only say that by the natives of lands where the plants grow naturally, they have all been used from time immemorial, and that all three are welcome gifts from a rude state of civilization to the highest which exists to-day. By the savages and the Aztecs of America, by the roving tribes of Arabia, and by the dwellers in the farther East, the virtues of these three plants were recognized long before any one of them was introduced into Europe.

There is reason to believe that long before the discovery of America, Tea and Coffee had been vaguely known to travellers in the Orient, as curiosities, much as we to-day regard the Kola-nut and Maté, but neither Tea nor Coffee was then employed as a beverage anywhere in Western Europe. In fact, all trustworthy evidence in the case leads us to a surprising conclusion, namely, That _Chocolate was the first of these beverages to attract the attention of Europeans_. This beverage rapidly made its way throughout Europe, beginning from Spain and Portugal, whither its discoverers had brought it. The other beverages, Tea and Coffee, soon followed, and after a short time became associated together in popular regard.

In a duodecimo work published in 1685, and now very rare, the beverages derived from these three plants are described in a clear and forcible manner. The reproduction of the frontispiece of this book, given above, shows how intimate the association of these beverages was regarded even two centuries ago. It is interesting to observe the distinction made by the artist in the receptacles and cups for holding these three different drinks. On the floor, near the vase, is seen one of the chocolate-stirrers described on page 10.

At the outset the manufacture of chocolate in Europe was carried on with substantially the same appliances as those used by the natives. A curious indication of this is afforded by the engraving, which shows that the Portuguese mill was to all intents modelled after that used by the Mexicans.

[Illustration: CHOCOLATE-GRINDING IN THE SEVENTEENTH CENTURY.

From an early engraving.]

II.

THE NATURAL HISTORY OF THE CHOCOLATE-PLANT.

[Illustration: THEOBROMA CACAO.]

The chocolate plant is known to botanists as _Theobroma Cacao_. The first or generic word in this name means _food of the gods_. The genus contains six species, only one of which is generally cultivated. It is probable, however, that some of the seeds which find their way into commerce are yielded by other and wild species. It is, moreover, more than likely that among the numerous varieties of Theobroma Cacao now cultivated there may be some hybrids between the different forms.

[Illustration: FLOWERS, FRUIT, AND SEEDS OF THEOBROMA.

From an old engraving.]

The plant belongs to the Sterculiaceæ, a natural order containing forty-one genera and five hundred and twenty species. The general habit of the tree is well shown in the engraving.

[Illustration: FLOWERS, FRUIT, AND SEEDS OF THEOBROMA.

From a recent drawing.]

The seeds of the plant are borne in pods, represented in the illustrations on pages 17 and 18, the former taken from one of the early works on the subject. No. 1 in the first engraving exhibits the ripened pod, 5 and 6 the fruits in different stages of growth. No. 2

shows the pod cut open and displays some of the seeds, while 3 and 4 are the seeds themselves,--the former in its natural state, the latter with the seed-coats removed.

The pod is irregular and angular, much like some forms of cucumbers, but more pointed at the lower extremity, and more distinctly grooved. It measures in length nine inches to a foot, or even more, and about half as much in diameter. The color, when young, is green, becoming later dark yellow or yellowish brown. The rind is thick and tough. The pod is filled with closely packed "beans," or seeds, imbedded in a mass of cellular tissue, sometimes of pleasant subacid taste. The seeds are about as large as ordinary almonds, whitish when fresh, and of a disagreeable bitter taste. When dried they become brown.

The fruits are about four months in ripening; but they appear and mature the whole year through. In point of fact, however, there are chief harvests, usually in early spring, but this is different for different countries.

The following extract from a comparatively recent consular report gives a clear idea of the modern method of cultivating the plant in some parts of South America. The extract was given in our former edition, but it is thought best to transcribe it here.

"The tree grows to the average height of thirteen feet, and from five to eight inches in diameter, is of spreading habit and healthy growth, and although requiring much more care and attention than the coffee-tree, yet its equally reliable crops require comparatively little labor in properly preparing for the market.

"... There are two varieties of the cocoa-tree cultivated in Venezuela, known as El Criollo and El Trinitario, respectively, the former of which, though not so prolific, nor as early fruiting as the latter, is yet superior to it in size, color, sweetness, and oleaginous properties of the fruit, and in the fact that it always finds ready sale, while the latter is often dull or neglected. The difference in price of the two varieties is also marked, the former being quoted at $28 to $30 per fanega (110 pounds), while the latter commands approximately half that price.

"While coffee can be successfully cultivated under a temperature of 60 degrees F., the cocoa-tree, for proper development and remunerative crops, requires a temperature of 80 degrees F.; hence the area of the cocoa belt is comparatively restricted, and the cocoa-planter presumably has not to fear the fierce competition that he has encountered in the cultivation of cotton and coffee. Besides the condition of temperature above stated, this crop needs a moist soil and humid atmosphere; and so the lands along the coast of the Caribbean sea, sloping from the mountain-tops to the shore, bedewed by the exhalations of the sea and irrigated by the numerous rivulets that course down the valleys, are found to be, in all respects, well adapted to the profitable cultivation of cocoa. And while the lands in the interior possessing facilities for irrigation may be said to be equally as good for the purpose, yet the absence of roads, and the consequently difficult transportation of produce on the backs of donkeys over rugged mountain paths, materially reduce the profits on the crop before it reaches the market.

"A cocoa plantation is set in quite the same manner as an apple-orchard, except that the young stalks may be transplanted from the nursery after two months' growth. No preparation of the soil is deemed necessary, and no manures are applied. The young trees are planted about fifteen feet equidistant, which will accommodate two hundred trees to the acre. Between rows, and at like spaces, are planted rows of the Bucare, a tree of rapid growth, that serves to shade the soil as well as to shield the young trees from the torrid sun. Small permanent trenches must be maintained from tree to tree throughout the entire length of the rows, so that, at least once in the week, the stream, descending from the mountains, may be turned into these little channels and bear needful moisture to trees and soil. At the age of five years the plantation begins to bear fruit, and annually yields two crops, that ripening in June being termed the crop of San Juan, and that maturing at Christmas being known as the crop of La Navidad. The average age to which the trees attain, under proper care, may be estimated at forty years, during which period it will give fair to full crops of fruit; but of course it must be understood that, as in our fruit orchards, a new tree must be set from time to time to replace one that may be decayed or blighted. After careful inquiry it may be safely stated that the average crop of the cocoa plantation at ten years of age, and under a proper state of cultivation, will amount to five hundred or six hundred pounds per acre."

The method of preparing the fruit for shipment is thus described in the "Encyclopædia Britannica":--

"In gathering, the workman is careful to cut down only fully ripened pods, which he adroitly accomplishes with a long pole armed with two prongs, or a knife at its extremity. The pods are left in a heap on the ground for about twenty-four hours; they are then cut open and the seeds are taken out and carried in baskets to the place where they undergo the operation of sweating or curing. There the acid juice which accompanies the seeds is first drained off, after which they are placed in a sweating-box, in which they are enclosed and allowed to ferment for some time, great care being taken to keep the temperature from rising too high. The

fermenting process is, in some cases, affected by throwing the seeds into holes or trenches in the ground, and covering them with earth or clay. The seeds in this process, which is called "claying," are occasionally stirred to keep the fermentation from proceeding too violently. The sweating is a process which requires the very greatest attention and experience, as on it, to a great extent, depends the flavor of the seeds and their fitness for preservation. The operation varies according to the state of the weather, but a period of about two days yields the best results. Thereafter the seeds are exposed to the sun for drying, and those of a fine quality should then assume a warm, reddish tint, which characterizes beans of a superior quality."

Cocoa-beans are derived chiefly from the following sources, here arranged alphabetically. A recent author has classified them under two heads, unfermented and fermented; but this classification is very misleading, since it happens that from a few of the places mentioned variable proportions of both sorts are brought to market. Ariba (Ecuador), Bahia (Brazil), Caracas (Venezuela), Cayenne (French Guiana), Ceylon, Guatemala, Haiti, or Port au Prince, Java, Machala, or ordinary Guayaquil (Ecuador), Maracaiba (Colombia), Mararion (Brazil), St. Domingo, Surinam (Dutch Guiana), Trinidad (W. I.), from Africa, the Seychelles, Martinique, and Bourbon, variable amounts are beginning to appear as regular products. It is generally understood that some of the best sorts of South American cocoa are consumed at home and do not find their way, in definite quantities, or as a stated supply, to any foreign ports. Among these are Soconusco and Esmeraldas. At the last French exposition these and other very fine sorts from Venezuela and Ecuador were exhibited. New fields are being opened up in many directions to meet the increasing demand for the product.

III.

THE SEEDS OF THE CHOCOLATE-PLANT AS THEY APPEAR IN COMMERCE. THEIR MICROSCOPIC AND CHEMICAL CHARACTERS.

The seeds of the chocolate-plant are brought into the market in their crude state, as almond-shaped "beans," which differ in color and somewhat in texture. It is not uncommon to find the external surface of the bean more or less covered with a thin irregular layer of attached earth, but this is generally pretty well cleared off during the transportation.

Upon the color of shell and kernel, the relative brittleness, the flavor, and the odor, depends the market value of the seeds.

The dried seeds have a papery, brittle shell, which is very smooth on the inside, but on the outside exhibits, under the microscope, a few short hairs and round excrescences. But these are mostly lost by the rough handling and by the attrition of the seeds with one another during transportation. The kernel consists of two large cotyledons or seed-leaves, reddish-gray or reddish-brown, with a shining, oily surface; the whole crushing rather easily into a loose mass of fragments. The kernel, when dry, has a minute, tough, almost stony radicle which separates easily from the cotyledons. Microscopic examination shows that the cells of the seed-leaves contain albumen, oily matters,--sometimes in a crystalline condition,--crystals of an entirely different shape, starch, coloring substances in special receptacles known as pigment-cells, and ducts with spiral markings. The starch grains do not have any very characteristic form or markings: they are generally spherical and simple. The only peculiarity worth mentioning, is the relative slowness with which they are acted on by hot water and by iodine. The coloring substances are mainly of a carmine or violet color, and are distinguished by the change of shade when an alkali is added, becoming thereby darker.

These are the only structural elements which a pure powder or paste of chocolate should show under the microscope. Any other substances must be recognized as accidental or intentional additions.

All seeds of whatever kind contain, as a part of their substance, the matter of which cell-walls are made; namely, cellulose. The percentage differs in different seeds, in those of the chocolate-plant being about three in the hundred. Cellulose has the same chemical composition as starch; but its physical properties are not the same as those of starch, among which may be mentioned its entire insolubility in boiling water.

Starch forms, on an average, eight to ten per cent of chocolate-seeds. It consists of minute spherical grains, not distinguishable from that found in many other kinds of seeds. Traces of gum and of other allied bodies are also present in the seeds.

Albuminoids, or substances resembling, in a general way, the albumin of egg, occur in chocolate-seeds as they do in other seeds, and in a somewhat higher amount than in certain other cases in which the seeds are used as food. The percentage ranges from about fifteen to twenty, depending on the variety. These albuminoids are compounds of nitrogen, and are extremely nutritious. In the seeds they occur in a readily assimilable form, fit for digestion. Their peculiar relations as flesh-formers are referred to in the

section treating of the physiology of chocolate-seeds.

Cacao-red occurs as a coloring matter in small amount. It is rendered dark by alkalies.

Theobromine, the active principle of the cocoa-bean, constitutes less than one per cent of the weight of the seeds, but it varies greatly in amount in different seeds, ranging from [illegible] of one per cent in some, to a trifle over one per cent in others.

The ash left on completely burning cocoa-beans is not far from four per cent. Its composition is substantially that of the ash of seeds of other plants.

Cocoa-butter, or oil, constitutes not far from fifty per cent of good cocoa-beans. The oil is remarkable for its freedom from rancidity and its very bland character. Its uses are innumerable.

The following averages of many analyses by a leading recent authority may be of interest:--

UNROASTED.

Moisture 7.11 Oil 51.78 Theobromine .35 Starch 5.78 Cellulose 3.1 Other carbohydrates, glucosides, etc. 10.05 Protein matters 15.61 Ash 3.60

ROASTED.

Moisture 6.51 Oil 49.24 Theobromine .43 Starch 10.43 Cellulose 3.1 Other carbohydrates, glucosides, etc. 7.78 Protein matters 18.33 Ash 3.92

IV.

MANUFACTURE OF CHOCOLATE AND BREAKFAST COCOA.

We have already called attention to the simple process by which the natives of Central America prepared a nutritious beverage from the seeds of the chocolate-plant. The essential features of this process, modified and greatly improved by modern science, are worthy of consideration at this time.

The selected cocoa-beans are first cleaned from the dust and attached particles which have come from various sources during the fermentation of the seeds. The machines for cleaning the beans are very ingenious and effective, removing from the seed-coat every trace of foreign matter.

The cleaned seeds are next roasted in the most careful manner, every precaution being taken to secure a uniform effect through the whole mass. During the roasting the seeds change color somewhat and become more or less modified in taste. In under-roasted seeds the flavor is not fully developed, while in over-roasted seeds the pleasant taste is likely to become greatly impaired, or it may even be wholly replaced by a bitter and harsh flavor. These relations of color and taste to the roasting of the seeds make this portion of the manufacture one of the most delicate processes from beginning to end.

By the roasting the shell becomes more readily detachable, and its complete removal is the next step. The crushing of the seeds into small fragments is easily accomplished; and this is followed by a thorough winnowing, by which the lighter shells are carried away by themselves, leaving the clean fragments of the roasted seeds ready for further manipulation.

Among the fragments can be detected minute and very tough bits of tissue. These bits are the hardened germs, or rather portions of the germs, and these are separated from the rest by an apparatus of much simplicity and efficiency.

The clean shells are usually placed at once in packages for transportation. They are extensively used for the domestic preparation of a wholesome and very low-priced drink. This beverage contains a fair proportion of the active principle of the chocolate-seeds themselves, and the flavor is suggestive of chocolate.

The cleaned fragments constitute the so-called “cocoa-nibs” of some foreign markets, and in this state they are used for the preparation of a simple decoction. But in this form they require to be boiled a good while for the development of flavor, and it is therefore better to have them treated beforehand in order to reduce the time of boiling; and this is all the more necessary, since during the long boiling a part of the more delicate aroma peculiar to chocolate-seeds is apt to be dissipated.

We are next to trace these fragments, through the chocolate-mill, and afterwards follow similar fragments through the cocoa-factory.

In the preparation of chocolate, the fragments are ground by a complicated mechanism until they attain the greatest degree of fineness, and constitute a perfectly homogeneous mass or paste. If the chocolate is to be a plain chocolate, it is to receive its delicate flavoring and then go directly into the moulds for shaping it. Every step of the process has to be watched with the most assiduous care. When the chocolate is formed and properly cooled, it is wrapped and packed for the market.

But if the chocolate is to be sweetened, a definite amount of the purest sugar, previously pulverized, is to be added, the whole ground and commingled, the proper flavoring of pure vanilla added, and the semi-solid mass formed in moulds as before. After being moulded it is sent to the packing-room and wrapped.

The variations in the process are innumerable, but all of them are comparatively unimportant when taken singly; the skill in the manufacture requires that each of these slight changes should be made at just the right time and in the right way. In the manufacture of Walter Baker and Co.'s chocolate, this skill has become developed to a very high degree during the hundred years of success. That the firm is ready to avail itself of every appliance known in modern manufacture, is seen by their adoption of the complicated machinery illustrated on page 29. This chocolate-machine has a capacity of five tons of pure chocolate daily. It is accessible to visitors, who may apply at the office in Dorchester for permission to see it in operation.

It is unnecessary to detail the steps of manufacture of many of the chocolate specialties of the firm.

We turn now to the consideration of breakfast cocoa.

The manufacture of breakfast cocoa is based upon two important factors: first, the removal of a definite portion of the cocoa-oil from the roasted seeds; and second, increasing the miscibility of the powdered seeds by securing the greatest practicable degree of fineness.

[Illustration: ONE OF THE CHOCOLATE-MACHINES AT THE MANUFACTORY OF WALTER BAKER & CO.

CAPACITY, FIVE TONS OF CHOCOLATE DAILY.]

While the oil of the chocolate-seed is perfectly wholesome, there are some persons who find in the percentage natural to the seeds a too large amount for easy digestion. The removal of a part of this, which might with propriety be called an excess of the oil, was practised even in very early days, as is seen in the cut herewith given, taken from an old work on the subject. The present method of extracting the oil is not essentially different, save in a few particulars, from that here figured, and therefore need not be described in detail.

[Illustration]

The method of manufacture is substantially as follows: the ground fragments of roasted seeds are subjected to pressure, and with the result of withdrawing just as much oil as the manufacturers desire to abstract. The pressed mass is, in the most successful process, treated mechanically in such a manner as to divide and subdivide the minute particles until they are capable of passing through a sieve having several thousand meshes to the square inch. But such pulverization as this would, under ordinary circumstances, reduce the mass to a dull and unattractive powder. In the process devised by the firm of Walter Baker and Co., this high degree of fineness is secured without any loss of brilliancy in the powder,--the color being of the bright-red which is not only attractive in appearance, but when conjoined with the natural chocolate odor and flavor is characteristic of absolutely pure cocoa of the highest grade.

It is instructive to compare such cocoa with the cocoas prepared by what is known in chemical technology as the chemical process. The latter are prepared by treatment with alkaline matters which act on the coloring substances in the seeds, increasing the apparent effect of hot water when the latter is added. In chemically prepared cocoas, the exquisite natural odor and flavor of pure cocoa-seeds have been diminished or wholly lost by the severe treatment to which the materials have been subjected. In some cases the loss of the natural flavor is sought to be partially supplied by the use of fragrant gums, wholly foreign to the natural product.

The detection of these admixtures is generally easy. Comparison with the well-known pure breakfast cocoa of Walter Baker and Co. will reveal at once the vast superiority of a product which has not been treated by chemicals, but which contains only the finest

possible powder of the best chocolate-seeds freed from the excess of oil. The exquisite flavor and odor of the pure product are due wholly to the seeds themselves, since absolutely no foreign matter is added from first to last. Walter Baker and Co.'s breakfast cocoa can be used by students of the microscope and of chemistry as a perfect type of the highest order of excellence in manufacture. The enormous increase in consumption of Baker's cocoa and chocolate indicates that our discriminating public appreciate a thoroughly good article when they see it.

V.

SOME PHYSIOLOGICAL ASPECTS OF CHOCOLATE-SEEDS.--VALUE OF CHOCOLATE AS AN ARTICLE OF FOOD.

The seeds of plants contain a germ, or embryo, together with a certain amount of food. As soon as the germ sprouts, the food, or a good part of it, is consumed by the seedling, being used by it in the formation of new parts, such as roots and leaves by which the materials for more food can be obtained from the soil and air. Now it happens that the food of plants is pretty much the same as the food of animals, although there is this marked difference in the manner of procuring it: plants can construct their own food from inorganic or mineral matters taken from the earth and atmosphere, while animals, even those which are most like plants, must have their supply of food from organic nature.

Since, then, plants prepare the food which animals are to use (of course flesh-eating animals use their plants, so to speak, at second-hand), it comes to pass very naturally that the food in a good many seeds has been recognized from early times as very useful food for man. Thus the cereals--wheat, maize, oats, barley, and rice--are the seeds of grasses; and there are many other seeds, such as beans, peas, buckwheat, and so on, which have been appropriated as food by man from remote antiquity. But the seeds of some plants are unfit for human food, owing to disagreeable properties which they possess; while there are a few which stand on the very edge of the limit of foods, and have been used in time of scarcity.

The seeds of at least two plants are used as important adjuncts to our list of foods, and can be enumerated among foods without any impropriety. These are coffee and cocoa. They contain nutritive properties,--the latter in very much higher degree than the former,--and they possess also peculiar constituents which entitle them to rank as luxuries. These peculiar constituents are (1) flavoring matters, and (2) an active principle. But, either from its constitution or from its association in the seed, the active principle of coffee, although it has nearly or quite the same ultimate composition as the active principle of cocoa, is unlike it in its effects. The active principle of cocoa is substantially free, as used in its preparations, from any undesirable effects on the nervous system. This active principle of cocoa is _Theobromine_.

The essentials of a perfect food are (1) a certain amount of carbohydrates, (2) of albuminoids, and (3) certain mineral matters, these latter being substantially the same in all seeds used as food. In cocoa these three groups are combined in proper proportion to constitute a complete food, but there is superadded the active principle, _Theobromine_, which places it at once in the class of luxuries as well as of necessary foods.

When cocoa-seeds are prepared properly for food, without doing violence to the chemical relations of the different components, a comforting nutritive article of the highest value is obtained. This ideal method of preparation is not a chemical torturing by the addition of foreign ingredients, as in the alkali process, but it consists in the complete unlocking, by perfectly natural, mechanical means, of all the virtues of the seeds. We do not try to render the albuminoids of wheat and other grains soluble by means of ammonia, soda, or potash, nor do we think it desirable to increase the solubility of the albuminoids of egg and meat by adding caustic or carbonated alkalies to them before they are used. And yet chemical processes analogous to these have been devised and are sometimes used with regard to cocoa. In most cases these added substances are detected in the increased amount of mineral matters found in the ash after burning the preparation. The amount of ash in pure cocoa is about four per cent. Any appreciable amount above this may be attributed to the admixture of mineral matters used in the preparation.

The oil in pure chocolate-seeds is about fifty per cent of the whole weight. Although the oil is exceedingly bland and free from rancidity, it has been found expedient in some cases to withdraw a part of this oil, leaving a smaller amount in the product. This is the method pursued in the manufacture of the powdered cocoas. With this reduction in the quantity of oil, the resultant beverage is less likely to disagree with delicate digestion.

It is in all cases of the first importance to obtain only pure cocoa of the highest quality, free from any admixture of foreign matter, such as the alkalies or their carbonates; and further, the product ought to be of the greatest degree of fineness. With regard to the flavors added to chocolate, it is perhaps needless to say that they should be of the utmost degree of purity. This is especially true of

vanilla, which owing to its high cost is frequently replaced by artificial flavors. There is, in one respect, a notable difference between sweet chocolate and cocoa: the former may be flavored, the latter should never be. A pure cocoa must be absolutely dependent on its own delicious, natural odor and flavor. No addition of any substance of any kind is admissible.

SUGGESTIONS RELATIVE TO THE COOKING OF CHOCOLATE AND COCOA.

BY MRS. ELLEN H. RICHARDS,

Of the Massachusetts Institute of Technology.

The flavor of the cocoa-bean seems to be almost universally liked, and the use of the various preparations made from it is constantly increasing. From the sweet chocolate with which the traveller now provides himself in all journeys in which the supply of food is doubtful either in quantity or quality, to delicate coloring and flavoring of cakes and ices, nearly all kinds of culinary preparations have benefited by the abundance of this favorite substance.

In these forms, chocolate is used in a semi-raw state, the bean having been simply roasted at a gentle heat, ground, and mixed with sugar, which holds the fat. By varying the quantity of the chocolate to be mixed with the ingredients of the cake or ice, an unlimited variety of flavors can be obtained.

In preparing it as a beverage for the table a mistake has been frequently made in considering chocolate merely as a flavor, an adjunct to the rest of the meal, instead of giving it its due prominence as a real food, containing all of the necessary nutritive principles. A cup of chocolate made with sugar and milk is in itself a fair breakfast.

There is much to be said in favor of preparations of the whole bean which secure all of the valuable nutrition contained in this "food for the gods," and rightly understood, it is possible to make them more important articles of diet than they now are. But since the large percentage of fat seems to require correspondingly large quantities of sugar to render the beverage palatable, and this very rich, sweet drink soon cloys if made strong enough to be nutritious, it is, fortunately, possible to extract the larger part of the fat without injury to the flavor so characteristic of chocolate. In this form, called cocoa, less sugar and more milk are needed, and the resulting beverage suits even delicate stomachs, and is yet of high food value.

It is the object of all cooking to render raw material more palatable and more nutritious, and therefore more digestible. The cooking of cocoa and chocolate is no exception to this rule. Certain extractive principles are soluble only in water which has reached the boiling-point; and the starch, which the seed contains, is swollen only at this temperature.

Chocolate or cocoa is not properly cooked by having boiling water poured over it. It is true that as the whole powder is in suspension and is swallowed, its food material can be assimilated as it is when the prepared chocolate is eaten raw; but in order to bring out the full, fine flavor and to secure the most complete digestibility, the preparation, whatever it be, should be subjected to the boiling-point for a few minutes. In this all connoisseurs are agreed.

RECEIPTS.

BY MISS PARLOA.

PLAIN CHOCOLATE.

For six people, use one quart of milk, two ounces of W. Baker & Co.'s No. 1 chocolate, one tablespoonful of corn-starch, three tablespoonfuls of sugar, and two tablespoonfuls of hot water.

Mix the corn-starch with one gill of the milk. Put the remainder of the milk on to heat in the double-boiler. When the milk comes to the boiling-point stir in the corn-starch, and cook for ten minutes. Have the chocolate cut in fine bits and put it in a small iron or granite-ware pan; add the sugar and water, and place the pan over a hot fire. Stir constantly until the mixture is smooth and glossy. Add this to the hot milk and beat the mixture with a whisk until it is frothy. Or the chocolate may be poured back and forth from the boiler to a pitcher, holding high the vessel from which you pour. This will give a thick froth. Serve at once.

If you prefer not to have the chocolate thick, omit the corn-starch.

CHOCOLATE MADE WITH CONDENSED MILK.

Follow the rule for plain chocolate, substituting water for the milk, and adding three tablespoonfuls of condensed milk when the chocolate is added.

CHOCOLATE; VIENNA STYLE.

Use four ounces of vanilla chocolate, one quart of milk, three tablespoonfuls of hot water, and one tablespoonful of sugar.

Cut the chocolate in fine bits. Put the milk on the stove in the double-boiler, and when it has been heated to the boiling-point, put the chocolate, sugar, and water in a small iron or granite-ware pan and stir over a hot fire until smooth and glossy. Stir this mixture into the hot milk, and beat well with a whisk. Serve at once, putting a tablespoonful of whipped cream in each cup and then filling up with the chocolate.

The plain chocolate may be used instead of the vanilla, but in that case use a teaspoonful of vanilla extract and three generous tablespoonfuls of sugar instead of one.

BREAKFAST COCOA.

Breakfast cocoa is powdered so fine that it can be dissolved by pouring boiling water on it. For this reason it is often prepared at the table. A small teaspoonful of the powder is put in the cup with a teaspoonful of sugar; on this is poured two-thirds of a cupful of boiling water, and milk or cream is added to suit the individual taste. This is very convenient; but cocoa is not nearly so good when prepared in this manner as when it is boiled.

For six cupfuls of cocoa use two tablespoonfuls of the powder, two tablespoonfuls of sugar, half a pint of boiling water, and a pint and a half of milk. Put the milk on the stove in the double-boiler. Put the cocoa and sugar in a saucepan and gradually pour the hot water upon them, stirring all the time. Place the saucepan on the fire and stir until the contents boil. Let this mixture boil for five minutes; then add the boiling milk, and serve.

A gill of cream is a great addition to this cocoa.

CHOCOLATE CAKE.

For two sheets of cake use three ounces of W. Baker & Co.'s No. 1 chocolate, three eggs, one cupful and three-fourths of sifted pastry flour, one cupful and three-fourths of sugar, half a cupful of butter, half a cupful of milk, half a teaspoonful of vanilla extract, one teaspoonful and a half of baking powder.

Grate the chocolate. Beat the butter to a cream and gradually beat in the sugar. Beat in the milk and vanilla, then the eggs (already well beaten), next the chocolate, and finally the flour, in which the baking powder should be mixed. Pour into two well-buttered shallow cake-pans. Bake for twenty-five minutes in a moderate oven. Frost or not, as you like.

VANILLA FROSTING.

Break the white of one large egg into a bowl, and gradually beat into it one cupful of confectioner's sugar. Beat for three minutes, add half a teaspoonful of vanilla extract, and spread thinly on the cakes.

CHOCOLATE ICING.

Make a vanilla icing and add one tablespoonful of cold water to it. Scrape fine one ounce of No. 1 chocolate and put it in a small iron or granite-ware saucepan with two tablespoonfuls of confectioner's sugar and one tablespoonful of hot water. Stir over a hot fire until smooth and glossy, then add another tablespoonful of hot water. Stir the dissolved chocolate into the vanilla icing.

CHOCOLATE ICE-CREAM.

For about two quarts and a half of cream use a pint and a half of milk, a quart of thin cream, two cupfuls of sugar, two ounces of No. 1 chocolate, two eggs, and two heaping tablespoonfuls of flour.

Put the milk on to boil in the double-boiler. Put the flour and one cupful of the sugar in a bowl; add the eggs, and beat the mixture until light. Stir this into the boiling milk and cook for twenty minutes, stirring often.

Scrape the chocolate and put it in a small saucepan. Add four tablespoonfuls of sugar (which should be taken from the second cupful) and two tablespoonfuls of hot water. Stir over a hot fire until smooth and glossy. Add this to the cooking mixture.

When the preparation has cooked for twenty minutes take it from the fire and add the remainder of the sugar and the cream, which should be gradually beaten into the hot mixture. Set away to cool, and when cold, freeze.

CHOCOLATE PUDDING.

For a small pudding use one pint of milk, two tablespoonfuls and a half of corn-starch, one ounce of chocolate, two eggs, five tablespoonfuls of powdered sugar, one-fourth of a teaspoonful of salt, and half a teaspoonful of vanilla extract.

Mix the corn-starch with one gill of the milk. Put the remainder of the milk on to boil in the double-boiler. Scrape the chocolate. When the milk boils, add the corn-starch, salt, and chocolate, and cook for ten minutes. Beat the yolks of the eggs with three tablespoonfuls of the sugar. Pour the hot mixture on this and beat well. Turn into a pudding-dish that will hold about a quart, and bake for twenty minutes in a moderate oven.

Beat the whites of the eggs to a stiff, dry froth, and gradually beat in the remaining two tablespoonfuls of sugar and the vanilla. Spread this on the pudding and return to the oven. Cook for fifteen minutes longer, but with the oven-door open. Serve either cold or hot.

BAVARIAN CHOCOLATE CREAM.

For one large mould of cream, use half a package of gelatine, one gill of milk, two quarts of whipped cream, one gill of sugar, and one ounce of chocolate.

Soak the gelatine in the cold water for two hours. Whip and drain the cream, scrape the chocolate, and put the milk on to boil. Put the chocolate, two tablespoonfuls of sugar, and one of hot water, in a small saucepan, and stir on a hot fire until smooth and glossy. Stir this into the hot milk. Now add the soaked gelatine and the remainder of the sugar. Strain this mixture into a basin that will hold two quarts or more. Place the basin in a pan of ice-water and stir until the mixture is cold, when it will begin to thicken. Instantly begin to stir in the whipped cream, adding half the amount at first. When all the cream has been added, dip the mould in cold water and then turn the cream into it. Place in the ice-chest for an hour or more.

At serving-time dip the mould in tepid water. See that the cream will come from the sides of the mould, and turn out on a flat dish. Serve with whipped cream.

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How and what to grow in a kitchen garden of one acre

E. D. Darlington

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OF ONE ACRE.

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HOW AND WHAT TO GROW

IN A

KITCHEN GARDEN

OF ONE ACRE.

BY E. D. DARLINGTON AND L. M. MOLL.

EDITED BY W. ATLEE BURPEE.

[Illustration]

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EDITOR'S PREFACE.

In Burpee's Farm Annual for 1887 we offered cash prizes for the two best essays, to be sent us by October, 1887, upon the subject, "HOW AND WHAT TO GROW IN A KITCHEN GARDEN OF ONE ACRE." In its original form E. D. DARLINGTON'S essay covered more fully than any other the operations and best methods to pursue in the management of the garden, and was awarded the first

prize. Being desirous, however, of making this work not only practical but thoroughly complete in all departments, and from personal acquaintance with Mr. Darlington and his gardening operations, together with the fact that for some years he had tested numerous varieties of vegetables for us, we arranged with him to entirely revise and enlarge his essay. In compliance with our request he has entered more into detail in the directions for culture, and has added impartial descriptions of the varieties that he has found best adapted both to the Kitchen Garden and the table. To make the treatise more complete, he prepared a diagram of his own kitchen garden, which is one acre in size, as laid out for a year's work. Some varieties grown are not marked in the diagram, as they are worked in as parts of other rows, but this is all fully explained in the body of his treatise.

To add to the value of the book as a plain and practical guide for the novice in gardening, we have had illustrations engraved showing the two plans of hotbeds, the methods of storing roots for winter use, etc. We have also inserted engravings, mostly drawn from nature, of the leading varieties of vegetables described in the text, that the gardener may have an accurate idea of the form of the different varieties and may be able to tell whether his products are of the right type.

We take pleasure, also, in publishing the essay of Miss L. M. MOLL, of Illinois, which was awarded the second prize. We are glad to note that she has been explicit in describing the culture of some of the less generally grown varieties of salads and herbs which are valuable adjuncts to the table, and upon which Mr. Darlington has failed to treat. Some of the methods described in this essay are, however, unnecessarily laborious. For instance, the wide bed of perennials, as described, would require considerable hand labor to keep the soil loose and free from weeds; while, if planted in long rows, horse cultivation would lessen this tedious work and would also loosen the ground to a greater depth. The varieties recommended by Miss Moll, while generally good, have in some cases been surpassed by improved varieties of more recent introduction.

As presented in the following pages, the two essays will, we believe, make this book, for general use, the most complete and practical treatise on gardening published. Such has been our earnest endeavor, and we are confident that it will be recognized as a thoroughly trustworthy guide. With careful study of its teachings, the novice should be able to plant and successfully manage a Kitchen Garden, be it one acre, more or less, while we trust that experienced gardeners will find much to commend and will be able to gain some new ideas.

W. ATLEE BURPEE.

PHILADELPHIA, December 16th, 1887.

HOW AND WHAT TO GROW

IN A KITCHEN GARDEN

OF ONE ACRE.

BY E. D. DARLINGTON.

In order to treat this subject in detail, I shall first write on what the kitchen garden should be, where it should be, and how to keep it in the best order to produce the desired results, then take up "What to grow" and "How to grow it."

SITUATION OF THE GARDEN.

The garden should be situated conveniently near the farm buildings, as it should be visited frequently; a variety of tools are needed in its care, and each should be put away as soon as done with, that it may be preserved in the best order for use. It is often necessary to carry water to help along young transplanted stock that has been overtaken by a dry spell. Where the distance has to be traversed so frequently, it naturally follows that the shorter it is the greater will be the saving in time and the less likely is the garden to be neglected.

The garden should be as nearly level as possible, or, if sloping, not so much so as to be in danger of being washed by heavy rains. If sloping, the slope should lie to the south, or as nearly south as possible. A plantation or hedge of evergreens on the north side of the garden will be found a wonderful aid to the earliness of the garden truck and to the hardiness of the small fruit plants and roots which remain in the ground all winter; if a woods or high hill be directly on the north and northwest of your garden, it will answer nearly as well as the hedge of evergreens. The garden should be so situated as to have good surface drainage; without this or expensive underdraining, it will hardly be possible to raise early or fine vegetables at any profit. These I consider the most essential

points in selecting the plot for the garden; of course, a good, rich soil is to be desired, but the gardener can, by the liberal use of manure and thorough cultivation, remedy a deficiency of this kind in a couple of years, while he cannot make a favorable location for early vegetables on a north slope if he should try a lifetime. By a careful study of the varieties in cultivation, and by trials of their merits in your garden and _on your table_, experience will be gained which will enable you to grow as fine vegetables and fruits on heavy soil as on light, sandy loam, and _vice versa_.

THE SOIL OF THE GARDEN.

Ground that has been worked in some cultivated farm crop, such as corn or potatoes, is more desirable for starting a garden than fresh sod land, as it is more easily brought into fine condition in the early spring; while grass is one of the hardest weeds to exterminate, especially among small hoed crops, such as strawberries, onions, beets, etc. Sod land is also often full of grubs, which work havoc among the strawberry plants and young melon and squash vines. In either new ground or in the old established garden, it will be of great advantage to put the long, coarse manure on the ground in the fall, and plow it well under as soon as the ground can be cleared of the summer crops. The soil should be left just as it is plowed, without harrowing, leaving the lumps and ridges to the action of the frost. This will be found of especial benefit to heavy soils that are late in drying in the spring; it also adds a great deal to the appearance and cleanliness of the garden, as the weeds, old stalks, etc., are all cut off and burnt before plowing, instead of being left to scatter their seeds with every winter wind.

The gases arising from the decaying of the coarse manure in the soil tend to lighten it, instead of being wasted in the air, as is the case when the manure is in heaps or in the barnyard. By plowing-time in the spring the manure will have assimilated with the soil and will be thoroughly worked through the cultivated surface, thus affording food for the crops in all stages. If such manure is applied in the spring, it will make dry or thin soil still drier, and unless plowed well under, where it would take the roots a long time to reach it, will burn the young plants up if the season should happen to be a dry one. The great value of compost in starting young plants is that it affords rich food in proper form for the tender young rootlets, enabling the young plants to make a quick, tender growth, which is very essential if vegetables of fine quality are desired. By fall manuring and plowing the whole garden is composted, while the action of the frost on the lumps and ridges pulverizes them, leaving the soil in a fine, friable condition.

LAYING OUT THE GARDEN.

It is most convenient to have the garden as nearly square as possible, which in our garden of one acre will be 208 x 208 feet. This makes the length of the rows a very good measure of the quantity to be grown, and affords as many rows to the ground as can be profitably worked, for it is desirable that the rows should be as nearly east and west as possible, and they should be the long way of the plot (if not a square), as it will result in great saving of time in planting and cultivating. Moving the line and drawing the cultivators out of one row and turning into the next, takes nearly as much time as the working of the short row.

In plowing, a good, wide headland should be left at each end of the garden; it should be wide enough to allow the horse and cultivator to come clear out from between the rows and to turn into the next row, without damaging the plants at the ends of the rows by trampling and dragging the cultivator over them.

In winter, while there is plenty of time before the spring opens, the summer campaign should be planned--what vegetables are to be raised and what quantity of each will be needed, in what part of the garden it will be best to plant each variety so that the pollen from different members of the same family, such as cucumbers and cantaloupes, will not mix and spoil each other's fine flavor. If the soil is of different quality in different parts of the garden, it should be planned so that the heavy and the lighter portions shall be occupied by such crops as will succeed best in the respective soils.

Ease of cultivation and the rotation or succession of crops should also be considered. The small-growing plants which require hand hoeing should be together, and likewise those which are to be worked with the horse cultivator. Where the ground is to bear two crops--one planted after the other has matured and been taken off--it will be of advantage to have such crops together, thus making larger plots for the replowing and a consequent saving of time and work.

Beside these conditions in laying out a new garden, when it comes to the second or succeeding seasons, the crop or crops raised in the plot the year before must be taken into account. The situation of the crop of each particular vegetable should be moved to another part, as each draws certain proportions of the food elements from the soil, and those of a different character should occupy the ground in rotation, that the soil may be kept in the richest state. Thus the quality or size of the crop will not be lessened by being planted in a situation that it has depleted, to some extent, of its own particular food the year before. Reference should also be had

to the kind of food which the plant requires, as in the case of strawberries and potatoes, which should not succeed each other without special manures, as they both exhaust, to a great extent, the potash in the soil, so that the soil, having borne a heavy crop of one, would of necessity make but a poor return of the other if planted in direct succession. If this cannot be overcome by a change of location, the gardener will know that the proper food elements have been depleted by the previous crop, and must try to supply them with special manure or commercial fertilizers.

It is of great importance to rapid work and good gardening that all this should be arranged and settled in the gardener's mind, or better, plotted out on paper, before the first plowing is done in the spring. The plan being kept would be valuable in laying out the garden the succeeding year, as it would show just where each vegetable had been grown and where the different kinds of manure had been applied. If, in addition, the success of the various crops and notes of their growth were marked upon it, it would form a most valuable text-book for the study of improved gardening, each garden being an experimental station and each gardener a student in pursuit of knowledge and advancement in his work, feeding at the same time both physical and intellectual needs.

DIAGRAM OF THE GARDEN.

The accompanying plan may be of use to the novice in gardening on the scale suggested by our subject, as it is planned to admit of a proportionate quantity of such vegetables and fruits as are grown in the ordinary garden, while directions for planting and cultivating the various vegetables will be found in the special descriptions of the several varieties. (See p. 16.)

PROCURING THE SEEDS AND PLANTS.

[Illustration:

KEY TO DIAGRAM.

ROW NO. 1. 25 grape vines, planted about 7½ feet apart. The first three years these are trained to plain stakes or bean poles, the space in the rows between the vines being planted with strawberries, peas, beans or some other low-growing crop, to occupy the ground and insure good cultivation. When the vines have made strong canes and have reached the tops of the poles, a post is set at each vine and a trellis made, as described in the chapter on grapes. This row is six feet distant from the north boundary line of the garden.

ROWS NO. 2. These rows are twelve feet distant from each other and from the row of grapes, and are planted with blackberry vines, at a distance of three feet in the rows. Though this may seem like a good deal of "elbow room," it is as close as they can be planted to keep them in good order; if planted closer they will form an impenetrable jungle by the end of the second season.

ROWS NO. 3. These two rows are planted with red and black raspberries, the rows also twelve feet apart, but the plants set 2½ feet apart in the rows.

ROW NO. 4. This is planted with rhubarb, sage and thyme, currants and gooseberries, and is twelve feet distant from the rows on either side.

ROW NO. 5. Is twelve feet from row No. 4, and is planted with asparagus, as described in the special chapter on that vegetable.

ROWS NO. 6. These two rows are to be planted with spring-set strawberries for the next year's crop, and are four feet distant from the asparagus and from each other. The strawberries are intended to be grown on the matted row plan, and to be cultivated with the horse cultivator; if they are to be grown in stools, another row can be planted between them, and the whole worked with the wheel or hand hoes.

ROW NO. 7. This row is for watermelons or cantaloupes, and the line of hills is six feet distant from the row on either side. The space in the row between the hills can be planted with egg plants, cabbage, lettuce or such other plants as may be desired.

ROW NO. 8. This row is a space four feet wide, with room for the cultivator on either side; this is raked fine and planted in four rows one foot apart, the first row containing beets and carrots; the second, onions; the third, lettuce, radishes, etc.; the fourth, with a dozen plants of parsley, and the balance of the row in endive and parsnips. When the two middle rows have been cut out, the cultivator can be used to work the beets, parsnips, etc., in the outside rows.

ROW NO. 9. This row is three feet distant from the parsnips, and is planted with early cauliflower and early cabbage, with two plants of lettuce between each of the other plants, which are set 1½ feet apart.

ROWS NO. 10. These are four rows of peas, different plantings, two kinds, early and medium, in each row, in equal quantities, rows three feet apart. These are to be pulled out as soon as the crop is gathered, and two rows of celery planted six feet apart.

ROWS NO. 11. Here are four rows of early sweet corn, in four plantings of successive kinds, to be cleared off and followed by turnips, drilled in rows one foot apart, and worked with the wheel hoe; or the seed may be broad-casted after a thorough cultivating, when the ears of corn are well set, without clearing the ground. This is not nearly so satisfactory a plan as to wait until the ground can be cleared and drilled. The rows of corn should be four feet apart.

ROWS NO. 12. Two rows, 4½ feet apart, of Lima beans, with the poles about 2½ feet apart in the row.

ROW NO. 13. This row should have six feet clear on each side for the vines to run, and is to be planted with cucumbers and squashes. The space between the hills can be occupied with pepper plants or sweet corn.

ROWS NO. 14. Two rows of tomatoes, four feet apart.

ROWS NO. 15. Four rows of late sweet corn, four feet apart.

ROWS NO. 16. Two rows of sweet potatoes, five feet apart and five feet from the corn and pole beans on either side.

ROW NO. 17. One row of pole snap beans. About three kinds should be planted, that they may be had in succession.

ROWS NO. 18. Five rows early potatoes, three feet apart, plowed in when the ground is plowed in the spring. When cultivated for the last time, plant a row of late cabbage between each row of potatoes; when the latter are ripe, dig with a fork, clear the ground of vines and cultivate the cabbage thoroughly.

ROWS NO. 19. Sweet corn planted between the rows of berry bushes; a large late variety will be the best for this purpose.

ROWS NO. 20. Two rows of fruiting strawberries, to be plowed under and be replaced by peas sown in August. This, of course, applies only to a garden of at least a year's standing; and the fruiting plants of strawberries will come in a fresh place each year. The rows No. 6 being the bearing plants next season.]

Having the plan of work all settled, the next thing is to know what is to be grown, the varieties of each that are best adapted to the situation and soil of the garden, and where they can be procured of the best quality. Under this head come the seeds needed for the vegetables and the roots, tips and runners for the plantings of small fruits. This should be done as soon as convenient, as I have found by experience it is a great saving to have the entire supply of seeds on hand a week or two before it is possible to begin planting. This is an important item, as I have sometimes lost my crop from planting inferior seed purchased at the last moment from the commissioned seeds that are sold in the country stores. It does not pay to economize or try to garden with poor seeds; it is a waste of time and labor in planting, and a waste of ground and manure, as the inferior vegetables raised will hardly cover the original cost of the seed. The gardener who sells his products, unless his crops are of the best, will soon find his trade falling off, and will be compelled to seek new customers each market day. Personally, I have found it more satisfactory and productive of better results to buy each season almost all the seeds needed from some reliable seedsman, rather than to depend on those of my own saving. For instance, such as peas, sweet corn and other vegetables, where the earlier the crop is ready to market the greater the profit; these mature much earlier if the seed is procured from reliable seedsmen who have their supplies grown in the North. Such northern grown seeds retain their instinct to hurry up and mature in a short season, while in one's own saving they begin even in the first year to grow more leisurely and to accommodate themselves to the longer season. In the case of peas, those grown in Northern New York and Canada, such as are sold by all our leading seedsmen, will mature from one to two weeks earlier than those saved in our own neighborhood. The northern peas are also generally free from the weevil or striped bug, which bores the large round hole in all the home-saved peas and destroys their germinating power. So it is with almost every known variety of vegetable; each has some special locality in which it reaches a higher degree of perfection than in others less favorably situated. While, of course, these facts are of interest to the gardener, they are only learned after years of experience, and it is the seedsman's business to know the peculiarities of the different varieties, and to raise or procure his stock from the best strains grown in the most favorable localities. It is for the gardener to purchase from a seedsman whom he knows to be thoroughly reliable, and whose interest it will be to serve him with prompt shipments and carefully-selected strains of the vegetables desired. All this is equally true of the nursery-man or small-fruit grower from whom the supply of roots and plants is to be purchased. On no part of the farm is "_Pedigree Stock_" of more importance than in the kitchen garden. I will speak further on of the saving of seeds, and refer now only to those which it is necessary to buy. First, it is often a saving of several days to have the seed on hand, as it is

sometimes impossible to foretell just when you will need the seed to plant a certain plot, how soon the ground will be fit to work, or how soon will come the opportunity, in the press of other work; if you have the seed at hand that part is always ready, and this is quite an item where the garden frequently has to be attended to in the intervals of farm work. Next, it is a cash saving to order all your seeds at one time. If, as is most frequently the case, you have to send to some large city for your supply, by procuring all that you need at one time, you have but one freight or express charge to pay. In making up your order, stick to the old varieties that you know suit your soil and your market; all the more if your market is your own table, for the greatest pleasure in gardening is in testing the merits of your fruits and vegetables with the appetite engendered by their culture. Also take into consideration the preferences of the household department as to the cooking merits of the different varieties. Do not experiment with your main crop of any vegetable, but do not neglect to try such new varieties as seem to possess merit, for the varieties are being continually improved by good culture and selection, as well as by hybridization or cross-breeding. To have a fine garden, the gardener must know the merits of all new and old varieties, and be as progressive as is the successful man in any other line of business. I know of nothing so interesting as watching the growth and development of some new and improved variety that has been recommended to the gardening public in the most glowing terms, and often in glowing colors on a beautiful colored plate. Although I have been "taken in" fully as often as the average gardener of my experience, I have been many times repaid all trouble and outlay by the numerous successes that I have met with and the great improvement in some of the varieties grown. Sometimes I have made quite a nice little sum out of these novelties, when I have been able to sell the selected seed of the new variety to some other seedsman or to my neighbors. In these new varieties, more than in any others, do you need to order early, or, instead of the seed that you desire and which is to make reputation and money for you, "being something superior to anything ever grown before," you may get one of those provoking little slips stating that the seedsman "regrets to inform you that, owing to the great demand, the supply is exhausted for this season, and hopes that the substituted kind will do as well."

HOTBEDS AND COLD FRAMES.

With a garden of this size I would have hotbeds, cold frames and rich seed beds of fine light soil; these I would not have in the garden itself unless that be the most convenient place. Where there is time to attend to them, they will be a measure of economy, it being much cheaper to raise than to buy the plants, if you use more than a few dozens, while, if you have the time and room, quite a business can be done by supplying your neighbors who do not garden on such an extensive scale. It is best to locate the frames on the sunny side of a barnyard wall, or against a building that will shield them from the north wind and make a warm nook for them on sunshiny days. They should be situated conveniently near both to the manure pile and to a good supply of water, where they will constantly be under the eye in passing to and from the farm work and will not suffer neglect from being forgotten or overlooked. It is quite important that there should be good drainage from these beds, as they are most needed at a rainy time of the year; dampness is not only injurious to the young plants, but it also takes up a great deal of the heat which should go toward forwarding the growth of the young plants. The sashes can be bought, ready painted and glazed, at the planing mills in most cities, and this is much the cheapest way to procure them, as they can often be bought for what the bare sash would cost in a small order at a country shop. They come 3¼ feet wide by 6 feet in length, and are 1½ to 2 inches in thickness, and if stored in the dry when not in use, and are treated to an occasional coat of paint, will last a lifetime.

Three or four sash would be amply sufficient for a garden of an acre if used in succession, sowing one lot of seed as the preceding planting is set out in the garden; though, of course, more sash can be handled without any great increase of labor, and the season much advanced by growing radishes, lettuce, beets, etc., to maturity under the glass.

[Illustration: Illustration showing the manner of making the hotbed when sunk below the surface of the ground.]

In making the hotbed, dig a trench a few inches short of six feet in width, or as wide as the sashes will cover, about two feet in depth and as long as the combined width of the number of sashes which you wish to use. This is then to be boarded up with rough boards, but they should be neatly joined and plastering laths or building paper tacked over the cracks, so as not to waste the heat. The back or north side of this frame should be 6 or 8 inches higher than the front, so that the rain may run off the sashes. The sashes held at an angle in this manner will also receive more sunlight for the front part of the bed than if front and back were level. The whole frame of the bed should be banked round with the dirt thrown out, or better with fresh stable manure, which will help to keep it warm and will make a bank to drain away any surface water, which, being very cold in the spring, would, if allowed to penetrate the bed, tend to chill the heat of the fermenting manure, and consequently check the growth of the young and tender plants, even if it did not generate that great enemy of all young plants, fungus or mildew, causing them to rot or "damp off."

[Illustration: Illustration showing the manner of constructing a hotbed above the surface of the ground.]

Or, if there is plenty of fresh stable manure at hand, it can be corded in a pile two feet high and extending a foot wider than the sash frame on all sides; and when the frame has been put in position on the heap, the manure should be carried up on the outside nearly to the top of the boards, making a warm jacket for the plants within. A portable frame of boards is made for the sash to rest on, twelve inches high at the back and eight inches in front. This style of bed does away with any digging and secures good drainage for the bed. It would probably be the most satisfactory way for the gardener, who is also a farmer, as the bed can easily be removed as soon as it has served its purpose for the season, and the manure, which has become well rotted by this time will make an excellent compost for corn, melons, celery, etc. The frame and sash can also be set on a good piece of ground in the fall and filled with young lettuce plants in the early part of October, which will furnish salad throughout the winter.

The manure and litter which are to produce the heat for the bed should be thoroughly forked over and heaped together a week or ten days before the beds are to be started. While a large proportion of the material should be fresh horse stable manure, where a large quantity of heating material is needed, it can be mixed with any litter obtainable, such as straw, leaves from the woods, weeds, cut fodder, or anything that will furnish bulk and that will decay rapidly, and, by decaying, produce heat; when the material has all been gathered and heaped solidly together, a good sprinkling with water, hot, if possible, will aid in starting the fermentation. In about a week or two, when the heat of the heap has gone down to 95° or 100°, the manure should be placed in the beds and well trampled down; it should come up to within eight inches of the front of the frame and should be covered with about three and a half or four inches of fine, rich soil. It is a good plan to sift the dirt through a coal sieve, as it then makes a fine bed for the seeds and young plants.

Place the sashes on as soon as this is done; handling the manure and repacking it will produce some fresh heat and it will still be too warm to sow any seed, but the heat will destroy such weed seeds as may be in the soil, and the steam and gases arising from the manure will tend to put the soil in the finest possible condition for forwarding the growth of the young plants. A thermometer should be placed in the soil of the bed every day or two, to see if the temperature has fallen sufficiently to admit of sowing the seeds. As soon as the temperature has fallen to about 75°; or, if no thermometer is at hand, as soon as the top sod is only perceptibly warm to the palm of the hand, the bed should be sprinkled, and as soon as this has dried off a little, rake it up thoroughly and sow the seed. The seed will produce finer and stockier plants if sown in drills about six inches apart, which will admit light and air to the roots of the plants, and will permit a weekly hoeing. In planting seeds, the depth of their covering should be about five times the diameter of the seed, and this covering should be firmly packed around them after planting. The starting and planting of these beds must be calculated, so as to have the plants ready to set out as soon as the garden can be worked. In this vicinity (Philadelphia) the first sowing of cauliflowers, lettuce, beets and early cabbage should be made about February 15th, or even earlier, depending on the forwardness of the season or of your own particular garden. The plants will then be of a suitable size for transplanting by the time the early part of the garden has been plowed. If the sashes are covered with old carpets or straw on cold nights, it will be a great saving of the heating power of the manure and will prevent the young plants from being chilled. The young plants should be treated to fresh air whenever the outside temperature is not too cold, that they may not become “drawn,” or “spindle up” into long, slim stems. As planting-out time approaches, the young plants should be left uncovered as frequently as is safe, that they may become sufficiently hardy not to miss the covering when removed to the open ground.

Tomatoes, peppers and egg plants and a second sowing of early cabbage should be sown in the same manner about the middle of March. If a few extra early plants are wanted, they can be transplanted into the earliest beds when the cabbage and other plants have been set out in the garden, and the sash again put on. If some sweet potatoes are buried about two inches deep in the dirt of one of the cabbage frames, and kept warm, they will produce a fine lot of sprouts, or, as they are called, “sets,” which can be broken off and planted in the garden when the weather has become sufficiently warm. If a number are wanted, or there is danger of their growing too large, they can be taken off and “heeled in” in another sash until planting time, and the potatoes put back again, as they will produce two or three crops of the sets. Or a hill of cucumbers can be planted in the centre of each sash as a second crop, and by the time it would be warm enough to leave them uncovered, these will have filled up the frame with bearing vines, gaining at least a month on those planted in the open ground.

While the cabbage, cauliflower, beets and lettuce may be planted out as soon as all danger of frost is over, the tomatoes, peppers, egg plants, etc., should not be set out until the thermometer stands at over 60° all night, or until the oak leaves are as large as a five-cent piece. In a small hotbed it is best to have a partition between each sash and the one next to it, so that such as are tender varieties may be kept warm and the more hardy cabbage may have plenty of fresh air, for if the latter should become “drawn,” all the advantages of an early start will be lost and the plants may become entirely worthless.

Sowings of seeds for early plants may be made in the same manner as above described for hotbeds, in cold frames, which are the same without the artificial heat germinated by fermenting manure, depending solely on the heat of the sun and the protection of the sash to forward the plants. They can be planted about two weeks later than the dates given for the respective vegetables in hotbeds, and the plants will be ready for setting out about the same length of time later than those raised with the artificial heat. These frames can also be used for wintering over a few fall-sown cabbage plants, which are useful in a very early season and can be kept full of parsley, lettuce, etc., making a pleasant variety of greens for the table during the winter.

As soon as it is warm enough to dig them and bring them into fine order, seed beds should be made in a sheltered spot of the garden, for the sowings of late cabbage and celery, which will be spoken of in detail under the special directions for growing these vegetables.

TOOLS.

Although not positively necessary, it is of great advantage to have a variety of tools for thoroughly working the soil and to facilitate the labor of planting and harvesting the crops, and exterminating weeds. If, however, the garden is as well cultivated as it should be, there will be no chance for weeds to start, as they will all be destroyed in their earliest stages.

While there is a general assortment of tools on every farm suitable for use in the garden, I will give a short list of some especially adapted for use in the kitchen garden and the modes and purposes of using them.

First is the PLOW. For the first plowing in the spring, and for the general plowing in the fall, I use a large two-horse plow, which takes a generous slice and will put the manure down as may be wished and return the enriched soil to the surface in the spring, again turning in another coat of manure, if it is to be had in sufficient quantities to do so. So long as the fresh manure does not come in direct contact with the young plants, I do not think it is possible to put in too much, at least in the first three years of the garden. In my soil, which is rather heavy, I plow six to eight inches deep; in light soil I would plow deeper, as the roots penetrate it much more rapidly. For working among the strawberries and permanent rows of small fruits, I use a light one-horse plow, with a swingle tree just wide enough to permit the horse to move freely; this plow is also used in plowing out the potatoes and in preparing the ground for a second crop. If the share is kept sharp, as it always should be, it will be found very useful in the cultivation of the berries, melons, etc., as with a good plowman it will go deep or shallow, or will slip around some point to be missed much easier than the cultivator.

When these plows are not in use I give the mould-board and all bright parts a coat of thick whitewash; this keeps them from rusting, so that plowing a single round leaves them bright and shining. A coat of this on all bright tools, spades, hoes, etc., in the fall, will keep them in the best order through the winter, so that no time will be lost getting them into good working condition in the spring.

A good companion to the light plow is a one-horse HARROW, of a V shape, with long, slender teeth. It is a splendid tool for making a good, deep bed of fine earth for seed sowing or setting out small plants. Where more land has been plowed than is needed for immediate planting, I run over it with this implement when working the balance of the garden, so keeping it clear of weeds and in fine condition for planting. It is especially convenient to have the ground in this shape for planting cabbage, celery, tomatoes, etc., as you can take advantage of a good shower to set them out while the ground is thoroughly wet. My plan is to commence planting when the rain begins, the fresh plants having the full benefit of the shower.

The ROLLER and the Harrow generally go in succession, and a light one-horse roller will be found very convenient, but the large farm roller will do equally good work where one is at hand and there is room for it to be used. A small hand roller, about three feet in width, for rolling in small drilled seeds, such as beets, onions, turnips, etc., and by which the dirt can be settled over a row of peas or corn when only a few rows are planted at once, will many times repay the labor of making it. A piece of six- or eight-inch drain pipe, with the bell knocked off, an iron bar run through the centre for an axle, and the whole inside filled with mortar or concrete and allowed to get perfectly hard, will make as fine a hand roller as need be, or one can very easily be made from a smooth section of a tree trunk. This implement would probably be much more useful than the one-horse roller. It always pays to roll ground every time it is plowed, and too much stress cannot be laid on the value of firmly compacting the soil around freshly sown seed.

The CULTIVATOR is the most important and most frequently used tool in the garden, and should be of the best make obtainable. I consider the IRON AGE or PLANET, JR., the best, they having a light iron frame which is very strong without being clumsy; the spreading bars close inward, so that they do not catch or interfere with the plants in narrow rows, and admit of working rows not more than two feet apart, so that the ground can be cropped to its full capacity. They have a variety of adjustable and reversible

teeth, including plow, shovel and cutting teeth, which will throw the soil to or from the row, or leave it loose and level; in light soil this cultivator will loosen and let in the air seven or eight inches deep. These adjustable teeth are all sharpened at each end so that they can be turned around, so saving the number of times that they will need grinding, as both ends can be used and one grinding suffice where it would take two in the ordinary style of teeth. When worn out, the whole set can be taken off and new ones purchased at a very moderate cost. This part of the implement should be well watched and the teeth kept in good cutting condition, as it will not only kill the weeds a great deal more thoroughly when sharp, but will also be much lighter of draft.

Next to the cultivator comes the WHEEL HOE or hand cultivator. By the use of this implement, roots and small growing vegetables, such as onions, beets, parsnips, lettuce, radishes, parsley, etc., may be planted and thoroughly worked in rows from six to twenty-four inches apart; thus more than doubling the amount that can be raised by horse cultivation. A good implement will not throw dirt over the small plants as the larger cultivator does, so that the rows can be worked closely enough to avoid having to be gone over with the hand hoe after the thinning out has been done. In my experience, I have found that a man can hoe more ground and do it twice as deep and well in one hour with one of these implements than he could do in a day with the old style hand hoe. There are numerous styles of wheel hoes on the market, but the only good one that I have ever seen is "Lee's Wheel Hoe," which is made in Philadelphia under the patent of the inventor, who is himself a prominent trucker. It is strong, light and well built; it has five sharp, finger-shaped teeth back of the wheel, which loosen and pulverize the soil, and a broad hoe blade behind, which travels beneath the surface, turning the soil over and cutting off under ground any weeds which may be in its track. When the soil is in good order, it leaves it as smooth and fine as would a steel rake. To obtain the best results with this tool or with the cultivator, you should go through each row three or four times, so as to pulverize and work over the soil thoroughly. The hoe blades are of different widths, for working rows of different widths, a set of three going with each implement. These hoes can easily be sharpened by any blacksmith. Keep them well sharpened, and it will be surprising to note how much less muscle it takes to push them and how much better the work is done. I have tried several different makes, as I work an acre or more each year with one of these hoes and a "Fire-fly" hand plow, which is run before the wheel hoe when the ground is very hard, and Lee's is the only one that works satisfactorily. When the ground is in the best condition a man can hoe the acre in a single day, so that it will readily be seen what a labor saver it is.

The FIRE-FLY HAND PLOW just spoken of is a very convenient tool for making drills, and will plow out a furrow from one to four inches deep, for sowing peas, corn, beans, etc., and coming back alongside of the open furrow will cover them nicely, not taking one-quarter of the time necessary to make the drill with a hoe and cover with a rake, as it is ordinarily done. It is also very handy to strike out a furrow in this way when planting strawberries, cabbages, tomatoes, etc., especially where two are employed on the same work, as one can strike out the furrows, and drop a plant where each one is to stand, while the other, following, sets the plant with one hand and with the other pulls in and places the loose covering dirt, and finally tramps the soil firmly round the new-set plants with his feet. These two last-mentioned tools are very useful in the ordinary small garden; they enable the work to be done much more quickly and very much more thoroughly than is often the case, the spring spading being generally the only good stirring the soil gets in the season.

A SEED DRILL is a very handy tool, but it is quite expensive. In the kitchen garden there is seldom more than one or two rows across the garden to be sown with any one kind of seed, and this can be done almost in the time it would take to adjust the drill, although the drill works a great deal more evenly than the seed can be sown by hand. On a farm where root crops are raised for soiling, the drill will be a measure of economy, even for a single season, and can readily be used in the garden. The combined implements, with plowing and hoeing attachments, are "a delusion and a snare;" if you want a tool that will do good work, and will not get out of order or break, do not have it "combined" with anything else.

Of HAND-HOES, STEEL RAKES, TROWELS, SPADES, SHOVELS, ETC., there should be enough to furnish each man employed, as it is frequently desirable to have all hands working on the same job. Of these, the hoes, spades and trowels should have an intimate and frequent calling acquaintance with the grind-stone. It is much easier to work with a _sharp_ hoe or spade, and the work is much better when done.

There should be a good stout cotton LINE, long enough to reach across the garden, and a reel to keep it on is a great convenience, as it takes such a short time to wind it up that there is not the same temptation to leave it out all night. A good cotton line, carefully housed, will last for years, and is one of the most important requisites in the garden. Neatness is one of the essentials of good gardening, and I have never known a gardener successful who was "hit or miss" in laying out his rows; every plant must be squarely in the row to admit of close working with the cultivator. If it is necessary to keep a few inches away from the row to avoid cutting the stragglers, either the soil is not loosened around the plant as it should be, or it has to be gone over with the hand hoe,

which consumes time in a large garden.

PLANTING THE GARDEN.

It is common in most gardens to plant blackberries, raspberries, currants, etc., around the fences. This is not only a waste of half the fruit, as it can only be borne on one side, but involves much needless labor in keeping the plants trimmed and worked, and unless hoed frequently the plot becomes a harbor for weeds. The only advantage in so planting is the protection the fence affords in winter, as it catches the flying leaves and weeds in the fall, and these with the shade afforded by the fence and drifted snow make a natural protection for the roots and canes. It is not the severity of the frost which determines the hardiness of a plant, so much as its ability to withstand freezing and thawing in rapid succession. For this reason I would have the small fruits planted at the north side of the garden, especially if it be the highest part, and if there is some kind of wind-break or protection, as this will cause the snow to drift and lie longer, making a natural covering, while the slope will drain the surface water quickly away, so that it does not form hard ice around the crowns.

If it were possible, I would prefer to have no fence around the garden, as it makes it much easier to keep clean. A fence is always a nuisance and waste of ground unless absolutely necessary; but if a fence is needed, have one that will not only keep out stock, but also the gardener's most aggravating enemy, the poultry. A scratching hen seems to have an instinct which tells her as soon as the seed has been planted, and which are the hills containing the choicest varieties.

In plowing the ground in the early spring, I think it is best not to plow more than is needed for the first planting, and to plow the remainder somewhat later, when it has become more dry and friable, as it will not then become packed and hard again by the heavy spring rains. For the first planting the ground should be plowed and planted as soon as it can be got in order; the hardier vegetables will even stand a light frost, and while adapting their growth to the weather, will be ready to take advantage of the first warm spring days. I shall speak of the time of planting and sowing in the chapters devoted to the separate treatment of the different vegetables.

The following simple test will be of use to the novice in determining not only when to plow, but also when to cultivate and hoe the ground. Take a portion of the soil in the hand and try to press it into a ball; if it makes a ball and sticks to the hand it is too wet, while if it crushes hard it is too dry. In both cases, if worked in this condition, it will be left in a hard and lumpy state, that will take a long time to bring into good order. To be in good working condition the soil should crumble easily and finely in the hand, and should leave no dirt adhering to the fingers. It will not only give the best results when worked in this state, but it can also be done in half the time. Sometimes we cannot wait until the ground is in the very best order, as in a drought in summer, when it is needed for the second crop. In such a case it must be brought into as fine condition as possible by repeated harrowing and rolling; the latter is an operation too frequently neglected in the ordinary garden; every farmer knows the value of having the soil firmly compacted round the fresh-sown grain, and it is of equal value in every variety of seed sown in the garden. Where there is not room for the roller to be used after sowing a row, I always have it pressed in by the broad sole of the gardener's boot, which nature usually provides shall be of generous size. It is even more important that the soil should be firmly pressed around the roots of newly-set plants, as if this is not done the first heavy rain uses the roots as water courses, and deprived of contact with the soil, the roots rot off and the plants are stunted or die.

Among the first things to be planted in the spring are the small fruits, such as grapes, blackberries, raspberries, currants, strawberries, etc. These should all be in the kitchen garden, and with them the rhubarb and asparagus beds, where they can and will be cultivated as well as the vegetables, the soil kept loose and free from weeds, that they may devote their energies to making strong canes and bearing fine fruit, instead of wasting their strength in a continuous battle for life with grass and weeds, leaving them an easy prey to insects and disease. Those who have never given them this thorough cultivation will be surprised at the large crops and superior quality of the fruit that can be raised under these favorable circumstances. These fruits, when once planted, with the exception of strawberries, last for many years if well manured, trimmed and cultivated. They should all be at one side of the garden, where they will not be in the way of working the garden with the large plow in the spring and fall, but should have their own plowing with the small plow, two to four inches in depth, spring and fall. In the fall plowing the furrows should be turned toward the row, which will bank them up slightly and afford additional protection through the winter. In the spring this ridge can be worked down level again with the plow and cultivator, the dirt from around the crowns being drawn away with an ordinary hand hoe.

In planting the rows in the spring, the width of the cultivator and swingle tree must be taken into account. If the ground has been heavily manured the vegetables can be planted as closely as will admit of working, and allowing a good supply of light and air to the

roots, excepting melons, and other vines, which should have plenty of room in which to spread and sun themselves. Thus, peas, beets, bush beans, etc., can be sowed as closely as two and one-half feet apart, while corn, pole beans, etc., which grow as high as the horse's sides and the cultivator handles, should have the rows four or four and one-half feet apart, not only to allow of working but to admit of the sunshine and air penetrating to the roots.

WHAT TO GROW.

ASPARAGUS.

This is the earliest vegetable to be ready for use in the spring, excepting those that have been forwarded under glass. While it is quite hardy and withstands much ill treatment, nothing will better repay careful culture and generous feeding. One row across the kitchen garden would make a liberal supply for an average family. The seed should be sown where the row is to stand, and the young plants thinned out until they stand one foot apart in the row. This should be done as soon as they are three or four inches high and well started; if left longer it will be a very troublesome job. These young plants should have every encouragement of manure and cultivation, to make as strong a growth as possible; the stronger and faster they grow the better will be the size and quality of the shoots when old enough to cut. No shoots should be cut until the third spring after sowing, and then should not be cut too long the first season. The fourth and succeeding seasons it may be cut from the time the first shoots appear until the first peas and lettuce are ready to take its place on the table. Then it should be well worked and allowed to attain its full growth, that strength may be stored in the crowns to furnish the shoots for the next season's cutting. As soon as the tops begin to yellow, and the berries to ripen in the fall, it should be mowed off close to the ground and the tops burnt, taking care that all the seeds are consumed; if left on the plants all winter the seed becomes scattered, and, owing to its capacity for sending up shoots, it is a very difficult weed to exterminate. If you do not wish the labor of sowing the seed and tending the young plants, a year can be gained by purchasing the plants. The one-year old plants are preferable unless the older ones have been transplanted each year, as they are gross feeders, and become stunted if allowed to crowd each other while young. To produce the large, fat shoots, it is necessary that the seed shall have been saved from the strongest shoots obtainable, and the plants fed constantly. The best way is to cover the crowns, after the ground is frozen in the fall, with as much manure as can be spared, and work it down to the roots in the spring as soon as it can be forked in; or, if there are several rows, the manure could be placed on them thickly and the soil ridged over it for the winter by throwing up a couple of shallow furrows with the plow; this to be worked down with a sharp harrow in the spring. As soon as it is dry enough in the spring, the soil and manure of the bed should be lightly forked over with a manure fork and the surface raked fine; the reason for using the stable fork is that the tines are slightly curved, and if the handle is held in a nearly horizontal position the bed can be dug down to the roots, and the fork will slide right over the tops of the crowns without injuring them. Where more than one row is desired they should be planted about three feet apart, to admit of cultivation and free access to the beds for cutting. An advantage in sowing the seed is that the crowns are naturally established at a proper depth. In planting the crowns obtained from the nursery-man they should be set at a depth of three or four inches at the most; not one foot under the surface, as is the common practice of truckers. Market gardeners cut the shoots as soon as the tips appear above the surface, so that their shoots are blanched for their whole length; but they do this at the expense of the table quality, as only the tips are edible in this way, and even these taste very much like old hay to any one who has been accustomed to the richness and delicate flavor of shoots cut at the surface when they are from three to four inches in height; this method has also the advantage of not destroying the young shoots just coming up, as the stalks are only cut an inch or so underground, and the knife only reaches the one intended to be cut. If the appearance of the blanched asparagus is desired, it can be much better obtained (that is, with less sacrifice of quality) by placing four or five inches of hay, straw or other litter over the crowns, which can be pushed away from the stalk when cutting and easily replaced. There is another strong reason for not following the deep planting, as usually practiced, and that is, in having your crowns so much nearer the surface they feel the warming and growing influence of the sun sooner in the season, and you are able to have your asparagus for cutting a full week earlier than your neighbor who plants deep.

VARIETIES OF ASPARAGUS.

As mentioned above, this succulent is capable of great improvement by careful selection of seed from the best stalks. The old Purple Top variety is no longer grown, its place having been taken by the larger shoots and better quality of the variety known as Conover's Colossal. This latter, however, has been propagated so extensively and with so little care that it is now almost impossible to obtain seed or plants that will produce the splendid shoots of the original stock. Of the new varieties Barr's Mammoth seems to be the most promising, and as grown in some fields in the vicinity of Philadelphia produces shoots which will average nearly an inch in diameter.

BEANS.

The first planting of snaps or dwarf bush beans can be made when the first planting of peas and beets are sown, but will not do as well nor produce beans of as fine quality as those planted about two weeks later, when the weather has become warmer and more settled. These yield very abundantly, and a drill fifty feet long will produce as many as can be used in a large family. While planting in a drill, for the sake of convenience and quickness in planting, the seed should be dropped in hills about ten inches apart and five seeds to a hill. If the beans are kept picked closely, the plants will continue longer in bearing, and they may be had throughout the season if successive plantings are made, though the pole snaps are to be preferred through the summer and fall, for their greater bearing qualities and the ease of gathering them. In both the bush and pole snaps, care should be taken to secure varieties that are entirely stringless, as they are not only much easier to prepare for use, but are much more tender. The different "Wax" varieties are very fine, but the bush beans of this class have not done well in this locality for the last three seasons, the pods being covered with a species of black spot or rot that spoils fully two-thirds of them.[1]

The pole beans should not be planted until the ground is thoroughly warmed in the spring, or until the thermometer stands over 60° all night. It is quite common to plant these with poles 8 to 9 feet in height. I think this is a mistake, as no ordinary picker can reach higher than about six feet to advantage, and as the vines grow to the tops of the poles before commencing to fruit, both beans and time are lost. The poles should be set in rows four and one-half feet apart and two and one-half to three feet apart in the rows. Two hundred poles of Limas will furnish an ample supply throughout the season, and will ripen a bushel of dried beans for winter use as well. Twenty-five poles will furnish an ample supply of snaps, though we allowed one row across the garden in the diagram given, the surplus being allowed to ripen for winter use. Where the saving of room is an object and the ground has been well manured, these pole snaps can be planted in the hills of corn, and allowed to use the stalks as poles; they will produce a good crop, but not nearly so many, nor are they as easy to pick as when grown on the poles. For this purpose they should be planted with some strong growing variety of corn, such as Stowell's Evergreen or other late variety.

The white soup bean, that is dried for winter use in various ways, including the famous "Boston Baked Beans," is generally grown by dropping one or two hills between each hill of corn, and instead of picking them, the whole plant is pulled up in the fall, and the beans thrashed out with a flail when dry. For Limas and pole snaps, the poles should be set by the aid of the garden line, and where any pole is bowed or crooked it should be planted so as to bring it in line with the row, lengthwise, as nearly as possible, that they may present an orderly appearance. In setting the poles, make a hole from one to two feet deep by driving the sharp end of a crowbar into the ground, place the butt end of the pole in this hole and ram it firmly in its place; then put one or two shovelfuls of compost around the base of the pole, and with a sharp steel rake make a hill of fine dirt over the compost. Five or six beans should be planted to each hill, but if all grow should be thinned out to two or three. If the young plants do not climb the poles readily at the first start, they should be trained up and tied till they begin to take hold for themselves. Be careful, in planting Lima beans, to push them into the soil with the eye down, for, as the first leaves are quite large and heavy, it assists them materially in breaking through the soil to plant them in this manner.[2]

The Limas may be brought into bearing somewhat earlier in the season by placing pieces of sod, cut four inches square and about three inches thick, grass side down, in the hotbed, and planting four or five beans in each piece; if this is done in the latter part of March they will be of good size by the time it is warm enough to plant them out, which is done by planting the piece of sod at the base of the pole, in hills, as prepared for the seed. If the end of the vine is pinched off when it is about four or five feet up the pole, it will assist the lateral shoots in blooming early, and consequently produce beans earlier, though, like all forcing methods, it will, to some extent, lessen the vigor of the vine, and most likely, to some extent, the amount of the crop.

BUSH BEANS--_Golden Wax_.--This is one of the best bush beans; it matures early; the pods are of very handsome appearance, brittle and entirely stringless; it is a good bearer and makes an excellent shelled bean for winter use.

Best of All Dwarf Bean.--This is a green-podded bean, and is probably the best for the first planting, as it is not only very early but also very productive; the pods are six inches long, entirely stringless, very fleshy and rich flavored.

Champion Bush Bean.--This is a strong grower, attaining about fifteen to eighteen inches in height, and an immense cropper. The beans can be used as string beans in the green state, but its chief quality lies in the superiority of the beans when dried, and the large crops which it produces when grown for winter use.

[Illustration: BEST OF ALL DWARF BEAN.]

[Illustration: CHAMPION BUSH BEAN.]

POLE BEANS, SNAP VARIETIES--_Golden Wax Flageolet_.--This bean is of recent introduction, and is worthy of all the praise that has been bestowed upon it; it is a tremendous bearer, and is almost as early as the dwarf wax varieties, the pods are much larger, being seven to eight inches long, round and very fleshy; they are entirely free from strings and of the finest quality. Unlike the other pole beans, it begins to produce beans at the bottom of the pole as soon as it starts to climb; and if these are used as they mature, it will continue in bearing the entire season.[3]

White Creaseback, or Best of All.--These for early and the _Lazy Wife's_ for late are the best of the green-podded pole beans. The pods are about six inches in length, thick fleshed, and of very fine quality. The Creaseback is very early and matures its crop in a short time, thus making it a very profitable variety for market. Both varieties are very productive, entirely stringless, and of superior flavor.

[Illustration: CREASE BACK POLE BEAN.

LAZY WIFE'S POLE BEAN.]

LIMAS--_Extra Early Lima_.--This variety matures very nearly as early as the Small Lima, while the beans are more nearly the size of the late Lima; the quality is very fine and the quantity large, as it bears the pods in clusters of four, with four to six beans in a pod.

Dreer's Improved Lima.--This variety is early and very productive if measured in the green state; the pods are smaller than in the ordinary Lima, but the beans are very plump, and are so close together in the pods as to crowd against each other. As a green bean it is very early, and shells out more quarts to the basket of pods than the larger varieties; but the quality is not as fine, and in the dry state the beans shrivel up till they are only about the size of dry bush beans, and are not nearly so good as the other varieties.

King of the Garden.--This is a new variety, in which the green beans are of unusual size and very fine quality. I have seen half an acre planted with this variety which I am sure had at that time more than twice the quantity of beans that could be grown on the same ground of the ordinary kinds; vines were loaded with clusters of pods seven to eight inches in length, and it was no rarity to see them with five very large beans in a pod. From its great productiveness and the fine quality of the beans, it deserves the first place among the Limas.

BEETS.

Seed of these should be sown when the first planting is done in the spring. They may be had still earlier by planting the seed in a hotbed while the ground is still frozen, and transplanting them to the garden a week or so after the cabbage and lettuce have been planted out. Care must be taken in transplanting the young beets, that the tap-root does not get broken, or it will make a number of fibrous roots instead of the large, smooth globe desired for the table. When the seed is well up, the plants should be thinned out until they stand six or ten inches apart, as the size of the variety demands. A second sowing should be made about June 1st, and the main sowing about the 15th of July or 1st of August, to raise roots for winter use. These frequent sowings are necessary to have the beets of fine quality; as the roots get older and larger they become "woody," or hard and fibrous, and exceedingly tasteless. Where the season is short, or there are prospects of a dry fall, the second sowing should be large enough to produce the winter crop, as the later one may fail to mature in time. The beets may be stored and the flavor retained by the method described for pitting turnips, and will keep in good order until spring.

The Bassano and other light beets are of quick growth and are tender and palatable while young, but are of coarse texture and not nearly so fine in appearance when cooked as the blood beets. The blood beets retain their deep, rich color, while all the light-leaved or light-stemmed varieties are colorless, or nearly so, when cooked. It certainly adds to the attractiveness of a dish for the vegetable to have a handsome appearance when cooked.

The seed should be sown in drills, from twelve to eighteen inches apart, if to be worked with the wheel hoe; if for horse culture, two and a half to three feet will have to be allowed between the rows. The ground should be raked clear of clods and made as fine as possible. A drill is made by drawing the rake or hoe handle along the line. The drill should be about an inch in depth and the seed should be dropped about two inches apart, thinning out to six or eight inches apart when well started, and if it is desired, the thinnings can be transplanted to another row. If no small roller is at hand, the drill can be covered and packed by the same operation, by removing the line and shuffling along the row with the feet placed in a V, the forepart of the foot drawing in the fine soil

while the heels at the point cover and press the dirt down upon the row; the foot, of course, is only moved a few inches at a time, but with a little practice the rows can be covered in this manner quite rapidly.

VARIETIES OF BEETS.

ECLIPSE.--This is a very early beet, of quick growth and very fine quality. As the leaves of this variety are small and the stems short, they can be grown quite closely together. The roots are perfectly smooth, regular, globe shape, blood-red skin and flesh, fine grained and very sweet when cooked.

EDMAND'S EARLY TURNIP.--This variety is turnip-shaped, that is, tapering more gradually below the shoulder than the Eclipse; the foliage is short and stocky, enabling a heavy crop to be grown, as they can be grown as closely as six inches apart; the flesh, of a deep blood red, is of the finest quality.

[Illustration: EDMAND'S EARLY TURNIP BEET.]

[Illustration: BURPEE'S IMPROVED BLOOD TURNIP BEET.]

BURPEE'S IMPROVED BLOOD TURNIP.--This beet attains quite a large size and is very smooth and regular in appearance; the flesh is deep blood red and of fine quality, whether eaten in summer or stored for winter use; it is one of the best varieties for the latter purpose, and should be sown as described for the winter crop.

CABBAGES.

Of this vegetable two distinct crops are raised in every garden, while many gardeners, by successive sowings and the use of several varieties, have them fit for use constantly from early spring until fall, and throughout the entire winter by storage. In the ordinary garden the same result may be obtained by planting larger quantities of the early and summer varieties, and cutting them as wanted for use, as most of them will stand the whole summer without bursting or going to seed, and by early fall some of the winter cabbage will be large enough for use.

EARLY OR SUMMER CABBAGES.--The seed for these should be sown in a hotbed from the 1st to the 15th of February. As soon as the plants are large enough to set out they should be given plenty of air, and should be gradually hardened off until they are able to stand the cool nights without protection; but they should not be allowed to freeze. Treated in this way they will be ready for planting out as soon as the ground can be worked. In making this sowing I would have it of two kinds--some of a small, hard-heading, early variety, and about twice as many of a larger-heading summer kind. These latter are described as second early in the seed catalogues.

These early cabbages need very little care except to have frequent and thorough cultivation, as they are comparatively free from insect pests as long as they make a healthy growth. If attacked by the black fly or green worm, they should be dusted with land plaster or slug shot early in the morning, while the dew is still on them. The soil around these and all other crops that depend on quick growth for their superior qualities, must not only be cultivated, to kill the weeds, but must be kept loose and well stirred, to admit the air to the roots of the plants; it must not be allowed to lie heavy and packed after dashing rains, but should be stirred up as soon as dry enough. The rows may be as close as can be worked with the cultivator, say about three feet, and the plants about one and a half feet apart in the row, or even closer, if the variety grown makes but small heads.

LATE OR WINTER CABBAGE.--As soon as the ground becomes warm in the spring, or early in May, a seed bed should be made and sown with the late varieties of cabbage and celery, or the seed may be sown in drills in the garden; the seed being sown in very thinly, so as to produce plants standing about half an inch apart in the row. Where it can be done, it is best to sow the seed in a special bed or cold frame, where they can be watered and nursed to a good size by the time they are wanted for planting. The Flat Dutch and Drumhead types are the best for this planting, though many prefer the Savoys, claiming a superior delicacy of flavor, on account of their having more leaf surface to the number of ribs or veins; they are not, however, nearly such sure headers, nor are they as good keepers when buried.

It is important to get the seed sown early, that the plants may be had of good size by the middle of June, though they will make a partial crop if planted as late as the middle of August. As these varieties make larger heads than the summer cabbages, they cannot be planted so closely; the rows should be 3 to 3½ feet apart, and the plants 2 to 2½ feet apart in the rows. These can be planted and grown between the rows of early peas, corn or potatoes; but I would prefer to wait until the first crop of corn be cleared

off the ground, as it can then be brought into much better condition. It adds greatly to the labor of harvesting the first crop when the ground is so closely planted, and the soil is apt to become hard and packed before it can be cultivated again.

When possible, the young cabbage plants should be set out directly before or after a good rain, but if there is no prospect of rain, they should be planted in the evening and a tincupful of water should be poured in each hole before the plant is set in; then draw the dry earth up around the stem and pack firmly around the plant; this will enable them to withstand at least a week of dry weather. If the drought should continue longer, or they do not come up fresh in the morning after a flagging day, they must be watered in the cool of the evening, when the plant will have the benefit of the water all night. It is waste of time to water them while the hot sun is shining, unless they can be shaded with papers, old pans, etc.

As soon as they become well established, the soil around them must be carefully loosened and cultivation begun. To obtain the best results they must be cultivated frequently and deeply. It is a common sight in some gardens to see the cabbage with stems two feet high and a small bunch of wormy leaves at the top; a closer examination will show that the soil is hard and trampled, and that the plants have been left to grow as best they may, while in the well-cultivated garden the stems are short and the heads are large and solid.

The young plants of late cabbages are generally infested, while in the seed bed, with a small black fly, which greatly checks their growth, and sometimes entirely destroys them. These can be gotten rid of, or better, entirely avoided, by the application of dry road dust, soot, slug shot, or land plaster, dusted on the young leaves early in the morning, while the dew is still on them; this should be repeated every two or three mornings until the fly is exterminated and the plants have grown to good size. When the plants have been set out and are nearly ready to head, the green cabbage worm makes its appearance, and if fine marketable heads are desired this pest must be destroyed. Many remedies for this are given, most of which are ineffectual. It is best to sprinkle well with tar water or alum water, taking care to get it well down into the centre of the loose leaves, using an ordinary watering pot for the purpose; if a garden syringe is at hand, it can be thrown into the plant much better than by sprinkling. To make the tar water, the tar is put in a barrel of water and well stirred; then, when it has been allowed to settle, the water from the top is dipped off and used. It should be strong enough to have quite a decided taste. The alum maybe dissolved in the watering pot, about one tablespoonful to the gallon, and stirred till dissolved. See that the solution gets well into the centre of the loose leaves just below the head, as this is the favorite place of attack by the worms.

The cabbage is quite hardy and will stand considerable frost in the fall without damage, being rather improved in quality by it. By the third week in November they should be put in pits or the vegetable cellar; or, where these conveniences are not at hand, they should be pulled up, root and all, the outside leaves wrapped closely around the head and stood side by side, on their heads, on a well-drained piece of ground; they should be placed in a long row two or three heads wide, and where a good many are to be buried or gotten out at once, two additional rows may be placed on top of these, as shown in the illustration.

[Illustration: FIG. 1.

FIG. 2.

Illustrations showing the manner of storing cabbage for winter use. Figure 1 showing three rows of heads and Figure 2, five rows. C. Heads of cabbage. S. Soil banked over the heads. D. Drainage ditches to carry off the water.]

Dry soil is then thrown on these heads to the thickness of five or six inches and the roots left sticking out of the top; this covering should be firmly packed, to prevent the entrance of water, and a small gutter should be dug round the heap to carry it off. If, after the cold weather has set in and the ground is slightly frozen, the heap is covered with three to four inches of corn fodder or litter, it will prevent the covering from freezing so hard, and will greatly lessen the work of getting out the heads when wanted for use. When heads are wanted, one end of the bank is opened and as many taken out as are desired; the open end is then carefully covered over with soil. Too many should not be taken out at once, as they retain their flavor better when buried in this manner than when kept where they are exposed to the open air. If it is desired to save some of the best heads for seed, the roots of the plant must be buried as well as the top; they can then be replanted early in the spring and a cross cut made in the top of the head to assist the flower stalks in bursting through, as the heads are sometimes so tight that they will rot before bursting.

[Illustration: EXTRA EARLY EXPRESS CABBAGE.]

[Illustration: EARLY JERSEY WAKEFIELD CABBAGE.]

EARLY VARIETIES--_Extra Early Etampes._--This cabbage is the earliest heading variety that I have ever grown. The heads are small but round and very solid, and it is ready for use nearly two weeks ahead of the other early varieties.[4]

Early Jersey Wakefield.--This has long been the chief favorite for the general crop of early cabbage, and is deservedly popular, as it is sure to head when the seed is good; the heads are of good size and shape, and the quality is fine.

Early Summer.--This succeeds the Wakefield, and has heads about twice the size of the latter; they are round, very solid and slightly flattened on top; it has few outside leaves and can be planted closely; this variety matures about two weeks later than the Wakefield, and a month after the Etampes.[5]

VARIETIES OF LATE CABBAGES.

At the head of these I would place BURPEE'S SUREHEAD, which has done so well for me since I began planting it, never failing a single season, that I now plant my whole crop of it, instead of planting two or three kinds as formerly, to guard against poor seed or a bad season. It is an improved type of the Premium Flat Dutch, to which it is superior in the evenness and regularity of its heads and the "sureness" of every plant to form a fine head. With me the heads average larger than the Flat Dutch, are rather more rounding in shape and are of the finest quality.

[Illustration: EARLY SUMMER CABBAGE.]

[Illustration: BURPEE'S SUREHEAD CABBAGE.]

[Illustration: BURPEE'S SHORT-STEM DRUMHEAD CABBAGE.]

SHORT-STEM DRUMHEAD.--This variety produces on extra short stems, only a few inches in height, very large solid heads, often twenty-five pounds in weight. It is from this kind that the very large heads seen at the county fairs in the fall are grown, and where the ground is heavily manured and well cultivated enormous crops of this variety can be grown; it is of fine quality, very solid and an excellent keeper.

[Illustration: The Vandergaw Cabbage

The Best Second Early and Summer Cabbage.

Equally as Good For Winter.

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BY W. ATLEE BURPEE & CO PHILADA]

DANISH BALL HEAD.--This variety has only been recently introduced, but bids fair to take a leading place as a winter variety; the heads are quite round and very solid; they are of medium size and very handsome appearance, which make it a good market variety, while the quality fully equals its good looks.

CAULIFLOWER.

The culture of this vegetable is the same as that for cabbage, in most respects, but it is not a certain crop in our changeable climate and hot, dry summers. It likes plenty of moisture, and if placed in a rather wet location or in a bed where it can be frequently watered, it will be much more certain to produce fine heads. Its superior quality and the high price that good heads command make it a most desirable crop to grow wherever it will do well. I have always found the short-stemmed, extra early varieties the best ones to grow, and as in the ordinary season but about half of them produce heads under ordinary garden culture, the rest of them maturing throughout the summer and fall, it is almost a continuous crop. The seed should be sown as early as possible, in the hotbed, and great care should be taken that the plants do not become either stunted or drawn, as none but the strong, healthy plants will produce good heads. It will greatly improve the appearance of the heads if some of the broad outside leaves are broken half through the stems and the tops bent over the heads while forming. This will blanch and keep them of that pure whiteness so attractive in this vegetable as grown by the market gardeners. The heads should be cut for use or sale as soon as they have reached their full size and before the buds begin to uncurl, as this spoils both the appearance and quality of this, the finest and most delicately flavored of the cabbage family.

VARIETIES OF CAULIFLOWER.

EXTRA EARLY DWARF ERFURT.--This is the best strain for general use; there are usually two or more grades of this offered in seed catalogues, but the best should always be purchased, even if you can only buy a single packet; by taking extra care of it you can make every seed count. This variety is quite early, has short stems, and makes good-sized heads of the best quality.

[Illustration: BURPEE'S BEST EARLY CAULIFLOWER.]

EARLY SNOWBALL.--This variety is quite early and makes fine large heads, of handsome appearance.

BURPEE'S BEST EARLY.--I have only grown this one season, but found it all that it was represented in earliness and good heading quality. Owing to a drouth early in the spring, the heads were not of large size; the quality was fine, and I think it bids fair to be one of the leading varieties.

CARROTS.

These are ordinarily little used as table vegetables, but will be found very palatable as an ingredient of soups and stews. They are very easily grown, the seed being planted in drills and the plants thinned to six or eight inches apart. The seed should be sown in April or May, and they will be ready for use early in the summer. For winter use they should be stored in the manner described for beets and turnips; they will retain their quality throughout the winter, and form a pleasant variety in the winter supply of vegetables. The rich yellow and red-fleshed varieties are the most popular, and retaining their bright colors when cooked, lend an attractive appearance to the dish of which they form a part.

VARIETIES OF CARROTS.

DANVERS HALF-LONG ORANGE.--This is claimed to have the greatest bulk with the shortest length of root, and is a remarkably heavy cropper. The root is of a rich, dark orange color, and grows very smooth and succeeds in all soils. It is quite a favorite market sort.

SHORT HORN.--The flesh of this variety is very fine grained, of deep orange color and superior quality. The roots do not penetrate deeply, and the top is small, which allows of their being planted quite closely.

[Illustration: IMPROVED LONG ORANGE

S^T VALERY

DANVERS

3 OF THE BEST CARROTS]

EARLY VERY SHORT HORN, OR GOLDEN BALL.--The earliest variety; the roots are round, turnip shaped, of small size, deep color, and the quality is of the best.

OX HEART.--This variety is of large size, the roots being seven to eight inches in length and three to four inches in diameter at the top; it tapers gradually down to one and one-half to two inches at the bottom, making very little waste in preparing it for the table. It is of fine quality, while its size will render any surplus valuable for feeding to the stock.

RED SAINT VALLERY.--This is a large late variety and makes a good kind to raise for winter use; the roots grow ten to twelve inches in length and measure two to two and one-half inches in diameter at the top, tapering gradually to a point at the base. It should have deep cultivation to produce the finest roots. The color is a deep orange red and the quality is very fine.

CANTALOUPE, OR MUSK MELON.

These are universal favorites, and too frequently are not grown by the kitchen gardener, who labors under the idea that they must have a sandy soil in some particularly favored section, and that they require great skill to grow them. If a variety suited to your soil is planted and given the same amount of attention and careful cultivation as the rest of the garden receives, melons may be had in abundance from the first of August till frost comes in the fall, though when the first cool nights come they lose their fine flavor. If the garden has a southern slope, that will be the place for the melons and other warmth-loving vegetables; but they will do almost as well in the level field. The rows of hills should be five feet apart and the hills at least four feet apart in the row, to allow the vines

plenty of room to run. It is a good plan to make the hills break joint, as they will then cover the ground to better advantage. When the line is set, a hole should be scraped with the hoe or shovel where the hill is to stand; this should be six inches deep and about twelve inches in diameter. Compost is then shoveled in, two rows being done at once; two or three shovelsful are put in each hill. The dirt thrown out in making the hole is then carefully made into a hill over the compost by using a sharp steel rake, care being taken to remove all stones and hard lumps of dirt. The seed is then scattered on the top of the hill, generally from twenty to thirty seeds being planted in each hill, that there may be an ample supply for the insects and yet leave a good stand. They should be thinned out gradually, extra ones being left in until they are at least a foot in length, as the insect pests are both numerous and destructive.

The hills should not be made until it is time to plant the seed, or they will get packed and too hard for the young roots to penetrate. When the seed has been planted on the hill it should be covered with about half an inch of fine soil, sifted and crumbled on with the fingers, and the whole top patted down with the palm of the hand. The seed should be planted as soon as the ground is thoroughly warm in the spring and when the temperature does not fall below sixty degrees at night. The melons will commence ripening about August 1st, and two rows across the garden should yield from one half-bushel to one bushel daily if the variety planted is of the small Netted Gem or Jenny Lind type. These small, round melons, of the size of a croquet ball, are very prolific, and if carefully grown, the quality is very fine. Some prefer the larger melons, which fill the basket more quickly, but in my experience the small ones have been so much more prolific that the yield has been almost double in bulk on the same amount of ground. The melon rows should be gone over early every morning while ripening, as they should not be allowed to become yellow on the vines. The quality deteriorates very rapidly when allowed to ripen in the hot sun, so that they should be picked while still green. The right stage for picking can readily be told by examining the point where the stem joins the melon; as soon as the stem begins to crack away from the melon slightly, or when the little drops of red juice form round the base of the stem, it is time to pick the melon. When picked, they should be put in a cool cellar or spring house until wanted for the table.

Seed may be saved from the largest and finest-flavored melons; but if your garden is on heavy soil, or if two or three varieties are grown near together, it is best to procure fresh seed from some melon-growing district every year.

The ground between the hills should be cultivated frequently, as long as it can be done without interfering with the vine; the soil in the hills should be kept loose and drawn up around the vines with the hoe. When the vines have grown too long to allow the passage of the cultivator, the patch can be kept clean by pulling out the large weeds by hand, which can be done very quickly after a good rain. The dense shade caused by the luxuriant vines will cause the small and low-growing weeds to rot off. While the vines are still small, it will be necessary to dust them every few mornings with road dust, soot, plaster or slug shot, to destroy the flies and striped bugs that infest them. When healthy young vines suddenly wilt and droop in the hot sun without apparent cause, dig around the root of the plant with the fingers or a stick until the grub is found which has cut the plant off underground. He should be searched for and “made an example of” as soon as the first vine is discovered to be flagging, or he will proceed to eat the whole hill.

VARIETIES OF MUSK MELONS.

BURPEE’S NETTED GEM.--The finest as well as the earliest of all the small-fruited varieties that I have tried, and where a variety of melons is not particularly desired, it will furnish a generous supply of fine-flavored fruit from the first ripening until killed by frost. It is a very good keeper, retaining its good quality for nearly a week after picking, if kept in a cool cellar. This is often a valuable characteristic in the latter part of summer, as several warm days furnish two or three baskets in the cellar, which keep up the supply if the warm spell is followed by cool or cloudy days, when the melons on the vines do not ripen readily. This variety is thickly netted, the meat is thick and solid, and they run as even in shape and symmetry as a set of croquet balls, which they also resemble in point of size.

[Illustration:

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EMERALD GEM CANTALOUPE.]

[Illustration: 16¼-lb MONTREAL NUTMEG MELON--ENGRAVED FROM A PHOTOGRAPH.]

EMERALD GEM.--This variety has the small size and prolific bearing qualities, with the handsome salmon-colored flesh, that originated in the Surprise Melon some years ago. Too much cannot be said of the _quality_ of this melon, as I do not think there is another variety that approaches it in flavor. The vines are strong and healthy in growth and well set with melons near the hills, and

the fruit is early in ripening. The melon has a thin, green rind and very small seed cavity, almost the entire body of the fruit consisting of the rich and luscious meat.

MONTREAL GREEN NUTMEG.--A handsome variety, in which large size, regular shape and fine appearance are combined with thick flesh of the finest flavor. In shape they are nearly round, slightly flattened at the ends, very deeply ribbed and heavily netted. These melons have been grown to over thirty pounds in weight, and will average ten to twelve pounds in ordinary culture.

CELERY.

While one of the most troublesome vegetables to bring to perfection in the ordinary garden, this is one of the most desirable, as well as one of the most profitable, when well grown. The Michigan celery that is being shipped to our eastern cities in such large quantities does not seem to have lowered the price materially, but has crowded all the inferior and less finely-grown plants out of the markets, and the high express charges still guarantee a good profit to the near-by grower. When the ground has become fairly warm in the spring, a bed should be made in some shady corner for the seed; if such situation is not to be had, the seed can be sown in a spent hotbed, cold frame or other convenient place, and can be artificially shaded with fresh brush or lath shades through the hottest part of the day. Celery is naturally a swamp plant, and to make a rapid growth should have the ground as rich as possible, and also as much water as possible, without making the ground heavy and sour. The soil should not be allowed to become dry or baked, and the weeds should be pulled out as soon as they appear. This bed, and, indeed, all other seed beds, should be made very rich with well-rotted manure; not with horse-stable manure or phosphate, as both of them are dry and heating, and in dry weather would stunt or entirely burn up the young plants. The seed should be sown in drills about six inches apart, to admit of working the soil with a narrow hoe, as the continued watering will harden the surface of the bed and check the growth of the young plants. When the plants are well up they should be thinned out so as to stand an inch apart in the drills, and if the plants are ready some little time before they are wanted for setting out, they can be made more stocky and stronger by shearing off about half of the tops.

When ready to set out, I run a double furrow where the row is to be--that is, the plow is run both ways in the same furrow, casting up a ridge of dirt on either side of a shallow trench; then in the bottom of this trench fine compost or well-rotted manure is placed to the depth of one to two inches, and some of the fine soil from the sides is drawn down over the manure with a fine rake until the manure is covered about three inches. This will still leave a depth of about two inches below the surface, which will serve to draw and retain the rain water, or, in a dry time, can be flooded with a hydrant hose or irrigating ditch. Where the ground has been heavily enriched or the celery is planted as the first crop--that is, when no early vegetable precedes it on the same ground--no manure is used in the trench or furrow, which is plowed out in the same way, the additional depth assisting in the labor of earthing up for blanching. To obtain fine quality and appearance the plant should be pushed to as rapid a growth as possible from the time the seed is sown until the stalks are ready for use; if allowed to become stunted, the stalks will be knotty in appearance and bitter in taste.

For my own use and marketing I usually sow seed of two or three varieties, so that if one kind fails for any reason, I may still have a crop sufficient for the table from the other varieties, while if it is all good I have no difficulty in disposing of the surplus; this is the more easily done, as it occupies ground that has been cleared of early peas, corn, etc. Another point in not confining your planting to the one variety is that the handsome "Self-blanching" varieties are not good keepers, and as the older kinds take a long time to whiten, and a good deal of cold weather to develop the fine flavor, they are about ready for use when the early kinds are gone.

While celery is raised as a second crop and has always been considered to require frost to develop the fine nutty flavor, at least one row in the garden should be planted with a "Self-blanching" variety as early in the spring as the plants can be procured. For this it is a good plan to sow two or three drills of celery in the hotbed at the same time with tomatoes, peppers, etc., that they may be ready for planting out early in the spring. These will grow quickly before the very hot weather sets in, and in a favorable season will be ready for use by the latter part of August; if kept earthed up they will be of as handsome appearance and as crisp and fine flavored as are the older varieties in December.

For the main crop the young plants should be ready to set out by the 1st of July, though in a favorable locality they can be planted as late as the middle of August, as they spend the summer largely in making roots and do not grow much until the cool weather. As soon as the plants attain eight to ten inches in height, or, rather, _length of leaf stalk_ as they lie spread out, the earthing up should begin on all kinds of celery, although the seed catalogues will tell you that it is unnecessary in self-bleaching kinds. These latter may be bleached easily by tying the stalks together with straw or soft twine, but the earthing-up process is much more satisfactory

both to produce a compact bunch of stalks and an even whiteness in color; otherwise, the outside stalks will remain green.

My plan in earthing for the first time, or "handling," as it is called, is to have the dirt loose and fine on each side of the row, then to stand astride the row, gather all the leaves up and hold them closely in the left hand, and with a short-handled hoe draw the loose dirt in and pack it firmly around the stalks, leaving about two inches of the tips stick out at the top. It is important to hold the stalks closely, that the dirt may not sift down among the stalks, which would either rot the heart or cause the inner stalks to become twisted and crooked. The second and succeeding bankings are done by a boy standing over the row, clasping the stems in his hand closely, while a man on each side banks up the loose dirt with a shovel; as they raise the bank the boy slides his hand further up the stalks, until, as before, all but two inches of the tips are covered. The boy moves along the row backward, facing the two men who are using the shovels; as they finish one plant he grasps and bunches another, always having a plant in each hand. This method is a great time saver, and also enables the work to be done more neatly than where the plant has to be held while the dirt is drawn from a distance with the hoe. This earthing up should be repeated every two or three weeks until it is time to store the celery for the winter. Immediately before banking, I run the light plow or the cultivator on each side of the row, which furnishes plenty of fine, loose dirt ready for use. The soil will pack better and remain in the banked form better if it is moist when handled, but must not be so wet as to be sticky, for it would then "rust" or spot the stalk. The plants should be set in rows five or six feet apart, so that there may be plenty of soil for the earthing up and room to pass between the rows when banked; the taller growing varieties will require full six feet between the rows.

About the third week in November the celery should be dug and stored; for if it is left out longer, there is danger of its being spoiled by hard freezing. If it is to go in the cellar it should be stood upright in barrels or in boxes, the sides of which are as high as the stalks are tall, so as to keep them straight and white; the roots are left on and packed in moist soil, in order to keep the plants fresh and crisp; but the soil must not be allowed to come up among the stalks, or it might cause them to rot. The root cellar must be kept cool and have plenty of air whenever it can be admitted without freezing the contents of the cellar.

[Illustration:

Illustration showing the manner of storing celery in the field for early use. C. Plants of celery. D. Banks of soil. S. Straw covering. E. Board laid on top of the straw to keep it in place.]

Another plan is to set the plants on a well-drained plot, side by side in a long row, three or four plants wide and as closely together as possible; earth banks are then raised on each side of the row about four to six inches thick at the top, and the ends closed in the same manner. The roots are packed solidly in the soil, and the banks are carried up level with the longest tops; when the very cold weather sets in the whole top, banks and leaves, is covered with straw, leaves or corn fodder, to keep the frost out. I would not recommend this method of storing unless it is expected to have the supply all used or marketed by the 1st of January. The best way to store celery is in a hotbed or cold frame, which is built two or three feet deep in the ground, as already described. The celery plants are set side by side in this, as in the boxes or barrels, and the roots tightly packed in moist soil; then the sash can be put on at nights and in the daytime can be entirely removed or slightly raised to admit air, according to the temperature. On very cold nights the sash can have an extra covering of straw or old carpet, and if there is a heavy fall of snow it can be left on a few days, until the weather again becomes warmer. Stored in this manner, it is no trouble to get the celery when wanted; it can be given plenty of air, without which it will not keep, and the late kinds, if packed closely together, will complete their bleaching. If the kinds which require blanching are not kept earthed up as the growth advances, it will be almost impossible to blanch them.

VARIETIES OF CELERY.

The dwarf and half-dwarf kinds are the best, as they are superior both in quality and appearance and are much easier grown. Of these the _Dwarf Golden Heart_ is one of the best varieties; the stalks are very thick and solid, fine flavored, and blanch to a fine white, excepting the centre, which is of a fine golden yellow.

[Illustration: NEW GOLDEN SELF-BLANCHING CELERY.]

GOLDEN SELF-BLANCHING.--The handsomest and most generally satisfactory kind that I have ever planted. I know of none that can equal it in appearance or quality; the stalks are large, straight, crisp and very solid; it is very vigorous in growth, attaining a height of one to one and a half feet, and I have had single plants of three inches in diameter. The leaves of this variety are of a beautiful golden yellow after the plant has been bleached, which adds greatly to its handsome appearance when prepared for the table. The young plants should be earthed up as soon as they are large enough to handle, and in two weeks the celery will be in the

finest order for the table, thus gaining from one to two months over the ordinary kinds. The quality is the finest and the stalks are crisp, brittle and delicious.

WHITE PLUME.--This is also a self-blanching variety, but not to the same extent as the preceding kind. In this sort the inside stalks are naturally white, and the leaves of these white stalks are variegated in the most striking and beautiful manner, which gives it the name and renders it the most ornamental variety grown. To bleach the outer stalks the plant should be kept earthed up, and it will then be ready for use at any time. It is not, however, so fine in the small state as the Golden Self-Blanching, which is of fine eating quality even when growing in the seed bed; the stalks are not so thick and meaty in the White Plume, but have a strong "nutty" flavor.

CRIMSON OR RED CELERY.--The red celery is very handsome and fine flavored when bleached, and after the self-blanching varieties is the most desirable one to grow. It grows tall and straight, is crisp and brittle, and when well blanched is a beautiful golden yellow, the ribs and ridges being tinged with crimson.

SWEET CORN.

The first sweet corn should be planted early in April, and should be of some small-growing, very early variety, such as the Cory or Minnesota. This corn will have to struggle with the frost and chilling nights, but with the aid of the ever-present worm, which inhabits each ear, will be ready for use long before any of the really fine kinds can be had. There is only one good thing that I have been able to discover in the worm's favor in connection with his labors in horticulture, and that is the way in which he assists in ripening all the earliest specimens of the different fruits. To be sure, his efforts in this line are not always appreciated, but he is always there when you find a fruit ripening before its regular time. About the third week in April a second sowing of this early corn should be made, and at the same time should be planted some early large-eared variety, such as Crosby's Twelve-rowed, and an equal amount of a late variety, such as Stowell's Evergreen. Thereafter a planting should be made every ten days or two weeks, of a favorite sort, which, with me, is Stowell's Evergreen, although I plant other kinds throughout the season, for the sake of variety. These plantings should be kept up until the 10th of July, after which the late kinds will hardly mature; but if the ground can be spared, I would keep on planting until the 10th of August, as, if the fall should be late, it will come in very acceptably. Most gardeners exhaust their supply about the middle of September, as they do not continue to plant late enough. If there is danger of heavy frost early in the fall, the corn that has well-set ears that have not yet ripened should be cut off at the ground and stacked against the south side of a fence or building; it should be stood up nearly two feet in thickness, to prevent freezing, but should not be thicker, as it will heat too much and will be awkward to handle when sorting over for the good ears. Treated in this way it will provide ears for use well into November, but of course they will not be of as fine a quality as those matured in the ordinary way.

As the earliest varieties only grow about three feet high and have the ears set close to the ground, the best way of planting them is to drop the seed ten inches to one foot apart, in drills. Sow plenty of seed, and if it comes up too thickly it can easily be thinned out when hoeing; all suckers should be broken off at the same time, so as to throw the strength of the plants into the ears.

If two rows are planted across the garden at each planting they will furnish an ample supply for the average family. If it is needed for canning or drying, an extra large planting should be made early in May, which will mature after the heavy harvest work is over and before the fall fruit is ready to preserve.

If some fine compost is placed in the drills or hills, it will help greatly to give the young plants a good start until they can reach the manure with which the garden has been dressed; where this compost is put in it should be covered with an inch of soil before the seed is sown.

The climbing snap beans may be planted in the hill with the tall-growing corn, or hills of pumpkins; squashes or cucumbers may be made in every fourth hill and every third row, although the vines will be very much in the way of continued cultivation if the ground is inclined to be weedy. Sweet corn should not be planted within one hundred yards of field or pop-corn, as the pollen will be sure to mix and spoil the quality of the table corn. It will sometimes mix at greater distances, but this distance would be safe in most cases.

VARIETIES OF SWEET CORN.

THE CORY.--This is the earliest variety known, and is at the same time superior in size and quality to the varieties which have been grown as extra early, before its introduction. It ripens nearly a week in advance of any other variety, while the ears are much larger than either the Minnesota or Marblehead. The grains are well formed to the tip of the cob, making a much handsomer ear than the

other early varieties, while in sweetness and quality it is also superior.

[Illustration: A RIPENED EAR OF THE CORY CORN.]

AMBER CREAM.--This is a medium early variety; it is a strong, vigorous grower, reaching six to seven feet in height; the ears are about ten inches in length and the quality is rich and sugary. When used on the table the grains are milky white; the "Amber" of its name coming from the ripe seed, while the "Cream" is evidently an attempt to describe its excellent quality. In planting and picking for the table, the size of the ears of this variety and of Stowell's Evergreen should be taken into account; a dozen ears being nearly equal to two dozen of some of the smaller-eared kinds.

CROSBY'S EARLY TWELVE-ROWED does not grow quite so tall as the Amber Cream, nor are the ears as large; although called "twelve-rowed," it frequently has only ten rows. The great merit of this kind is in its excellent quality, it being very sweet and juicy, and fully equal to any variety that I have ever eaten. It is one of the best sorts to plant after the very early kinds.

POTTER'S EXCELSIOR.--An excellent medium early variety; the ears are of good size, with twelve rows of deep grains. It is remarkably sweet and juicy, and quite productive, averaging two good ears to a stalk.

STOWELL'S EVERGREEN.--This is, in my opinion, the finest variety for late and general planting. It is strong-growing and prolific, while the ears are of large size and handsome appearance. The quality is rich and sweet, while the grains are juicy and luscious, when picked at the right stage. To have the finest corn of any variety it should be picked in just the right condition; that is, when the skin of the grain breaks at the slightest puncture, and plantings should be made frequently enough always to have a supply at this stage. The quality is inferior if it is a few days too old or too young.

CUCUMBERS.

In raising cucumbers care should be taken to procure seed that is perfectly pure, as it mixes readily with other varieties and deteriorates rapidly. The seed should be planted in hills, prepared in the manner described for cantaloupes, three feet apart in the row, and the rows 4½ to 5 feet apart. If there is not enough compost at hand to manure them, as directed in the manner of making them, the hills can be raked up a few inches above the surface and the young plants allowed to feed on the general dressing which has been applied to the whole garden; the elevation serving to give the young plants a better start than on the level surface. While the cucumber is a lover of heat and moisture, it is apt to damp off in its early stages if it should be cold and wet; the hills tending to lift the young plants up into a drier and warmer soil. A liberal quantity of seed should be sown in each hill, say twenty to forty seeds, that there may be enough young plants to survive the depredations of the striped cucumber bug and of the borers. The young plants should be dusted every few mornings with ashes, plaster or slug shot, to destroy these pests, and as soon as the plants are sufficiently large to take care of themselves they should be thinned out to only three or four plants in a hill. The first planting should not be made before the middle of May, for they will not stand cold. The cucumbers should be picked as soon as they attain sufficient size and before the seeds become developed or hard; this should be done every morning while it is still cool, and the cucumbers placed in a cool cellar. The very best way is to put them in the water in a cool spring-house; there is no place where melons, squashes and cucumbers retain their freshness and crisp, fine flavor so fully as in such a spring. If the picking is carefully attended to and all the fruit picked off as soon as large enough, the vines will continue to grow and bear all summer, especially if they are in a rather shady situation, such as among the sweet corn. A few fine specimens may be allowed to ripen for seed, but if many are left the vines will dry up and die as soon as they have ripened a crop. Where a quantity of small pickles are wanted, the best way is to make a planting about the first week in August or latter part of July. These will produce large quantities if the ground is rich, and will continue to bear until killed by frost. Like the summer crop, they should be picked every day or two, and as soon as they are of the size desired, as they will bear a great many more if not allowed to grow large; also the smaller the pickle the more attractive it is, and the more readily it sells.

VARIETIES OF CUCUMBERS.

EARLY RUSSIAN.--The earliest variety grown, and is of very good quality for table use, but only grows about three inches in length; it is very solid and has but few seeds. Its small size and earliness render it a very good variety for pickles.

EARLY GREEN PROLIFIC.--This is largely grown for pickling, and is immensely productive. The shape, quality and great bearing make it a very valuable kind.

IMPROVED EARLY WHITE SPINE.--This variety is more generally grown than any other, and is deservedly popular for both table use and for pickling. It is of medium length, and from 1½ to 2 inches in diameter; when not too old the flesh is very crisp and fine flavored.

LONDON LONG GREEN.--Grows from twelve to sixteen inches in length, is a very dark green in color, and presents a fine appearance, while the flesh is firm and crisp, and the quality excellent.

[Illustration: GIANT PERA CUCUMBER.

EARLY RUSSIAN CUCUMBER.

EARLY GREEN PROLIFIC CUCUMBER.

IMPROVED WHITE SPINE CUCUMBER.

LONDON LONG GREEN CUCUMBER.]

BURPEE'S GIANT PERA CUCUMBER.--This wonderful new variety differs in almost every respect from the cucumber as generally grown, and in size and quality far surpasses the ordinary kinds. The vines are very vigorous in growth, with dark green, luxuriant foliage, which enables it to bear large crops of cucumbers of extraordinary size, as they are nearly three inches in diameter and are from 15 to 22 inches in length. The fruit is uniformly round, smooth and straight, the skin being of a pale green and entirely free from spines; when ripe the skin is a russet brown. The green cucumbers are fit to eat at any stage of their growth. The flesh is entirely white, not tinged with green, as in the ordinary kinds, and is crisp, tender and brittle. It has none of the cucumber taste of the older kinds, and is not always relished at first by those who are fond of the strong-flavored varieties, but after becoming accustomed to it for a short time, it is preferred to all others. In its native home it forms one of the staple foods of the inhabitants, being eaten in the natural state without any dressing whatever, in the same manner that we would eat an apple or a pear. It is certainly one of the most remarkable vegetables of recent introduction.

EGG PLANT.

Since the advent of the potato bug in our Eastern States the labor of raising this fine fruit is almost trebled, the bug regarding it as a delicacy superior even to the potato vines, and from its manner of bearing the fruit it is dangerous to apply Paris green or other poisons for their destruction. Where there is time to attend to it I prefer to have the bugs picked off by hand every day, but this is slow work, as we frequently get as many as a pint from two dozen of plants, and they do considerable damage by eating the young shoots and buds, even between such frequent pickings. The best way is to dust with Paris green or other poison, until the plants are of sufficient size to bear fruit, and then to keep the bugs off as thoroughly as possible by hand picking. In preference to Paris green or other strong poisons, I use _Hammond's Slug Shot_, an insecticide that is sold in all seed and implement stores, and which is said not to be injurious to man or beast, though poison is present in the impalpable powder; it is also claimed that it is an excellent fertilizer, as well as being sure death to insects. Having used it three seasons, I have found it very satisfactory for the preservation of all small plants, excepting in one case of young seedlings just coming through the soil, in which case a too heavy application burned them up.

The egg plant is a strong, rank grower and a great lover of rich soil and of heat. The seed should be started in a warm hotbed or greenhouse about the last of March, and the soil should be as rich and light as possible. If the plants grow rapidly, they will be improved by transplanting in the hotbeds, as it will help them to form a good bunch of fibrous roots, so that they will sustain no check when planted out. They should not be set out in the garden until warm weather is assured, and then should be planted in hills enriched as for melons. These hills need not be higher than the surface of the garden, but if strong growth and large fruits are desired, a hole should be scraped out where each plant is to stand, and two or three shovelsful of well-rotted manure or compost put in, and the soil leveled off again before the plant is set. If the ground is dry when the plants are set out, water should be poured in the holes dug to receive them, and the dry soil drawn up around the stems when the plant has been set. The roots of the freshly set plants should not come in contact with the manure, but should have two or three inches of soil through which to seek it as they become established. The fruit should be cut as soon as it is of sufficient size and before the seeds become hard, as it soon loses its fine quality when it begins to ripen. The plants will also continue longer in bearing if this course is pursued, as it takes greatly from the strength of any plant to ripen its seed. When there is danger of frost in the fall all the fruits large enough to use, from the size of an egg up, should be picked off and stored in the cellar, as they will remain fresh and fit for use for over a month at this cool season of the year; by so doing I have frequently enjoyed this fine fruit long after it has disappeared from the tables of my neighbors.

[Illustration: NEW YORK IMPROVED EGG PLANT.]

The hills for the plants should be about two feet apart in the row, and the rows four feet apart. Three dozen plants, which will occupy hardly a third of one of our kitchen garden rows, will furnish an ample supply for a large family. The small early variety matures three or even four weeks before the ordinary kinds, but as they are hardly larger than a good-sized goose egg, it is not worth while to bother with them unless you are especially fond of the fruit and wish to have it as early as possible.

VARIETIES OF EGG PLANT.

EXTRA EARLY DWARF ROUND PURPLE.--This variety is in every respect similar to the New York Purple, excepting in size and time of ripening; the fully developed fruit being about two inches in length and being ready for use a few weeks after planting out in the garden.

NEW YORK IMPROVED LARGE PURPLE.--This is the best and most popular variety. It is of large size, very handsome color and appearance, and the largest in diameter of any variety, yielding large slices for frying. The quality is of the finest.

HORSE RADISH.

This pungent root is a great favorite as a relish in the early spring, and is credited with tonic properties; at any rate it is a very pleasant appetizer at a season when we have been almost without fresh vegetables for several months. It can be raised in almost any soil, though preferring a moist situation, and is most at home where it is constantly moistened or occasionally overflowed by some stream. It is raised from pieces of root, three or four inches in length and from ¼ to ½ inch in diameter. These slips are made from the tails or rootlets cut off in trimming the roots for grating, they should be cut off square at the top and sloping at the bottom, that you may readily know which end goes up when you plant them. The slips should be kept in a box of moist earth, in a cool cellar, after they have been trimmed, until planting time. The slips can be planted with a long trowel; but the best and quickest way is to drive a spade, full depth, into the soil, flatways with the garden line, move it slightly back and forward, to widen the hole, and slip a piece of root down each side of the cut made by the spade, which will make them six or seven inches apart; the spade should then be driven in about one inch back of its previous position and the handle pressed forward, which will pack the dirt solidly against the planted roots, the tops of which should be placed about one inch under the surface. Where it is desired to increase the supply as fast as possible, and where the roots have been used at home, the crowns or tops, with an inch or so of root adhering, can be planted again, but they will not make long, smooth roots, like the slips, but will have a tendency to make several small roots.

HOPS.

At the end of one of the berry rows, or in some corner where they will be out of the way of the plow, there should be a few poles of hops. These are grown from pieces of root, and after being once planted will not need further attention except to be kept clear of weeds and grass, to be supplied with a good topdressing of manure in the fall, and suitable poles to climb upon. These poles should be good strong ones, at least 8 to 10 feet in height. About the last of August or first of September the vines should be cut off near the ground and the poles pulled up, so that the crop may be gathered. There is an old saying that “the September winds should never be allowed to blow on the hops.” The hops should be spread on sheets and placed in some cool, airy garret or loft, to dry. It will take five or six good poles to make a bushel of hops.

LETTUCE.

This is generally known as salad, which is a misnomer, as _salad_ means anything that is served in a green state; it may be onions, tomatoes, cabbage, lettuce, or anything of that kind. By general usage the word salad has been appropriated to the lettuce, as the latter is the plant most frequently grown in this country for salad. But call it whichever you like, it is one of the greatest additions to our tables, and in our kitchen garden it should not be made a side issue of a week or two in the spring, but should be raised in the finest condition possible throughout the season, and by using the hotbeds and cold frames it is possible to have it the whole year round.

To raise head lettuce in perfection the greatest care must be taken to reserve the very best and tightest heads for seed, or if the seed is to be purchased select the hardest-heading varieties. For the earliest planting the seed should be sown in the hotbed and have the same treatment as its associate, the cabbage; the young plants should not be allowed to stand too thickly; they should be at least an inch apart in the seed bed, or be transplanted to that distance when half an inch high. When the cabbage is set out, one

or two lettuce plants may be set between each pair of cabbages in the row, according to the distance the cabbages are apart. There must be space enough between the plants to give the soil a good stirring with the hoe around each plant, as thorough cultivation is essential to the best development of both cabbage and lettuce. A second lot of seed should be planted when the tomatoes and egg plants are sown; these can be set out in the garden as soon as they are large enough to handle. The third sowing should be made in the open garden when the first planting is done, and the young seedlings should be transplanted as soon as the plants are large enough and before they begin to be crowded in the row, as this last sowing will not form heads without it receives the best of care. These three sowings are about all that can be depended upon to make hard heads, unless it can be planted in some rich, shady corner, and carefully nursed with the watering pot.

[Illustration: PERPETUAL LETTUCE.]

About the first or middle of May a sowing should be made of the "Perpetual Lettuce," and the plants, when large enough, should be transplanted and treated the same as the head lettuce; it will not form tight heads, but produces a fine bunch of broad, yellowish-green leaves, which are very crisp and delicate, not being strong and bitter, as most lettuces are in hot weather. This lettuce will stand from four to six weeks without running to seed, so that if plantings are made about once a month it can be had in perfection throughout the balance of the season. If the head lettuce is more particularly desired, a sowing should be made about the first of August, and another about the fifteenth; the young plants should be transplanted and treated in the same manner for heading as is followed in the spring; the first sowing will not produce heads unless the latter part of August and the first part of September be cool and moist; but you are almost sure to have fine heads from the second sowing. Personally, I prefer the Perpetual, both for its fine qualities and the ease of growing it.

Another way, and the easiest, to have a constant succession of lettuce for the table throughout the season, is to sow the seed thickly in drills and to cut the loose leaves close to the ground when it is three or four inches high; this produces rather narrow leaves, which are very tender and juicy, but which have not the substance of those grown as separate plants or heads, and are not so easily prepared for the table. These sowings can be made every few weeks, and a constant succession of young leaves be had for use throughout the entire season. It should be the object in sowing lettuce to plant small lots frequently, that it may always be had in the best condition.

About the second week in September a sowing of some early hard-heading variety should be made, and a succeeding one about the first of October; from these two sowings the cold frames should be planted, about one-third from the first and two-thirds from the second; the plants should be set about six inches apart each way, which will allow about fifty plants to each sash. When cold weather comes the sash should be put on, and the outsides of the frames banked around with long stable manure. The plants must be treated to plenty of fresh air whenever the weather will permit of it, and on very cold nights the sash should be reinforced with a covering of straw, old mats, or carpet. The lettuce grown in these frames is apt to be infested with the small insect known as the "Green Fly;" to prevent or to get rid of the presence of this pest, tobacco refuse and sweepings from a cigar-maker's shop should be strewn on the soil under the leaves; this will destroy the fly and act as a fertilizer, but if too much is applied it will spoil the delicate flavor of the lettuce.

If a few very early cabbages are desired, the seed should be sown about the first of October and transplanted with the lettuce into the cold frames; planting them about two inches apart each way; if these are in good condition and the spring favorable, they can be planted out about the 15th of March, and will produce heads one to two weeks earlier than those raised in the hotbeds.

VARIETIES OF LETTUCE.

BURPEE'S HARD-HEAD.--This is the fastest growing and the best heading kind that I have ever grown. With this variety the ordinary gardener is able to grow as fine, large, solid heads as those grown by the professional market gardener. In shape it very much resembles a cabbage, as even the outer leaves tend to curl in over the head, instead of spreading outward, as in most lettuces. In appearance it is quite novel and striking, the edges of the leaves being tinged with a deep brownish-red, while in the centre of its hard heads the leaves are blanched to a beautiful creamy white. In quality it is remarkably tender, rich, juicy, and never bitter.

[Illustration: BURPEE'S HARD-HEAD LETTUCE.]

[Illustration: BURPEE'S TOMHANNOCK LETTUCE.]

BURPEE'S TOMHANNOCK.--This is the finest of all the cutting lettuces, as it is of large size, handsome appearance, and the very choicest quality. It grows very quickly, is soon ready to cut, and stands a long time without running to seed, retaining throughout the season its delicate and delicious flavor. The growth is erect; a fully developed plant is ten to twelve inches in height, and nearly as great in diameter across the top; the outer edges of the leaves curl outward. The outer leaves are shaded with reddish-brown, while the inner leaves are almost white. It is entirely free from any bitter taste throughout the entire summer.

STONEHEAD GOLDEN YELLOW.--This is a new variety, which makes very solid heads, of handsome appearance and the finest quality. Its earliness, large, tight heads and superior quality render it one of the best kinds for forwarding under glass.

[Illustration: GOLDEN STONEHEAD LETTUCE.]

BURPEE'S SILVER BALL.--This, next to the Hard Head, is the best heading variety for general purposes, and where the brown markings in the latter kind are an objection, the gardener will find in this kind all the good qualities that go to make a desirable lettuce. It produces a beautiful head, very firm and solid, with handsomely curled leaves. The head is of a silvery white color, very rich and buttery in flavor, and stands for some time before running to seed. Other excellent varieties of cabbage lettuces are _Philadelphia White Cabbage_, _The Hanson_ and _The Deacon_, while _The Tennis Ball_ is a great favorite with market gardeners for forcing.

[Illustration: BURPEE'S SILVER BALL LETTUCE.]

OKRA.

This plant, like the carrot, is too little grown, as its green pods impart a fine flavor and consistency to soups and mixed stews; besides being very palatable when stewed and served as is a dish of asparagus; the pods can also be dried for winter use. The seeds should be planted in drills, and if the dwarf variety be used, which I think is preferable, as it produces an abundance of pods and does not take up nearly so much room, the plants may be allowed to stand about one and a half feet apart in the row, the rows being three feet apart, though a quarter or half a row in the kitchen garden, as here described, will furnish an ample supply, both for use and drying. For either purpose, they should be cut before the pods attain their full size or they will be hard and woody. For drying, the best way is to string them on a fine wire or thread and suspend them to the rafters of a cool loft or garret until wanted for use. The culture of this vegetable is very simple, as the seeds are planted in drills about two inches deep, and the after treatment is the same as for corn.

[Illustration: OKRA.]

ONIONS.

In raising onions in quantities the practice of late years has been to grow the crop from seed in one season, instead of the method formerly almost universally practiced in this section, of raising and keeping over sets to form the next year's crop. This latter method is now only practiced to save labor in small gardens and to bring a few onions in for use early in the season.

To raise a satisfactory crop the ground must be free from weed seeds; it must be made as rich as possible and have constant cultivation from the time the seedlings break through the ground until the bulbs begin to ripen. The soil must be plowed, harrowed and raked, until it is in the finest possible condition to receive the seed, and it is important to select a plot for this purpose that has been kept free from weeds the preceding season. Root crops are the best to precede onions, as they not only leave the ground free from litter, but also, if they have been properly cultivated, leave the soil in fine tilth.

In our kitchen garden I would sow the seed in drills, twelve to fourteen inches apart, and cultivate with the wheel hoe; in field culture, or raised more extensively in the garden, plant in rows as closely as they can be worked with the cultivator, which, if it is provided with very narrow-bladed teeth, can be run through any rows where the horse can walk. For the kitchen garden, make the surface fine with a sharp steel rake, and if no drill is at hand, take a rake handle or blunt stick, and, drawing it along the garden line, scratch a drill about an inch deep. Sow the seed thinly, say an inch apart, but if there is reason to doubt the freshness of the seed, sow it thicker, so that a good stand may be assured. When the onions are an inch high, they should have their first working. Follow the wheel hoe or cultivator with a narrow-bladed hoe, not wider than an inch and a half at the cutting part of the blade; it must be sharp and lightly handled, just loosening the ground and cutting off any stray weeds. If there are no weeds the soil can be quickly loosened with a sharp steel rake. They should be worked every eight or ten days from this point until they begin to ripen; if it is neglected for longer periods than these, the gardener will rue it in days of back-breaking labor on hands and knees. When the

young onions have made leaves two or three inches in height, they should be thinned out to from four to six inches apart in the rows, according to the size of the bulb made by the particular variety planted. The seed for onions grown in this way should be sown as early in the spring as the soil can be gotten into the proper fine condition, so that they may make as strong a growth as possible before the hot summer weather ripens them off. As they begin to ripen, all those with thick necks should be pulled and used upon the table, as they will not ripen properly, and if put away with the good bulbs will start all to rotting. There is a theory common with old gardeners that, by bending the tops over when they begin to ripen, the bulbs will be increased in size and will ripen more quickly; personally, I have tried it frequently, and have never been able to observe any difference in those bent and the ones left to ripen in the natural way. As soon as the bulbs are well matured, take them up at once, as a few rainy days might start them to growing again if left in the ground; pull off all the tops and roots which adhere to the dry bulbs and spread them thinly on the barn floor or on the floor of a cool loft. When it becomes too cold to let them remain longer in this position without danger of freezing, I put them in peach baskets, the stripped sides of which allow a free circulation of air, and store them in a cool, well-ventilated cellar, where we try to keep the temperature just above freezing by admitting air whenever possible, as it takes but very little warmth to start them to growing, and then they soon become unfit for use. If the gardener saves his own seed, the finest and best-shaped onions should be laid aside for planting out in the spring, for this purpose.

Where the crop is raised from sets it is not necessary, though quite desirable, to have the soil made as fine as for the seed bed. As the small onions are set in, planting at the proper distances apart, almost all the cultivation can be done with the narrow onion hoe, and if it is regularly attended to at proper intervals no hand work is necessary. The onion is a hardy bulb, and the sets can be planted as soon in the spring as the ground can be gotten into proper condition; this makes an important feature in the earliness of the crop, as the sets have several weeks the start over the onions raised from seed. For the very earliest onions, or those used when the bulb and neck are about of equal thickness early in the spring, and which go by the name of scallions, the sets are planted in October and allowed to remain in the ground all winter, so that they are ready for use almost as soon as the spring opens, two weeks' growth sufficing to bring them to a proper size. Where the main garden crop of these fragrant bulbs is raised from seed, enough sets should be planted to make an early supply for the table; if no sets are at hand in the fall, to plant for the spring crop of scallions, they could be grown by sowing the seed about a month earlier than you would plant the sets for the same purpose.

In sowing seeds for sets the same directions apply as given for the crop of bulbs, excepting that the seed is sown much more thickly, so that the bulbs will touch each other and stand two or three wide in the row. If they do not seem to be making the proper growth as the season advances, they should be thinned to the proper extent to enable them to grow to the right size, one-half inch in diameter, though my own trouble is that they usually grow too large; to remedy this when they are nearly the proper size I allow them to become choked with grass and weeds, which checks their growth, but when this is done they must be watched that this mass of stuff does not rot them off when ripe. I think a better way would be to go along the row with a straight-edged hoe or spade and cut off some of the roots. The main object in having the sets of this small size is that they shall not run to seed when planted out in the spring. Any sets which exceed three-quarters of an inch in diameter should be used for pickling or cooking. When the sets begin to ripen it will sometimes facilitate the process to bend all the green tops over close to the bulbs, as it helps to dry and shrivel the tops more quickly. When thoroughly ripe they should be gathered at once, the tops and roots pulled off, and should be spread out and stored for winter in the same manner described for the large onions. Any of the sets that persist in growing and not drying properly, should be thrown out, or they will spoil the whole crop. If a suitable cellar or loft is not available for storing the bulbs where they will be sure not to start into growth, they may be wintered on the barn or loft floor, covering with hay as the cold weather advances. The hay should be only two inches thick at first, but should be increased to one foot in thickness as the season advances, and in the spring should be removed by the same graded process.

VARIETIES OF ONIONS.

YELLOW GLOBE DANVERS.--This is a splendid variety, and is the most popular and profitable kind to grow for market. It is similar to the Yellow Danvers as ordinarily grown, excepting in shape, which is much finer, in my opinion. No one can fail to be pleased with this fine variety when well grown. It is quite early, and is one of the very best keeping kinds.

[Illustration: YELLOW GLOBE DANVERS ONION.]

LARGE RED WETHERSFIELD.--A strong grower and produces immense crops of large, fine bulbs. It is rather flat in form, deep purplish red on the outside and a much lighter shade inside. It has a strong flavor, and is very solid, making an excellent keeping and shipping sort.

[Illustration: RED WETHERSFIELD

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LARGE RED WETHERSFIELD ONION.]

WHITE GLOBE.--One of the handsomest onions grown, beautiful in shape and color, having a clear, white skin; the flesh is fine grained, of mild flavor, and the bulbs are of good keeping quality.

WHITE SILVERSKIN, OR WHITE PORTUGAL.--This is an old and favorite variety, being very desirable for planting in the family garden; the flavor is the mildest of the American varieties; the small onions are very fine for pickling. I think this variety should be marketed as early as possible, as with me it is not a good keeper.[6]

[Illustration: WHITE SILVERSKIN

SILVERSKIN, OR WHITE PORTUGAL ONION.]

ITALIAN VARIETIES OF ONIONS.

GIANT RED ROCCA.--These onions are of large size, handsome appearance and mild, delicate flavor. In this variety we have an onion which attains a weight of from one to two pounds under ordinarily good culture, and of most handsome shape and appearance, the outer skin being always bright red, while the flesh is white, mild and pleasant.

EARLIEST WHITE QUEEN.--This variety does not grow to the large size of the other Italian kinds, more resembling our American Silverskin in size and appearance, but has the great advantage over the latter variety (which takes two seasons to attain the same size), of remarkably quick growth, while the flavor is equally, if not more, delicate. The bulbs are flat, pure white and about two inches in diameter. It is the finest variety for pickling grown. Sown in February, they will produce onions early in the summer, while if sown in July, they will be ready to harvest in the fall, and will then keep in splendid condition throughout the winter.

[Illustration: NEW GIANT RED ROCCA ONION

GIANT RED ROCCA ONION.]

[Illustration: WHITE QUEEN ONION.]

GIANT YELLOW ROCCA.--This variety is similar to the Giant Red Rocca described above, except in color, which is a clear golden yellow. It is this variety which is the real "_Spanish Onion_," so generally sold at the fruit stands in the cities.

BURPEE'S MAMMOTH SILVER KING.--This I believe to be the handsomest variety of onion grown, as I think the white-skinned varieties the most attractive. The bulbs are slightly flattened, but are very thick through, averaging five to six inches in diameter, and have been grown to the enormous weight of over four pounds to the single bulb, while two-pound bulbs are frequently produced under fair culture. The skin is a beautiful silvery white; the flesh is even whiter, while the flavor is very mild and pleasant, the Italians eating them as we do apples.

PARSLEY.

This should be grown by every gardener on account of its usefulness, both for seasoning and garnishing. As it seeds in the second season, fresh plantings should be made every spring. The seed, being very slow to germinate, should be soaked in tepid water for twenty-four hours before planting. The best way is to sow in the hotbed or cold frame and transplant to the garden, but it can be sown in drills where wanted and thinned out to the proper distance apart. I always try to have a bed of it near the kitchen door, as it saves much running; if such a bed cannot be conveniently placed, some should be cut and brought in with the other vegetables, as it will keep fresh some days if kept in cold water. In the fall some of the best roots should be taken up and planted in the cold frame, or put in pots and boxes in the sunny windows of the house, for a winter supply. The leaves and tops from trimming the celery are also very fine for flavoring.

[Illustration: EXTRA CURLED DWARF PARSLEY.]

The EXTRA CURLED DWARF is so much finer and handsomer than the other kinds that it should be the only one grown.

PARSNIPS.

This is a winter vegetable, needing hard freezing to refine and bring out its best quality; the roots should be left to stand where grown until they can be dug in the spring or through the winter as wanted, though some may be dug and stored in heaps for use when the ground is frozen too solidly to admit of digging them. If there is more than are wanted for table use, there should be no delay in getting them dug and marketed as early in the spring as possible, for when they begin to sprout and grow, they very soon become woody and unfit to eat. A row should be sown in the garden at the same time as the onions, beets, etc., are planted. It is best to sow the seed quite thickly; by thickly I mean one seed every inch or so; when the young plants are about three inches high they should be thinned out to six inches apart in the row, care being taken to leave only one plant in a place, as, if two are left, they will spoil the symmetrical shape of the roots by growing against each other. In planting the seed I always try to run it in between two rows of beets, onions, lettuce, or other early crop, thus working it with the wheel hoe while small, and when the other crops have been taken off there is room to work it with the cultivator, which is run as close to the rows and as deeply as possible, so that the roots may attain the largest size. In digging the roots when the ground is frozen hard and is impenetrable to the spade, I use a long iron post digger with a steel blade.

[Illustration: IMPROVED GUERNSEY PARSNIP.]

VARIETIES OF PARSNIPS.

For the last three seasons I have grown the IMPROVED GUERNSEY, and have found it so much superior in size and quality to the Long Smooth, as to be above comparison. The roots are smooth, fine shaped, and free from small roots, while the quality is very superior.

PEAS.

The first planting should be made in the spring, as soon as the ground can be prepared. It is my practice to sow three varieties at the first planting, and two varieties at each subsequent one, kinds being sown which will mature in succession, one being ready to pick about the time the preceding one is past. The same result may be obtained by making plantings of the same sort a week apart. I think my way the easier, and besides, relish the variety. A drill of fifty feet would probably be sufficient for an ordinary family to have in bearing, but as my own family is large and very fond of this vegetable, and insist upon having them upon the table every day in the season when it is possible to grow them, I find a full row across the garden none too many to have in bearing at one time.

For several years past I have given up raising the tall growing peas requiring brush or sticks for their support, as it is not easy to procure sufficient brush for a garden of this size, unless you have a convenient woods upon which to draw, and even then it takes a great deal of labor to get the brush and stick the peas; while it takes more than twice as long to clear the ground for the succeeding crop, and the rows must be planted at a greater distance apart, to admit of cultivation.

The quality of the dwarf kinds is fully as good as of the tall growing ones, and in many kinds the crop borne is fully as prolific; the only strong point that I know of in favor of the brushed peas, is that the pickers do not growl half so much at picking them as they do over the lower growing ones, and that some of the varieties can be had later in the summer, as their height serves to shade the ground between the rows and thus keeps it cool. As for the growls of the picker, the short vines admit of no loafing place, and no true gardener or lover of his craft ever seems to be aware that he has such a thing as a spine (except on his cucumbers) till he tries to straighten up at the end of the day's work.

For sowing the seed, plow a drill as deeply as possible with the hand plow; sow the seed thickly, say a quart to 200 feet of drill, and cover by plowing the dirt back again; when the hand-plow is not among the assortment of tools, scrape a drill three inches deep and as broad as the blade of the hoe, scatter the seed the whole breadth of the drill, using about one-third more seed than above directed, and then press them into the bottom of the drill with the sole of the boot, covering the fine dirt in afterward with a steel rake; this takes longer to do, but is a much better way to plant them when the time can be spared; the row being broader it gives the plants more room, and the seed being planted more deeply will better withstand the hot weather. For the very earliest planting the seed should only be covered about an inch deep, and more soil can be drawn around them when well started. The successive plantings of peas should be kept up until the middle of June; those planted later than this will mildew, and not fill out the pods, unless in a cool and shady situation. The plantings should be resumed about the first week in August, and three successive

plantings, about ten days apart, should be made. The vines and pods of these peas will most likely mildew, but the peas that you will get in the cool days of the fall will be the finest in quality, of the whole season. In selecting the sorts to plant, the wrinkled varieties will be found of better quality than the smooth kinds, the latter requiring to be picked while quite young, as they become hard, while the wrinkled ones remain longer in good condition.

VARIETIES OF PEAS.

BURPEE'S EXTRA EARLY.--This is a remarkably early selection of the well-known Philadelphia Early. It is the first variety to ripen, ripens nearly all its pods at one time, and is very sweet and tender when cooked; the vines grow about two feet in height, but can easily be supported by driving stakes every few feet and confining the vines with twine running from one stake to another.[7]

[Illustration: BURPEE'S EXTRA EARLY PEA.]

AMERICAN WONDER.--This little fellow is really a _wonder_, as it grows only eight to ten inches in height and is literally covered with pods. It is remarkably early, ripening in from thirty-five to forty days, and in succulent sweetness cannot be surpassed.

[Illustration: AMERICAN WONDER PEAS.]

EXTRA EARLY PREMIUM GEM.--This variety is about ten days later than the American Wonder, and grows from twelve to fourteen inches in height. The peas are remarkably fine in quality, and I have planted it for several years as my main variety.

PRIDE OF THE MARKET.--A new pea that I have grown the past two seasons, and find of very superior merit. The price of the seed has been too high to admit of extensive planting, but with these three dwarf kinds, the only ones planted for the table this last season, I can say that I have never been better supplied, or with finer peas. This variety grows about a foot and a half in height and bears a very heavy crop of pods, which latter and the peas that they contain are of unusual size and substance.[8]

[Illustration: LAXTON'S EVOLUTION PEA.]

LAXTON'S EVOLUTION.--This variety is a novelty in the way of peas; in the other varieties the object having been of late years to have the pods all mature as nearly as possible at the same time; this object has been sought for the benefit of the market gardeners, while in this new variety we have a kind which will, from its everbearing habits, be a great boon to the family gardener. The vines grow about three feet high, and bear continuously, for a space of nearly three months, an abundance of handsome, large pods, each of which contains eight to ten wrinkled peas, the pods being borne in clusters of two, which facilitates the picking. Like all wrinkled varieties, the quality of this remarkable pea is most excellent.

CHAMPION OF ENGLAND.--This is a large growing late sort, and is very productive, with peas of delicious flavor. The vines grow to four or five feet in height, and this past summer I ate them in perfection fully a month after the other varieties had disappeared from the table.[9]

[Illustration:

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BURPEE'S QUANTITY.]

PEPPERS.

The seed should be sown about the middle of March, in the hotbed, if wanted for summer use, and as soon as the nights are warm they should be planted out. They can be sown in the open ground if the fruit is not wanted for use before fall. As they are used in preparing various kinds of pickles, etc., it would probably be the better plan to plant some at both times. When about six inches high, they should be transplanted to the rows where they are to fruit, and should be set about two feet apart in the row. Where room is scarce, I usually set two pepper plants between each hill of cantaloupes, as they grow well above the vines and are not at all in the way, while having the ground shaded from the hot sun by the vines of the melons, the surface being kept cool and moist by their broad leaves, is of great advantage to the peppers. In choosing varieties, those kinds having the mildest flavor and handsomest appearance should be selected.

VARIETIES OF PEPPERS.

BURPEE'S RUBY KING.--This variety produces the handsomest, and at the same time the largest and mildest peppers that I have ever grown; one specimen this season being six inches long and over ten inches in round circumference. When ripe the fruit is a beautiful, bright, ruby-red color, and the flavor is mild and pleasant, being much milder than in any other variety of red pepper.

[Illustration: BURPEE'^S RUBY KING.]

BURPEE'S GOLDEN UPRIGHT.--In this variety the fruit grows in a different manner from any other large pepper that I have ever seen; it grows upright on the fruit stems, instead of pendulous. The fruits are large and handsome, being about four to five inches in length, and are of rich golden yellow tinged with red. In taste it is as mild as the Ruby King--the two making a very fine contrast when used together.

[Illustration: BURPEE'S GOLDEN UPRIGHT PEPPER.]

BULL NOSE AND GOLDEN DAWN are the finest of the older kinds, but do not compare with the two above given, either for size or mildness of flavor.

RED CLUSTER.--This is one of the finest varieties that I have ever grown; it is low and bushy in growth, and is covered with a profusion of thin, round peppers, about three inches in length and one-quarter inch in diameter at the base, tapering to a long, sharp point. When ripe, the fruit is a brilliant coral red, and a plant covered with fruit looks like some brilliant-foliaged plant that has escaped from the flower garden. It is very hot and pungent in flavor, and an idea of the productiveness can be had from the fact that over twelve hundred were counted on a single plant this last summer.[10]

PUMPKINS.

These take up so much room that they properly belong in the corn field, or in a patch of their own, in one of the cultivated fields. If there is no place for them outside the kitchen garden, and they can be kept far enough away from the squashes and cantaloupes, they can be planted about every twenty feet, in every fourth row of potatoes or sweet corn. They should not be planted until the corn or potatoes have grown three or four inches high, or they will be in the way of cultivating these crops. If one row of the corn were left out, and a row of pumpkins planted, it would probably be the most satisfactory way to grow them, as the tall growing corn, of which there should be at least five rows between them and any other vines, would prevent the pollen from mixing, and as the hills need only be four or five feet apart, a great many could be raised in a row. The pumpkins must all be gathered in and stored before any heavy frosts, as it will spoil and start them to rotting.

[Illustration: SMALL SUGAR PUMPKIN.]

[Illustration: NEW GOLDEN MARROW PUMPKIN.]

VARIETIES OF PUMPKINS.

SMALL SUGAR.--This is very handsome and prolific, of small size, the pumpkins averaging about ten inches in diameter; the skin is a deep orange yellow. It is very fine grained in flesh, sweet in taste, and an excellent keeper.

GOLDEN MARROW.--Of round shape, slightly ribbed and flattened at the ends; the skin is a rich golden orange color; the flesh is of extra quality, and very soft and tender when cooked. It is a splendid keeper, vigorous grower, and keeps well throughout the winter.[11]

RADISHES.

These should be sown as soon as the ground can be worked in the spring, and successive sowings should be made every two or three weeks, as recommended with peas, lettuce, etc. Do not sow too many at one time, but sow frequently, that they may be had fresh and crisp; they soon become either hollow, or hard and woody, if allowed to stand long after they are of sufficient size for use. Where there is glass enough to spare, it is an excellent plan to sow two or three rows in the hotbed at each planting of seeds, which will furnish them for use several weeks before they can be had from the garden.

There is a general impression that radishes do not do well except in very light soil, while my experience is that it is mainly a matter of manure and cultivation, and that good radishes can be raised early in the season on the heaviest of soils, though later in the season they will not succeed unless the soil be favorable. Where "Night Soil" can be obtained and composted with ashes, it will

make the finest kind of manure for the radish bed; but it should be applied with judgment, as it will burn up any crop if applied too heavily. This manure can hardly be so readily applied in a special location in the garden worked by horse power, and I strongly disapprove of making "beds" in such a garden; it should be kept as level as possible, that all the cultivation may be done with the wheel and horse hoes; while "beds" mean lots of slow hand work, and hard beaten ground in the paths and edges, that are perpetual sources of weeds; while in the level garden the location of rows and crops can be continually shifted, every portion of the ground being used, and none escaping cultivation.

For the earliest plantings, the small, very early kinds should be used, and these will grow the finest radishes of the season, fresh, crisp, and slightly pungent. For summer use, the large summer kinds, of very mild flavor, should be selected. These latter should be planted from the first of June until the first of August, after which I begin to sow the small early kinds again, having found that I can grow them as fine and palatable as in the spring. In sowing these in the kitchen garden I sow a part of a row at a time, in the portion worked with the wheel hoe, where the rows are about one foot apart; the seed is sown thinly in the drills, and if it comes up too thickly, should be thinned out to one inch apart for the small kinds and two inches for the larger ones. The seed should be sown from one-half inch to one inch in depth, according as it is early or late in the season or in heavy or light soils. The radishes should be pulled early in the morning and kept in fresh water in a cool cellar until used, so as to have them fresh, brittle and crisp. The large winter varieties are not much raised, except by the Germans, being rather too pungent for the American taste.[12] The seed is generally mixed with the turnip seed and broad-casted or drilled in together, but if I were planting them, I would think it much better to sow them in drills and cultivate separately.

VARIETIES OF RADISHES.

BURPEE'S EARLIEST (_Scarlet Button_).--I have grown this new radish for two seasons and consider it the earliest and finest radish that I have ever grown. It is _the_ earliest, about one inch in diameter, handsome, crisp and brittle. The color is the deepest scarlet. It has very small leaves, and a great many can be grown in a small space, rendering it very valuable for forcing. Last winter I sowed seed between the rose bushes in my forcing houses and kept my table supplied, and had large quantities to sell.

[Illustration: BURPEE'S EARLIEST (SCARLET BUTTON) RADISHES.

Natural size, when ready for use.]

EARLY LONG SCARLET SHORT TOP.--This is a fine selection of the long, slender scarlet radishes so generally seen in the spring, and is preferred by some to the round or turnip radishes. It is very early, tender, crisp and fine flavored; the roots averaging half an inch in diameter at the top and tapering from that throughout their length of four or five inches.

EARLIEST CARMINE, OLIVE-SHAPED.--A very early radish, of a rich carmine color, and while not so early as Burpee's Earliest, attains fully twice the size; the roots are of an even, regular olive shape and very fine quality. It is an excellent radish for forcing, on account of its size and appearance and the small growth of top which it makes, enabling many to be grown in a small space.[13]

[Illustration: LONG SCARLET RADISH.]

[Illustration: EARLIEST CARMINE, OLIVE RADISH.]

SUMMER VARIETIES OF RADISHES.

GOLDEN GLOBE.--This variety is of very quick growth and fine quality, being ready for use in from four to six weeks after sowing the seed. In shape it is almost entirely round, the color quite bright, and the quality very sweet and crisp.

GIANT WHITE STUTTGART produces very large roots, frequently reaching the size of an ordinary turnip; it is very quick growing and resists the heat of summer well, being firm and brittle until it runs to seed. The skin and flesh are pure white, a good guarantee of its mild flavor.

[Illustration: GOLDEN GLOBE RADISH.]

[Illustration: GIANT WHITE STUTTGART RADISH.]

[Illustration:

LONG WHITE VIENNA, OR LADY FINGER RADISH.]

LONG WHITE VIENNA.--This is a very fine long, white radish, both skin and flesh being pure white; it is crisp and brittle and rapid in growth, and to my mind of a much more attractive shape than the large globe radishes, which, unless pulled young, are too large for any but the confirmed lover of radishes.

LARGE WHITE GLOBE.--A very large, round, summer turnip radish, with pure white skin and flesh, which is very crisp and brittle. It grows quickly and withstands heat well. It is similar to the Golden Globe, except in color.[14]

[Illustration: LARGE WHITE GLOBE RADISH.]

[Illustration: CALIFORNIA MAMMOTH.]

WINTER VARIETIES.

CALIFORNIA MAMMOTH WHITE.--This is the largest of all radishes, the roots growing eight to ten inches long and two to three inches in diameter, while the flesh is solid, snow white and of excellent flavor.

CHINESE ROSE.--This is a bright, rose-colored variety, of very attractive appearance; it is of excellent quality, a good keeper, and one of the best varieties for winter use.

POTATOES.

A small planting, say two or three rows, of these should be made as early as possible in the spring, the amount planted depending on how soon they will be followed by the main crop. These may be planted in the furrow when the ground is plowed, but I prefer to plant the earliest ones in furrows struck out about three inches deep, after the ground has been thoroughly prepared, as they will come up more quickly. The rows should be dressed with phosphate, to give them a quick growing start, and the pieces of tuber placed about one foot apart; the ground may be run over with a sharp spike harrow when the potatoes are just coming through, or left a little longer and then worked with the cultivator. The soil must be kept well worked, and as close to the roots as it is possible to run. The bugs must be watched for and destroyed as soon as they appear, either by dusting with Paris green mixed with plaster, or with other insect poisons, or by picking them off and destroying them by hand, which is the easier way when the patch is small and potato plants are young. If these early bugs are destroyed before they can lay their eggs, the work of protecting the summer crop will be greatly lessened. Where the main crop of potatoes is to be raised in the garden, they should be planted about the first day of May, or the middle of April, that they may be harvested by the middle or last of August, and the ground used for a crop of turnips, peas, or other second-crop vegetables. As soon as the vines begin to die, and the skin of the potatoes is well set, so that it will not rub off with the fingers, the tubers should be dug or plowed up and stored, not only that the ground may be used again, but because, if they are left in the ground, they will either start to grow again or begin to rot. When dug, I pile them in small heaps of twenty bushels or so on the barn floor, dusting each pile as it is made with dry, air-slacked lime, about a quart to a heap; this helps to dry and preserve them, and prevents any tendency to rot. The barn doors are left open through the day, for a few days, and the potatoes dry gradually, until time for storing them, when it comes cold, though where there is a cool vegetable cellar it will save time to store them at once, and, of course, at this time of the year the ventilators of the cellar should be wide open. Where the cellar is too warm and the potatoes start to sprout, it is said that it may be prevented by turning them frequently, but I have never had an opportunity to try it. The first planting should be made of some very early ripening varieties, while the main crop should be of a kind selected for good size, heavy cropping, and the best cooking qualities.

SWEET POTATOES.

Like some other vegetables, these are generally supposed to require special soil and situation to do well, but with plenty of manure and good cultivation they can be raised of fine size and quality in any garden. As described in the chapter on hotbeds, the old potatoes are planted in a warm bed, about the first of April, and when the ground is prepared, these are taken up and the sprouts broken off close to the potato. The potatoes should be buried two or three inches deep in the bed, which will give each shoot a bunch of fine roots when it is broken off. When the nights are warm, and the trees well out in leaf, plow a double furrow where the row of sweet potatoes is to be; that is, run the plow each way in the same furrow; then fill in two or three inches of fine manure, and plow the furrows back again, forming a ridge over the manure. In the centre of this ridge plant the sets about one foot apart; they must be kept well cultivated, and the running vines must not be allowed to strike root into the soil, or they will form lots of small potatoes, and none large enough for use; some gardeners keep the vines coiled round the central plant, but the easier way is to throw the vines from two rows together, then cultivate the side left bare, and throw them back again, cultivating the other side; after

the first time they need not be moved but once for each cultivation, as the blank side can be cultivated and the vines thrown over on it, leaving the other side free, which can be cultivated first the next time it is done, and the vines thrown back. Throwing the vines over can be done very quickly by running a rake handle or long light pole under them, and throwing its whole length of them over at once: they can be dug as soon as large enough for use, by scraping the dirt away from the side of the hill, the potatoes pulled off, and the vines left to form more. The whole crop should be dug as soon as the vines are blackened by the first frost, and spread out in a cool dry place, where there will be no danger of their freezing. On account of the vines taking so much room, the rows should be at least five feet apart.

SAGE.

A dozen roots or more of this herb should be planted in some part of the garden where it will not be disturbed by the plow, or if this cannot be done readily, the roots can be taken up when the plowing is done, divided and reset, which would probably raise a larger and finer crop of leaves than allowing them to stand in the same place year after year. The crop should be cut off a few inches above the ground, as soon as it has made its growth and before it begins to bloom. The shoots will again start to grow, and two or three crops can be cut in a season; the cut tops can be tied in bunches and hung to the rafters, or spread thinly on the floor of a cool loft or garret.

SPINACH.

This is a quick-growing green, and very hardy, making it valuable for early spring and late fall growing. It cannot be raised during summer, on account of its running immediately to seed without making many leaves. It can be sown as soon as the ground can be worked in the spring, and will be ready for use in a few weeks; about three sowings may be made, two weeks apart, or more, if the season is longer, though it will hardly be good if planted after the middle of May. The whole plant is cut off even with the ground, at any time before it starts to run to seed, the leaves and stems being used as boiled greens. Large sowings should be made in October, of the hardy variety, as it can be cut throughout the winter; a later sowing may be made the first of November, and lightly covered with litter when the ground has been frozen hard; this covering should be raked off early in the spring, and it will complete its growth before the first spring planting is ready for use.

VARIETIES OF SPINACH.

NEW THICK-LEAVED ROUND.--This variety produces large, thick, dark green leaves, somewhat crumpled. It possesses the valuable quality of standing for some time after attaining its growth, before running to seed.

[Illustration: NEW LONG-STANDING SPINACH.]

THE NORFOLK SAVOY LEAVED.--The leaves of this kind are wrinkled like a Savoy cabbage. It makes a large bunch of succulent leaves, producing more weight of leaves than any other variety, and is more hardy than any of the other kinds.

NEW LONG STANDING.--This is one of the best varieties for spring sowing, as it stands longer than any other before running to seed. The leaves are thick, fleshy and crumpled like the Norfolk Savoy Leaved.

SQUASHES.

Hills should be made for the culture of these, in the same manner and at the same time as described for cucumbers, cantaloupes, etc. These hills should be at some distance from the vines above mentioned, as there is danger of the pollen mixing and spoiling the melons, etc. There are some localities where the winter squashes do not do well or are difficult of cultivation; but the small summer squashes are of easy culture in any locality, though of finer quality on a warm sunny slope than elsewhere. The only trouble in growing them is to protect them from the ravages of the Striped Squash Bug while young, for which purpose I use slug shot, dusted on the leaves early in the morning, while the dew is still on them.

The vines should be allowed plenty of room to run, at least four feet on every side. The vines soon cover the ground and prevent using the cultivator; but the large leaves so shade the soil that few weeds grow, and where they rear their heads above the vines they can be cut out with hand hoes or pulled out after a rain, by hand.

As we can hardly use the product of more than a dozen hills, I divide the long row across the garden into three parts, planting the squashes at one end, watermelons in the centre, while the other end is occupied by cucumbers, which prevents any mixing of

pollen, and gives a sufficient quantity of each fruit without disturbing the symmetry of the garden. In gathering the squashes for table use, care must be taken that they are not too old, or they will be tough and stringy when cooked; the easiest way to judge them is to try them with the nail or small stick; if it does not cut the skin freely and easily they are too old; no push should be required to make the cut. This is also a good test when in doubt about the proper condition of sweet corn, and should be applied to grains near the base of the ear. No old squashes should be allowed to remain on the vines of the summer varieties, for if they are allowed to ripen, the vine, having fulfilled its natural purpose, will dry up and die, while if the fruits are picked off, it will continue to grow and produce fruit.

The winter squashes are raised in the same manner, but are more difficult to start, as the young plants are subject to a borer which eats them off under ground. Plenty of seed should be sown in each hill, and as soon as you see a plant wilting or cut off, dig around its roots with your fingers or a stick until you find and kill the borer, otherwise, he will continue his labors on the other plants in the hill. The plants should also have careful watching and dusting, to preserve them from the usual insects that prey on young vines. When the plants are about one foot in length they should be thinned out to two or three in a hill, though the danger from borers is hardly passed yet, but to allow them to stand too thickly after attaining this size would stunt them and lessen the crop. The squashes should be gathered before there is any hard frost and stored in a cool, well-aired cellar. Some of the winter varieties are equally good for summer use before they become too old and hard; if these are planted, the one planting will furnish fruit for both seasons.

SUMMER VARIETIES OF SQUASHES.

EARLY WHITE BUSH, OR PATTY-PAN.--This is the best known and most generally planted of the early squashes; when young the quality is very fine, the flesh is fine grained and of delicate flavor. It is a bush variety and the vine does not “run.”

[Illustration: EARLY WHITE BUSH SQUASH.]

[Illustration: GOLDEN SUMMER CROOKNECK SQUASH.]

GOLDEN SUMMER CROOKNECK.--A small crook-necked summer squash, the skin of which is a bright yellow color and is covered with warty excrescences. It is early, productive and of excellent flavor.

WHITE PINEAPPLE, OR WHITE TURBAN.--This variety produces a very handsome fruit, though of peculiar shape, as will be seen from the accompanying illustration. The blossom end of the squash is smooth and round, while from the stem end start ribs or ears, which attain their largest breadth and end near the middle of the squash; these ears usually grow in pairs. This variety is of excellent quality, and can be used at any stage of its growth, and the full-grown fruits can be preserved for early winter use. The skin and flesh are both of a pure creamy white tint; the flesh being very thick, while the seed cavity is quite small. The flesh is fine grained and of the best quality, possessing a rich cocoanut flavor.

[Illustration: WHITE PINEAPPLE SQUASH.]

[Illustration: ESSEX HYBRID SQUASH.]

WINTER VARIETIES OF SQUASHES.

ESSEX HYBRID.--A very productive squash of the finest quality and an excellent keeper, specimens having been kept until June, as sound and good as when gathered. It is one of the richest flavored, finest grained and sweetest of all squashes, while at the same time it is one of the largest and most productive, growing close together on the vines and averaging from eight to twelve pounds in weight. It is of early, quick growth, and can be raised very successfully as a second crop, following early potatoes, peas, etc.

[Illustration: HUBBARD SQUASH.]

HUBBARD.--This is a standard and well-known winter squash, and is of most excellent quality for winter use, but is not so well adapted to all soils and localities as the preceding varieties, nor of such easy culture.

TOMATOES.

These rank with the standard vegetables, such as corn, potatoes, etc., and yet it is not many years since they were grown in flower gardens only, the brilliant color of their fruit being then considered quite a pleasing novelty. Now, by the introduction of the canning industry, there is not a day in the year when they are absent from our table. Their culture is of the simplest, being largely a matter of soil and manure and good early plants, to be set out as soon as the weather will permit in the spring. The seed is sown in hotbeds, from the middle of March to the middle of April; if possible, they should be transplanted, when about two inches high, to another sash, where they may stand three or four inches apart. When there is not room for this, the seed should be sown thinly in drills four inches apart, and when well started, should be thinned out to two inches apart in the row. The hotbeds should be given plenty of air on warm days that the plants may be stocky and thrifty when planting-time comes. They should not be set out until the temperature is over 60° at night, or until the oak trees are well out in leaf. They should have plenty of room, at least three feet in the row and four feet between the rows, and for an ordinary family at least four rows should be planted. Two rows should be of the earliest and two with plants sown a month later, for in some varieties there is a tendency to die off after raising one crop, though constant picking as fast as they ripen, and not allowing surplus ones to remain on the vines, will greatly prolong the bearing period; so much so, that in most years I make but one planting. The earliest hotbed plants will begin to ripen fruit the last week in July or the first in August, while, if you make a hill, as for corn, about May 10th, and put in a dozen or so seed where you want the plant to stand, pulling all out but the strongest one when they get a good start, you can have this second lot in bearing about the last of August, without the use of glass or the labor of transplanting.

The young plants must be thoroughly cultivated and hoed; when hoeing, the dirt should be loosened right up to the plant, and when it has been worked loose and made fine should be drawn up to the stem, two or three inches in height. It frequently happens, when the season is late, that the plants have grown a foot, or even two feet, in height or length. This is no disadvantage, but rather a help, if treated in the following manner: A gutter two or three inches in depth and nearly the length of the plant, is scraped under the planting line with the hoe, and the plants laid lengthwise in this and covered over, all but about five or six inches of the top, which is bent straight upward and afterward treated as though it were a plant of that size; the long stem underground immediately forms roots and assists in feeding the growth of the plant.

The ground should be well manured, but if the soil is light it can be overdone, as the plant will run too much to vine and be late in producing fruit. I have found that, though there is a general impression that tomatoes do best on a light, sandy soil, the best tomatoes I have ever raised have been on my poorest and heaviest ground. On a plot of ground where the plow turned up the yellow clay at a depth of five or six inches, I have had the ground covered; covered so that you could hardly put your foot down anywhere in the patch without treading on a tomato, and not a cracked or rotten one among them. At another time I planted all the plants there were at that time of the now famous Turner Hybrid, in a patch of clay soil where young nursery trees had been grown for five years, and you can ask any nursery-man how much that leaves in the soil. Yet this patch produced tomatoes which astonished all beholders and led to its being placed at once upon the market; and right here I would say that the flavor and appearance of this variety have been so fine with me that I have obtained double price for my tomatoes since I have been growing it. In the last ten years I have had the handling of the first stock of three new tomatoes, each one of which has seemed near perfection when originated, yet each has been much superior to its predecessor. I mention this only to show how the craft of "assisting nature," or gardening, is always progressing and gaining new interest in the mind of the gardener. There is a constant charm about it, that, once it takes possession of you, never lets go.

If the full-sized, green and partly ripe tomatoes are picked off when there is danger of frost, and placed under the sash of the cold frame, or on the floor of the cellar, they will ripen gradually, and though not of very fine quality, may be had fresh almost until Christmas; they must, of course, be entirely green when picked, to consume so much time in ripening.

If some plants of the golden or yellow varieties are planted, they will add greatly to the attractiveness of the dish when mingled with the red ones, served sliced in the ordinary manner. If you save your own seed, the earliest ripened specimens should be saved for that purpose, and should be of perfect shape and evenly ripened, with no core, crack or rot about them. The easiest way to clean this seed is, take a small box, knock the top and bottom off, and nail some wire fly screening over the bottom; take the fresh tomatoes, not rotten ones, as are frequently used, and squeeze the seeds into this sieve, throwing the pulp and flesh away; the seed can be washed free and clean by running clean water upon them, keep them constantly stirred and pick out the bits of pulp as they become free and float upon the top of the water, while the water and finer particles will pass off through the screening. When clean allow all the water to drain off and spread the seeds thinly on a smooth board or cloth in the sun; they should be stirred frequently, to prevent their adhering to each other when dry. If seeds are washed out in this manner and carefully dried, you can depend on every one growing, while from those saved in the ordinary manner, from tomatoes that have been allowed to heat and

rot, sometimes not one seed in a hundred will germinate.

VARIETIES OF TOMATOES.

EXTRA EARLY ADVANCE.--This variety is said to be the earliest in cultivation; at any rate, it is certainly a very early variety, and at the same time its fruits are of large size, of handsome, bright, red color and good quality; the solid flesh is free from the hard, green core present in the old varieties.

[Illustration: EXTRA EARLY ADVANCE.

EXTRA EARLY ADVANCE TOMATO.]

[Illustration: BURPEE'S CARDINAL TOMATO.]

BURPEE'S CARDINAL.--I had the pleasure of growing this variety before it was introduced, having been presented with a small packet of seed by the originator, who requested me to make a trial of its merits, and though it was an unfavorable season, and, as I wished to keep it separate, I could not plant it in my best tomato ground, its fine qualities exceeded all that he claimed for it. It is of beautiful appearance, every fruit being a brilliant cardinal red, uniform in shape, and without blemish or cracks. The flesh is of the same bright color, is firm and free from any rot or core, and is of superior flavor. The vine is very heavy bearing, and one of the best for all purposes that I know.

BURPEE'S CLIMAX.--This variety resembles somewhat the preceding kind, excepting that the fruits are a light crimson in color and do not average so large as does the Cardinal. The fruit matures early, ripens evenly, without core or cracks. The flesh is fine-flavored, solid, and produces but few seeds; it is a good kind for all purposes.

[Illustration: ESSEX EARLY HYBRID TOMATO.]

ESSEX EARLY HYBRID.--Very early, solid, rich flavored and handsome. It is of large size and grows perfectly smooth; the color is a bright pink, ripening evenly all over. It is very early, a great bearer, and, being solid, is a most excellent variety for shipping purposes.

GOLDEN QUEEN.--This is the best yellow tomato that I have ever grown. The fruit is of good size, handsome color, smooth, round shape, and superior quality. They should be in every garden, for the sake of the pleasing contrast they make when served with the red varieties.

[Illustration: GOLDEN QUEEN TOMATO.]

TURNER HYBRID.--This variety I consider _the_ tomato above all others, not only for its large size, handsome appearance and heavy cropping, but most of all for _its superior quality_, which far surpasses that of any other tomato that I have over eaten; and if there is one crop more than another that I pride myself upon, it is my tomatoes. Mr. Burpee, of W. Atlee Burpee & Co., gave me, in 1884, the small paper of seed sent them by a customer, and I planted it, as stated in the general chapter on tomatoes, and was so much pleased with it that since that time I have planted it altogether for my own use, with the single exception of a few plants of the Golden Queen. It is a rank, strong grower, with peculiar foliage, the vines strongly resembling potato tops. The fruit is very large and remarkably early for the size of the tomatoes; the average weight of the fruit is from twelve to eighteen ounces, so it will readily be seen that the size is very large, while, as above stated, I do not think it is possible to recommend the quality too highly.[15]

[Illustration: TURNER HYBRID TOMATO.]

TURNIPS.

With our hot, dry summers, turnips can only be raised satisfactorily as a fall crop. They can be grown as a second crop, after early sweet corn, potatoes or peas, and should be sown as soon as possible after the first of August. The ground should be plowed or run over two or three times with the cultivator, and then harrowed till it is as fine as it is possible to make it. If the seed is sown broadcast, some winter radish seed should be mixed and sown with it. The ground should be rolled after sowing, not only to compact the soil round the seeds, which is essential to good germination, but also to prevent washing by the September rains, if the ground is at all sloping. But where the finest turnips and a sure crop are desired, it is much better to sow our garden turnips in drills, one foot apart if you have a wheel hoe, or as narrow as you can cultivate, if you have not. This will tend to having the roots of even size, and the finest appearance, as they can be frequently worked. When about three inches high, or when beginning to form

bulbs, they should be thinned out to four or five inches apart in the rows, with the narrow hoe, leaving each bulb to stand by itself. It will be found that by this method, with careful culture, a larger as well as a much finer crop can be raised on the same ground than if they were sown broadcast, and that not half as much seed need be used, as it is carefully planted just where it is to grow.

[Illustration:

Illustration showing manner of storing turnips, beets, carrots, etc., in the garden for winter use. S, straw covering and ventilating chimney; D, covering of soil over the straw.]

About the third week in November, or before there is danger of the ground becoming hard, the turnips should be pulled and the tops cut off; take enough in the cellar for immediate use, and store the rest in heaps. Select a well-drained piece of ground, as directed for burying cabbages; it will be most convenient to have them near together; spread about two inches of straw on the ground, and heap the turnips upon it in the shape of a cone, not more than ten or fifteen bushels in a heap; cover this with straw, an inch or two thick, and bind it together at the top, and let it stick up a foot or so above the top of the cone; then cover the heap with four to six inches of soil, all but the straw top to the cone, which acts as a chimney or ventilator; the roots can thus be kept in good order throughout the winter. The surplus beets and carrots can be put in with the turnips, and the whole can be gotten at, any day when the temperature is above freezing, by making a hole in one side of the heap, taking out what you want, and carefully closing the opening again. The straw bottom and sides are not absolutely necessary, but are a great improvement and convenience, and will preserve the roots in a much cleaner and finer condition; the straw not only helping to keep out the frost, but at the same time providing ventilation for the heap.

VARIETIES OF TURNIPS.

EARLY RED, OR PURPLE TOP STRAP-LEAVED.--The best known and most generally planted variety. It is a quick grower, and the flesh is very fine grained and flavored. The red top of the bulb, which extends down to where it rests in the soil, adds very much to the appearance of this popular variety.

[Illustration: PURPLE TOP STRAP-LEAVED.]

[Illustration: EARLY WHITE FLAT DUTCH TURNIP.]

EARLY WHITE FLAT DUTCH.--This is a quick growing and very early variety. The skin and flesh are a clear white, and the flesh is solid; very sweet and juicy, and of mild flavor.

EXTRA EARLY PURPLE TOP MILAN.--This kind is said to be the earliest of all turnips, maturing two weeks earlier than the Early Red. The bulb is very flat, of medium size, quite smooth, with a bright purple top; leaves grow very short, making a small, neat top. The pure white flesh is solid, fine grained, and of superior quality, even in the largest specimens. It is an excellent keeper, retaining its good quality throughout the winter.

WHITE EGG.--As its name implies, this is a pure white turnip, of egg-shaped growth. It grows very quickly; has a thin white skin, and very solid, fine-grained white flesh. It is very sweet and juicy, of mild flavor and grows to a good size. It is a good variety for either early or late planting.

[Illustration: WHITE EGG TURNIP.]

WATERMELONS.

These are also supposed to require special location and soil, but can easily be raised in any garden where the climate is warm enough for cantaloupes, tomatoes, etc. What they most need is plenty of encouragement, in the shape of thorough cultivation and liberal feeding with well-rotted manure. The hills are prepared in the same manner as for cantaloupes, excepting that where the manure or compost can be obtained, a good-sized hole should be dug, and well-rotted manure or compost put in as liberally as the supply will admit of, even half a barrel to the hill. If this kind of hills can be made, you can plant with seed of some of the large growing varieties, and be sure of success, unless your season is very short. If the season is too short, or if you have not the manure for large hills, I would recommend some of the smaller fruiting varieties, as they are fully as fine in quality, ripen early, and set more melons than the larger kinds. From ten to a dozen seeds should be sown in each hill about the last of May, or when the temperature does not go below 60° at night. When they have got a good start, thin out to two or three plants in a hill.

[Illustration: HUNGARIAN HONEY MELON]

If your melons are of the tough-rind variety, as for instance the "Ironclad," you can pick them off at the approach of frost, and by storing them in a cool, frost-proof cellar, have them in good condition till Christmas. Though my own opinion is that they lose their attractiveness when the hot weather is gone, still, it is always one of the main aims, in gardening, to have things out of season as well as at their regular period of ripening.

VARIETIES OF WATERMELONS.

HUNGARIAN HONEY.--This melon is one of the best for the small garden. Though not large, averaging eight to ten inches in diameter, it is perfectly round, so that there is a great deal of eating in one of them, while the quality is not equaled in any other variety. The melons ripen early, and the vines are vigorous in growth and very productive. As its name, "Honey Melon," implies, it is sweet and luscious, and of a rich honey flavor, melting completely and leaving no stringy fibre in the mouth. The dark green skin, and intense brilliant red of the flesh, make a very striking appearance when cut.

BURPEE'S MAMMOTH IRONCLAD.--A large melon, of superior quality, and where there is room to grow them, will be found a profitable crop for market. Under ordinary culture, it frequently attains a weight of sixty to seventy pounds. They take their name of Ironclad from the exceeding toughness of the thin rind. Cutting into one is almost like cutting into sheet iron, though the flesh inside is fresh, crisp and melting. So strong is this rind, that I have stood on one of the smaller melons with a companion, our united weight of over 340 pounds not cracking the ripe flesh within in the slightest degree; and I have seen a wagon load of melons driven over one in the field without damaging it in the slightest. While it does not produce many melons to the vine, it more than makes up in size and weight what it lacks in quantity, being a heavy cropper when this is taken into account. The flesh is very beautiful, of a dainty red color and rich, sugary flavor. The flesh is never mealy, but always firm and solid. In shape this melon is oblong, its length often being two and a half times greater than its diameter.

[Illustration: BURPEE'S MAMMOTH IRON CLAD]

ICING, OR ICE RIND.--This is a dark, green-skinned melon, of nearly round shape. It is a favorite variety, on account of the solidity of its flesh, thin rind, and rich, luscious, sugary flavor.

CUBAN QUEEN.--The melons of this variety are very handsome and attractive in appearance; the skin being striped, dark, and light green, in a pleasing manner. The vines are strong and vigorous in growth, and bear enormous crops when well manured. The melons are large, very heavy, and of the finest quality. The rind is very thin, being scarcely more than half an inch in thickness on a large melon; the flesh is bright red, very solid, rich, and sugary. This is one of the very best varieties for general culture in all sections. The shape of this variety is oblong, being about twice its diameter in length.

[Illustration: BURPEE'S CUBAN QUEEN

111-lb CUBAN QUEEN WATERMELON.]

KOLB'S GEM.--The skin of this melon is striped, as in the Cuban Queen, but is not so handsome, as there is not the same amount of contrast between the two shades; the shape is much shorter, being nearly round. The flesh is bright red, and of good flavor; and owing to its tough rind is a very good shipping and keeping variety.[16]

RHUBARB, CURRANTS AND GOOSEBERRIES.

These three I would plant in the same row, in the small fruit plot or permanent part of the garden, mainly because a third of a row of each will afford an ample supply for a good-sized family, and all require nearly the same treatment. The plants of each are all set together, each in its own third of the row, not interspersed. The plants should be set as early in the spring as possible, or can be planted in the fall and well mulched with manure. The crowns of the rhubarb should be set an inch or two under the surface, and no stalks pulled until the second or third season; in the fall, when the ground is frozen hard, the old leaves should be pulled off and the row well mulched with long manure; in the spring this should be worked down to the roots, when the ground is fit to work, and the soil kept loose and free from weeds while the rhubarb is making its growth. The stalks can be pulled as soon as they are large enough for use, and can be pulled until they become so small as to be unfit for use; then dig in some fine manure or compost, and let it grow at will until fall, when the stalks will again be fit for use, though this second crop is generally allowed to go to waste, mainly, I think, through ignorance of the fact that it is just as palatable as in the spring, and that it can easily be canned for winter

use. Like asparagus, it must be liberally and continually fed, to have it in fine condition and of good size.

The currants and gooseberries are subject to the ravages of the currant worm, which cleans up every leaf and berry on the bushes just as they are about to ripen. To prevent this, the bushes should be dusted with white hellebore when the first worm makes his appearance; as this is a very strong poison many are afraid to use it; and, indeed, great care must be taken in using the fruit; still, the worms usually appear about the time the bushes are in bloom, and if promptly welcomed will have disappeared, and the poison be washed off the bushes before the fruit has formed. Any one who does not like to use the hellebore can dust the bushes with road dust or dry wood ashes every morning while the dew is still on the leaves; care should be taken that the _under_ side of the leaves should receive a good portion of whatever is used. There is still another way of getting rid of these pests, and that is by hand-picking them; but any one who has tried it will agree with me that it is a somewhat tedious process when done every morning for a couple of weeks.

When the fall comes these bushes should be well mulched, and in the spring, before the growth starts, the old wood should be cut out of them, care being taken not to trim them too severely; never take out more than a third of the wood, or you will trim away your crop of fruit for the season. When the spring opens, dig in the mulch and keep the ground well worked and free from weeds, as in the asparagus and rhubarb.

BLACKBERRIES, BLACK CAP RASPBERRIES AND RED RASPBERRIES.

The culture is the same for all these, and they should be planted in liberal quantities, so that there may be plenty to preserve, as well as a full supply for the table. In my own kitchen garden I have two rows of Wilson's Early Blackberry, one row Gregg Black Cap, and one row each of Philadelphia and Cuthbert Raspberries, and still the family cry for more, so I shall add about two rows of Wilson, Jr. Blackberries, and one of Lucretia Dewberry, in the spring. The dewberry will ripen before the blackberries, and thus prolong the season, as is already done with the two varieties of red raspberries.

The plants should be planted as early in the spring as the ground can be gotten into suitable condition, and if purchasing from a nursery, select those plants which are grown from root-cuttings, for they will not "sucker" so much, and where the garden is constantly well fed and cultivated this will save much in working, and the plants being carefully trimmed will last for years without replacing. The rows should be ten or twelve feet apart, so as to admit of free passage in cultivating and picking. As they do not grow so wildly until after the fruit has been picked, a couple of rows of peas or a row of early corn can be grown between each row. I have tried planting at closer distances, with the invariable result that by fall the berry patch was an impassable jungle. For manuring the berries coarse manure should be applied in the fall, or short, well-rotted manure in the spring; in either case plowing it under as applied; if plowed in the fall the furrows should all be thrown toward the rows, thus partly banking them over for the winter.

In the first warm days in the spring these bushes should have their trimming; all the old wood that has borne fruit will be dead and should be cut out at the ground. Three or four good healthy young shoots should be selected to each plant, cut off at three and a half or four feet in height, and the side shoots cut back to three or four inches; cut off all the rest of the suckers. This is important, for if too many are left there will be but a small crop of inferior fruit. When the whole patch has been trimmed and cleared up it should be staked; or each plant may be staked as trimmed, but the trimming will have to be left until a week or so later, as the stakes cannot be driven in the frozen ground. For this purpose I use old fence rails, sawing them in the middle and then splitting each piece into two or three stakes, or the large limbs, say one to two inches thick, left from trimming brush, can be used; the fence-rail stakes, however, last longer than the fresh cut poles, and are much more easily driven.

It will be a great help in picking-time if the row is gone over with a large pair of hedge shears, and the longest of the young shoots shortened in, so as to allow easy access to the row. Where it is more convenient, the bearing wood may be cut out as soon as the crop is gathered, thus throwing all the strength of the plant into the young shoots.

Where there is not plenty of manure, bone dust or phosphate can be sown on after the plowing in the spring and worked down with the harrow or cultivator. It, of course, takes a good deal of rope to tie all these and a good patch of grape vines up every spring, so I go to a printing office and buy the old Sisal rope which comes on the bundles of paper; this is strong, and can be bought very cheaply, as it is all in short lengths, in fact, most offices would be glad to oblige a good subscriber by giving it to him. The bushes should be planted eight feet apart in the row.

GRAPES.

I grow grapes between the rows of berry bushes, half way from each row, which are twelve feet apart. The vines are eight feet apart in the row; at every vine is planted an old fence rail, the ends squared off, and the bottom coated with coal tar before planting; these stand six feet above the surface, and from top to top runs a light pole or single strand of wire. The vines are tied up to the posts and out along the rail; this gives a clear space underneath for keeping the ground worked, and it bears the crop in the most convenient position for gathering. The vines should be trimmed early in February, that the wounds may contract and harden before the sap flows. The vines should be tied up with fresh rope; do not depend on any old ties, as, though they may look strong, the birds will pick them to pieces to make nests of. Trim the vines to long canes, two to four to each post, and divide them at the top, carrying half out the top pole or wire in each direction; cut the side shoots back to two eyes each, as these are the spurs that will furnish the fruit branches. If fruit is desired in finest condition a two-pound paper bag should be tied round the neck, to the stem of each bunch, placing the bunch inside, when the berries are about half grown; this preserves the grapes from mildew and, what is more destructive, the ravages of bees and birds.

STRAWBERRIES.

There should be one or two rows of strawberries across the garden; the rows four feet apart. It will be found a great deal easier to keep them free from weeds and to gather the fruit when grown in this way. The varieties, one early and one late, or both rows of a continuous bearing kind, should be of the perfect flowering character, as there are plenty of varieties of this character which are as good and prolific as any pistillate sort grown, and they are not so much trouble to grow, or as uncertain a crop. The plants should be set early in the spring, in well-manured ground, twelve inches apart in the row, and should be hoed and cultivated as frequently as possible. As the runners start lay them lengthways of the row and let them root in, keeping the soil loose and fine, so that they can easily take hold.

The blossoms should be kept picked off the season of planting, or they will take the strength of the young plant so that it will make but a feeble growth and no runners. In growing the plants in this way the runners should not be allowed to form a row more than one and a half feet wide, as this will be fully two feet in the second season, and as much as a picker can manage. The grass particularly should be kept out of the rows of young plants, or it will take a start in the spring and entirely crowd out the strawberries.

These rows should be set out every spring, taking the plants from the outside of the rows planted the preceding year, as it is almost impossible to keep them free from weeds after the first season, besides which they do not bear more than half so many, nor nearly such large berries, the second season. Unless the ground is very rich where the young plants are set, it is a good plan to sow a heavy coat of phosphate, bone, or, best of all, wood ashes, just before they are worked with the cultivator for the first time in the spring. The young plants should not be planted in land that has just been in sod, as it is full of white grubs, which will eat the plants off underground, and care should also be taken that the manure for the strawberry plot is not infested with them. These rows should be lightly covered with long manure, old hay or other litter, in the fall, after the ground has become frozen hard, so that they may be protected from rapid freezing and thawing; and if the covering is not too heavy, it can be left on in the spring and the plants will shoot up through it, leaving it as a mulch and serving to keep the berries clean, by saving them from contact with the ground, as does the straw mulching, from which the berry is generally supposed to take its name.

In selecting varieties choose those which are recommended as suitable for your soil, heavy or light, or such as have proved good in your immediate neighborhood, as some of the finest kinds are worthless in a different soil from that to which they are adapted. If especially fine, large berries are desired, the plants should be set in rows three feet apart, the plants twelve inches, as before, and all the runners kept cut off as fast as they appear. In this case heavy mulching is imperative, or the stools will be thrown out of the ground in the spring freezing and thawing. When the spring opens, the mulching should be cleared away from the crown of the plant, but should be allowed to remain on the ground surrounding the plant, as the weeds can easily be kept from such a patch, and fresh fertilizer applied. The patch may be continued in bearing for two or three seasons, but it will be found a great deal easier if a fresh patch is planted in new ground each year.

COMPOST.

This should be prepared in the early spring for use in the hills, and if it can be stacked in the fall and allowed to rot through the winter, it will be all the better. It can be composed of barnyard scrapings, well-rotted manure, chicken manure, night soil, or other strong fertilizer, mixed with at least an equal bulk of soil or ashes. This should be wet enough to rot thoroughly, but should not be allowed to lie exposed to the weather where its strength will leach away. When thoroughly mixed, I place it in old barrels under a shed and pour water on top of each barrel occasionally, to keep it rotting.

MANURE.

A good supply of manure should be either made or bought, as the garden should have a good dressing at least two years out of three; the third year I usually use a phosphate, but would use the manure if I could spare it, using also a good dressing of air-slaked lime every two or three years. The manner of applying the lime and phosphate is the same, but they must not be used the same season, as the lime will destroy the effect of the phosphate. They are sown on in the spring, after the ground has been plowed, and before harrowing, the harrow thoroughly mixing them with the soil. The supply of manure may be largely increased by pulling up the early peas, corn, cabbage stalks, etc., as fast as the crops are gathered, and adding them to the manure heap; this should be so located that all slops and waste from the house can be thrown upon it, so as to assist in keeping it constantly rotting; where corn stalks, tall weeds, etc., are put on the manure heap they should be cut into short lengths, with a corn cutter or other implement, to facilitate rotting and handling when the manure is drawn out.

SAVING SEEDS.

The gardener will consult his judgment and his pocketbook in buying seeds, as there are many varieties of which, if he has a good strain, he can save as good seed as he can buy; but the greatest care should be used in doing so, as the quality and quantity will both rapidly deteriorate if inferior specimens are selected from which to save seed. Thus it will not do to take off all the best ears of corn, or the tightest heads of lettuce, using the nubbins and runts for seed, or the next year the nubbins will predominate and the lettuce will go to seed without taking the trouble to form a head at all.

The best plan is to set apart a section of the row of each variety for seed, and not gather any for use from that part; here all the nubbins and inferior specimens could be pulled off, throwing the full strength of the plant into the finest fruits; and the same way with the vines; one or more hills, as desired, could be kept for the purpose of bearing seed only.

All seeds should be thoroughly cleaned and dried, and each package should be carefully marked with name and date before storing. The seed chest should be in some cool place where there is no danger of frost or very warm heat, and, most of all, no danger from dampness. It is important to have the date of saving the seed marked, so that when all is not used it may be kept, as frequently a crop fails from a bad season or other causes, and a new lot of equal merit cannot be obtained, the date serving to tell how good the seed is; seed of some vegetables retaining vitality for only two years, and others as long as ten years.

HOW AND WHAT TO GROW

IN A KITCHEN GARDEN

OF ONE ACRE.

THE SECOND PRIZE ESSAY.

BY MISS L. M. MOLL.

To insure success in horticulture, the first requisite is a deep, rich, well-drained soil. For a garden, nothing can be more important than good drainage. Soil properly drained is warmer, dries faster, and can be worked earlier in the spring; it is easier to work in a wet season, and more open and moist in a dry season. Taking for granted, then, that the ground has perfect drainage, it should be plowed deeply in the fall, so as to allow the frost to penetrate and sweeten the soil. In addition to this, the frost will be out sooner in the spring, and the superfluous moisture drained off more quickly, thus leaving the land in a workable condition at least a week earlier.[17]

Putting manure on the ground in the fall, or during winter, is a practice I would not recommend, because some of its most valuable portions are sure to be washed into the drains by the melting snow and spring rains, leaving the plants rather a meagre supply of nourishment to draw from when they come to need it most. The proper way to do is to give the ground a liberal spreading of thoroughly decomposed barnyard manure in spring, as soon as the land is in a workable condition.[18]

This should immediately be plowed in, and be followed with a sharp, weighted harrow, to thoroughly pulverize and mix the soil. This is important, as the surface of the soil is not so liable to harden or bake afterwards, if the ground is well worked in the spring. The soil is also permeated to a greater depth by the sun and air, causing healthier and quicker growth, consequently better and earlier vegetables. The form of our one-acre patch should, by all means, be a rectangle, made longer than wide, with the rows running

lengthwise, and all perfectly straight, and everything else so arranged that as much of the cultivation can be done by horse power as possible. But let me say right here, that no one should undertake the cultivation of a kitchen garden without being willing to do a reasonable portion of the work by hand. This part of the work can, however, be greatly lessened by using the various labor-saving garden implements, to be purchased at reasonable rates, of most seed firms.

If "variety is the spice of life," it can certainly nowhere be more desirable than in the kitchen garden, which is to supply our table with its yearly demand for choice vegetables; I say _choice_, since every one having the care of a garden should strive to grow everything of the very best, and that, too, in great abundance and variety.

The most convenient mode of arranging the different kinds of vegetables is to; 1st, Place the perennial plants in one bed, running the entire length of the ground; 2d, Plant the vegetables side by side which are to remain out all winter, so as not to interfere with next spring's plowing; 3d, Arrange side by side those varieties which require the whole season to mature; and, 4th, Put beside each other the quickly maturing kinds, which may be succeeded by other varieties, in order that the ground to be occupied by a second crop may be all in one piece.

The preliminaries being arranged, we are now ready to go into details, and to this end we shall first take under consideration the permanent bed, so called from the fact that it is to contain such perennials as asparagus, rhubarb, horse radish, artichoke, and chives; also parsley, and a collection of herbs, without which no garden is complete.

The herbs are placed here because they require a soil especially prepared for them, by the addition of either fine sand or sifted coal ashes, to make it mellow and dry.

[Illustration: DIAGRAM OF THE GARDEN.]

ASPARAGUS.

Asparagus, one of the best and earliest of spring vegetables, would be in universal use, but for the prevalent though erroneous idea that it is difficult to grow. Being a gross feeder, the soil can scarcely be too rich. Although the process of deep trenching is now being discarded, yet, to attain the best result it is necessary that a large quantity of rotted manure be worked into the bed, to a depth of at least 18 inches. Instead of losing two years' time by raising plants from seed, send and get strong two-year old plants early in spring. Set these in the prepared bed, 18 inches apart each way, and about six inches deep. Give frequent and thorough cultivation, and as soon as the tops are ripe in fall, cut off and burn them, to prevent the nuisance of seedling asparagus about the garden. Next spring, and for at least fifteen years after, the bed should give a full crop, and should have a heavy dressing of manure put on each fall, which should be spaded in before the shoots appear in spring, together with a sprinkling of three pints of salt per square rod.

To facilitate gathering, make the bed of such a width as that the centre can be reached from both sides. Cut all shoots as soon as they appear, till the time for the final cutting, which will vary from the middle of May to the middle of June, according to latitude and your fondness for this most delicious plant.

RHUBARB.

Rhubarb, known familiarly as _Pie Plant_, succeeds best in deep, somewhat retentive soil. Coming, as it does, before berries or fruit, its acid leaf stalks form an admirable substitute. It may be raised from seed, but to get the quickest returns procure strong roots in spring, and plant them three feet apart each way, the ground having first been fertilized and dug to a considerable depth. Never permit a plant to exhaust itself by seed-bearing; stir the soil often, cover with coarse litter in fall, fork it over in the following spring, and you may rely upon a good supply of pie plant for many years to come.

HORSE RADISH.

The best is grown by planting 8-inch lengths of root grown the previous year. These young roots planted in spring, small end down, with the top two inches below the surface, in rich, well-cultivated soil, will form radish of large size and superior quality, in one season's growth. After having several weeks' growth rub off the young side roots from the newly-planted roots, to increase the size and insure a smooth, well-shaped root. See to it that no roots are scattered about the garden, as every piece of root, however small it may be, will, in a short time, become a strong plant, difficult to eradicate, and thus prove how annoying a good thing is in the wrong place.

GLOBE ARTICHOKE.

The Globe Artichoke is cultivated for its flower heads, which are cooked like asparagus, in an undeveloped state. On account of its hardiness, easy culture and perennial nature, this plant should be more generally grown. Plants raised from seed sown the previous year, set in any good garden soil two feet apart, with slight covering in winter, will remain in bearing a long time.

JERUSALEM ARTICHOKE.

The Jerusalem Artichoke needs only to be planted in order to thrive. Its _tubers_ can be made into quite palatable pickles, and I have seen instances where, in the absence of cucumber pickles, the artichoke tuber was prepared the same way and used as a substitute.

CHIVES.

Chives are perfectly hardy perennial little members of the onion tribe, and are grown exclusively for their tops, which are used wherever the flavor of onion is required. Planted in small clumps in any common garden soil, they will grow readily, and in time increase so as to render a division necessary. The tops appear very early in spring, and can be shorn throughout the season, hence this valuable little plant should have a place in every garden.

PARSLEY.

As parsley seed is so obstinate about germinating in spring, it does better if sown in autumn, as soon as ripe. Where that is not possible, the seed may be sown in spring, but "don't look for the plants till you see them coming," since parsley seed just comes up when it feels like coming up, and not before. The plants should be given a moist, rich soil and a partly-shaded situation. The curled sorts are ornamental, but the plain-leaved is best for general use in cookery. When once established, a supply can easily be kept up from self-sown seed.[19]

AROMATIC HERBS.

Aromatic or _Sweet Herbs_ are worthy of more attention than they generally receive. If cooks used them more freely, doctors would have less occasion for prescribing them. The soil of the herb bed should be mellow and warm, but not over-rich. Deep, fertile soil produces an increase in size and foliage at the expense of fragrance, strength and flavor. The seeds should be sown as early in spring as the ground can be prepared.

Sweet Basil, _Summer Savory_, _Sweet Marjoram_, _Sage_ and _Thyme_ are grown for their foliage, which is used for seasoning, while _Sweet Fennel_, _Dill_, _Coriander_, _Anise_ and _Caraway_ are chiefly prized on account of their aromatic seeds. Aside from being useful for culinary purposes, most of the above-named plants possess valuable properties.

This completes the permanent bed.

Before proceeding any further I wish to have it understood that hereafter, in the course of this paper, all seeds advised to be sown broadcast are to be sown in long, narrow beds, with narrow walks between the beds, for convenience in gathering the crop and to protect the plants from being trodden upon.

Where sowing in drills is advised, it is likewise to be understood that all drills are to be not less than eighteen inches apart, and the cultivation between them to be done with a hand cultivator or wheel hoe, followed by hand hoeing between the plants if necessary.

Where planting in rows is recommended, it is intended that all rows, unless otherwise mentioned, should be not less than two and a half feet apart, to admit of the cultivation with a one-horse plow or cultivator, followed also by hand hoeing around the plants or hills.

Concerning the distance plants should be apart in the rows or otherwise, it may be safely said that each plant should stand so that when fully matured its outside leaves will just touch those of its nearest neighbor. This rule does not apply to onions and root crops, which may stand closer.

Concerning the best varieties of the different kinds of vegetables the reader is referred to the catalogues of reliable seedsmen. I shall recommend such varieties as I know to be good from personal experience.

PARSNIPS AND SALSIFY.

Alongside of the permanent bed, plant parsnips and salsify. Parsnip seed germinates slowly and quickly deteriorates by age, therefore early sowing and seed of unquestionable freshness are of primary importance. The subsoil should by all means be thoroughly loosened by the subsoil plow, unless it is naturally of a loose, friable texture. When it is borne in mind that parsnip roots grow wholly under ground, and when well grown measure over eighteen inches in length, the necessity for this will be seen at once. Sow in drills and thin to five inches apart. Parsnips may safely be left in the ground all winter, as frost greatly improves them in saccharine quality.

Salsify or oyster plant, as the name implies, possesses the flavor of the oyster to a marked degree, and is highly esteemed by many on this account. It should have the same treatment in every respect as directed for the parsnip, and like it, too, is improved by frost. In the ground adjoining the parsnips and salsify, plant such vegetables as lettuce, spinach, radish, peas, bush beans, onions, kohl rabi, early cabbage, cauliflower, early potatoes and sweet corn. These mature nearly in the order named, and in time enough to be succeeded by other vegetables which will be mentioned hereafter.

LETTUCE, SPINACH AND RADISH.

Seed of lettuce, spinach and radish should be sown broadcast and as early as possible, with later sowings at intervals of about two weeks for a successive supply. Soil for lettuce and spinach should be of more than ordinary richness, and should contain sufficient moisture to insure rapid continuous growth. The best lettuce heads are raised by sowing seed in a hotbed and transplanting to the open ground when plants are two inches high. Cabbage varieties should be selected for this purpose. In this way I have grown heads of the _New York Lettuce_ to weigh two pounds each, under ordinary treatment. _Hanson_, _Burpee's Golden Heart_ and _Perpetual Lettuce_ are all good sorts. The _Cos varieties_ do best if tied up a few days before using, to blanch all the inner leaves.

The Radish will thrive in any good garden soil, but a light sandy loam is better than heavily manured ground. In order to be crisp and tender, the growth should be rapid and unchecked. I can recommend _French Breakfast_, _Golden Globe_, _White Stuttgart_ and _Chartiers_. The latter is of unusual merit.

PEAS.

As we all want green peas as early as possible, the seed should be planted early--the earlier the better. Peas will bear a great deal of cold without the slightest injury, either in the ground or after they are up. Sow in drills at the rate of one pint of seed to thirty-five feet of drill. To keep up a succession make a sowing of an early, medium, and a late variety at the same time. In about two weeks make another sowing as before. Soil for early varieties should be warm and very rich. Late varieties should be planted deeper than early sorts, but the soil should not be so rich, as late varieties are more productive on moist, cool ground, not over rich. _Philadelphia Extra Early_, _American Wonder_ and _Telephone_ can be relied upon. After trying various methods for training pea vines I am satisfied that brush is the most effective support. Place a few short twigs or sticks on each side of dwarf peas, to prevent them from leaning over and decaying on the ground, as is often the case in a wet season.

DWARF OR BUSH BEANS.

Dwarf or bush beans should not be planted before danger from frost is over. Being very tender, nothing is gained by planting earlier. They may be planted in hills one foot apart, with four plants to the hill, but the better way, I think, is to plant in drills, with plants three inches apart in the drill.

Seed should be covered lightly with mellow soil. Beans often fail to come up, from being covered too deeply, especially if there is much rain after planting. Two plantings of both early and late varieties, at intervals of two weeks, will give a supply until pole beans come in season. Beans should never be hoed while the foliage is wet, as that produces rust. _Black Wax_, _Early Valentine_ and _Golden Wax_ are standard sorts.

ONIONS.

Onions may be raised successfully either from seed or from sets. If to be grown from seed no time should be lost in getting it sown in the spring. Sow in drills and thin the plants when about the size of quills, disturbing the remaining plants as little as possible. For southern latitudes and for an early supply it is better to grow onions from sets planted three inches apart, in drills. Sets are small onions grown the previous year, from seed sown quite thickly. Sets may be planted very early, as they will not be injured even if the

ground should freeze after they are planted. _Wethersfield_ and _Danvers_ are good varieties. For extra large specimens, select _Italian varieties_.

KOHL RABI, EARLY CABBAGE AND CAULIFLOWER.

Seed of kohl rabi, early cabbage and cauliflower should be sown in a hotbed, and the plants transplanted to the open ground when four inches high.

Kohl rabi is grown for its turnip-shaped bulb, which is formed above ground, by the expansion of the stem. The bulb should be used while young and tender, as age detracts from its good quality. Set the plants eight inches apart in the row. For later use sow seed in drills and thin to the proper distance apart. When well grown and properly prepared for the table, the kohl rabi is one of the most desirable of vegetables, and should be in every garden. _Early White Vienna_ is the best variety.

Plant early cabbage in rows, with plants eighteen inches apart in the row. After trying several different sorts I have decided upon _Early Jersey Wakefield_, _Early Flat Dutch_, and _Fottler's Brunswick_, as the best varieties for this latitude, and, as the cabbage worm has made late cabbage an uncertain crop for several years past here, in southern Illinois, we have planted largely of the Early Flat Dutch cabbage and had it picked and put up before the cabbage worm made its appearance. This I know, from experience, to be better than the use of all the insect powders combined.[20]

To grow cauliflower to perfection, the ground needs extra heavy manuring, and the plants must be supplied with an abundance of water as soon as heads begin to form. Plants should stand the same distance apart as early cabbage. The outside leaves should be pinned together over the centre, to shield the head from the direct rays of the sun, which often cause it to turn green, thus rendering it inferior in quality or entirely unfit for use. _Early Snowball_ and _Erfurt_ are both good and reliable. Nowhere does success depend more on the quality of the seed than in the cauliflower.

SWEET CORN.

Sweet corn should be planted as soon as the ground is reasonably warm, in hills, three feet apart, three plants to a hill. The season for sweet corn can be greatly prolonged by planting early and late sorts, at intervals of a few weeks. There are many good early kinds, but I think the best late variety is _Stowell's Evergreen_, which produces ears of the largest size, that remain in a condition fit for the table longer than those of any other variety of sweet corn.

POTATOES.

If you wish to enjoy new potatoes early in the season, your seed potatoes must be planted as early in the spring as the ground can be prepared. Plant them one foot apart in the row and cover with the corn plow. I would advise the planting of medium-sized potatoes in preference to large ones cut to pieces. If large ones must be used cut them a few days beforehand, so that the newly cut surface may dry before planting, otherwise, there is danger of the pieces rotting in the ground, especially if there is much rain immediately after planting. The _Early Ohio_ gave us excellent returns for several years in succession.

* * * * *

We will next take under consideration that portion of the garden devoted to the vegetables requiring the greater part of the season to mature. The most important of these are:--

EGG PLANTS, TOMATOES, POLE BEANS, BEETS, CARROTS, LATE CABBAGE, CUCUMBERS, SQUASHES AND SWEET POTATOES.

Sow Egg Plant and Tomato seed in a hotbed and remove the young plants to a cold frame when three inches high, from whence do not remove them till the weather is settled and warm.

Egg Plant will repay the extra care it requires, and should be in every garden. Handle the plants very carefully in transplanting, and never remove them to the open ground before the nights are warm. At the North plants may be grown in flower pots plunged in a cold frame till the weather is sufficiently warm. Plants should stand 2½ feet apart in the row, and the soil should be very rich and warm. _New York Purple_ is the leading variety, but those who succeed with the _Black Pekin_ cannot fail to be pleased with its large, glossy fruits.

When all danger from frost is over, carefully transplant the Tomato plants from the cold frame to the open ground, to stand two feet apart in the row. As they grow tie them up on a trellis and remove all superfluous branches, so as to give the growing fruit the benefit of full sunshine, without which it will be of inferior quality and scarcely worth the having.[21] Nothing can be worse than allowing tomato plants to grow along the ground at will without any support. Better it would be not to grow any at all than to degrade them in that manner. Make a small trellis, four feet high, by nailing a few pieces of lath across small stakes driven into the ground. I regard _Livingston's Perfection_ as an excellent variety, and have grown extra large specimens of the _Mikado_, which, by the way, seems to have been cast in the same mold as the _Turner Hybrid_.[22] Be this as it may, I can heartily recommend either variety to all wishing to grow fine, solid, enormous-sized tomatoes.

POLE BEANS, as the name implies, require poles or some other support for the vines to twine upon. The poles must be set firmly, to prevent being blown over by the wind. Where poles are not procurable, the vines may be trained upon strings stretched up and down along two wires, which are stretched and firmly fastened to posts or stakes, one wire above and the other below. Pole Bean trellis, seven feet high, can be purchased, and will answer the purpose for which they are intended. The best pole bean of its kind is the _Large White Lima_. Being very tender, it should not be planted before the ground is warm. The beans will come up sooner if the eye in the seed is placed downward. The seed should be lightly covered with mellow soil, as this bean, considering its size, has less penetrating power in coming up than any other kind. In rainy seasons I have covered the seed with coffee grounds, which never became compact or hard from the beating rains, and nearly every bean came up nicely, while those covered with earth were almost a total failure.[23] The Large White Lima is generally considered difficult to grow, but I cannot say so, as I have grown it without much difficulty, and had beans to perfection by the pailful throughout the summer. Mine were planted in very rich soil and the rows were about four feet apart, three plants to a hill, and the hills two feet apart. If supported by a trellis, beans should be placed one foot apart in the row. The above applies to all pole beans, whether Limas or string beans. Of the latter class of beans I have found _White Creaseback_ a variety of great merit. _Southern Prolific_ and _Dutch Case Knife_ are also good. At the North, where the seasons are too short for the Large Lima, the _Small Lima_ or _Sieva_, as it is also called, should be planted.

Sow BEET and CARROT seed as early in spring as possible. Sow in drills and thin beets to five inches and carrots to three inches apart in the drill. To have Beets early we sometimes sow seed of an extra early variety in the hotbed and transplant to the garden when plants are a few inches high. The same may be done with early carrots. Sow _Early Scarlet Horn Carrot_ for early use and _Long Red Coreless_ for fall and winter. _Eclipse_ is one of the best early Beets and _Long Blood Red_ is the very best late variety.

Sow late CABBAGE seed in a seed bed, when danger from frost is over, and when plants are three inches high, plant them in rows three feet apart, with plants 2½ feet apart in the row. _Late Flat Dutch_, _Burpee's Surehead_ and _Large Late Drumhead_ are reliable sorts.

CUCUMBER and SQUASH seeds should under no consideration be planted before the weather is settled and warm, as the young plants are extremely tender and sensitive to cold. Cucumber hills should be four feet apart each way, and squash hills should be six feet apart. Scatter about a dozen seeds in a hill, and when the second pair of leaves have formed, remove all but three of the strongest plants. No fruit should be permitted to ripen on cucumber vines, as this greatly weakens the plant and prevents it from further setting fruit. Pinching off the tips of winter squash vines when they are about three feet long increases their productiveness. _Early Green Cluster_, _White Spine_, and _London Long Green_ are good varieties of cucumbers. The list of desirable squashes is long, but whoever grows the _Pineapple_ and the _Brazil Sugar Squash_ for early use, and the _Essex Hybrid_ and _Hubbard_ for winter use, will not be disappointed.

The term "hills," as used here and elsewhere in this paper, does not imply heaped-up soil, but simply means that several seeds are to be planted together in one place, on a level with the rest of the ground. This I have found to be better than heaping up the ground to form hills, which soon dry out and are difficult to water.[24]

The only plant requiring hills or ridges is the SWEET POTATO. Throw several furrows together with a plow and draw the soil up with a hoe, to form a tapering ridge; two feet high and three feet wide at the bottom. The plants, which are obtained by planting the tubers in a hotbed, are planted two feet apart on top of this ridge. Being of tropical origin, the sweet potato plants should never be planted till danger from frost is over. One hoeing is generally sufficient, as the vines soon cover the ridge, but these should not be allowed to take root, as that diminishes the productiveness of the plant. Late varieties are of better quality than the early ones.

PEPPERS, GUMBO AND LEEKS.

No garden is complete without at least a few plants of peppers, gumbo and leeks. To grow PEPPERS to perfection, the young plants should be grown in the hotbed and be transplanted to very rich soil, from twelve to eighteen inches apart, according to variety. When they commence blooming, a liberal quantity of hen manure should be strewn around each plant and be hoed in. This will increase the product wonderfully. _Burpee's Ruby King_ and _Golden Dawn_ are two superb new varieties.

GUMBO, or OKRA, is grown for its seed pods, which are used in soups and stews. Plant the seed eighteen inches apart, when the ground is warm, in spring, and use the pods while young and tender.

Sow LEEK seed very early, in a seed bed, in a sheltered place, if possible. When plants are about six inches long, transplant them to trenches six inches deep, with very rich soil at the bottom. Fill up the trenches as the plants grow, and later draw soil up to them. As a result, you will have fine, large leeks, blanched a foot long, which may be kept all winter if dug up with the roots on, and stored in moist sand in the cellar. Aside from being valuable for soups and salads, blanched leek makes an excellent dish when sliced and cooked like green peas. This fact does not seem to be generally known, as well-grown leek is so seldom seen in kitchen gardens.[25]

We will now go back again to the ground adjoining the parsnips and salsify. The early vegetables will mature and be harvested one after the other, so that there will be enough vacant ground in time for--

CELERY, ENDIVE, TURNIPS, WINTER RADISHES, KALE, CORN SALAD, WINTER LETTUCE AND WINTER SPINACH.

Sow CELERY seed in a hotbed or cold frame. When a few inches high, plant five inches apart, in a bed, in the open ground, which should be especially prepared for the purpose by extra heavy manuring. Let the plants remain in this bed, to grow strong and stocky. Never let the ground in this bed become dry; give thorough cultivation and cut off the tops of the plants once or twice, to make them grow stocky. When six or eight inches high, lift the plants carefully and set them six or eight inches apart, in trenches a foot wide and fourteen or more inches in depth. Several inches of rotted stable manure should be mixed with the soil at the bottom of the trench. When planting, firm the ground well around each plant. Supply enough water to keep the ground at the bottom of the trench very moist all the time. As the plants grow, press soil around the bottom of each plant and tie together at the top with string, to keep the stems straight and in an upright position. The blanching or earthing up is done by gradually filling up the trench with ground as the plants grow. Care should be taken not to get any ground into the hearts of the plants and never to earth up while they are wet. Sowing seed in the open ground and growing plants on the level surface may do for cool northern latitudes, but my experience is that it will not do here in southern Illinois. _Boston Market_ and _Crawford's Half Dwarf_ are as good as any of the taller varieties, and are more easily blanched.[26]

Seed of ENDIVE should not be sown early, as this plant is grown chiefly for late summer and autumn salad. In this latitude we sow at intervals from the middle of June to the 1st of August. Seed may be sown either broadcast or in drills, but the plants should be thinned so as to stand from six to nine inches apart. It may also be sown in a seed bed and be transplanted to the proper distance apart. When the plants are full grown, tie all the outside leaves together over the heart, to blanch the inner leaves, which will take about a week. To keep up a constant supply, some should be tied up every few days. Never tie up when the leaves are wet or they will soon decay. _Green Curled_ and _Batavian_ are both very good.[27]

TURNIP and winter RADISH seed may be sown from the latter part of July to the middle of August. If the ground is reasonably free from weed seeds it is advisable to sow broadcast, otherwise it is better to sow in drills. In either case, it is well to remember that the plants should be, like the first settlers, without a near neighbor. The size and quality of the turnips and radishes will depend, to a great extent, upon thin sowing of the seed, or, what is still better, a judicious thinning of the plants when young. The largest and sweetest turnips we have ever grown were of the _Purple Top Strap-leaved_ variety, and were grown as a second crop after onions. The seed was sown broadcast, and no further attention given the plants except thinning while young. In the same manner and on similar soil we raised _White_ and _Black Spanish_ winter radishes of excellent quality, that weighed from four to seven pounds each. The _Chinese Rose_, though not so large, is the handsomest and one of the best winter radishes grown. The _California Mammoth_ is a superb fall radish, but does not keep well in winter. The _White Stuttgart_ is regarded as a summer radish, but I have had it, grown as a winter radish, to keep firm and solid till April.

KALE, or BORECOLE, is a valuable plant for spring greens. The variety called _Dwarf German Greens_ is best for this purpose. Sow seed in drills about September 1st, and give thorough cultivation till the approach of cold weather. When winter sets in, give protection with a covering of straw or similar material, put on so as not to smother the plants. The most effective way of doing this is to place a layer of fine brush or cornstalks between the drills, to a height equal to or exceeding the height of the plants in the drills.

Then cover all with a layer of clean straw, six inches deep. The object of putting the brush between the drills is to provide an air cavity between the plants and the covering.[28]

CORN SALAD, or VETTICOST, is a valuable little plant which is used for salad, the same as lettuce. For spring use, sow the seed any time during the month of September, and at the approach of cold weather cover the bed with a few inches of straw or hay. It should be used very early in spring, as it soon runs to seed when warm weather sets in. Although this plant will bear neglect, it will also repay good treatment.

Seed of winter SPINACH and winter LETTUCE should also be sown during the month of September, and the plants should be protected with a covering of straw, or similar material, during winter. Put on part of the covering when the ground begins to freeze, and as the cold increases, add covering till it reaches a depth of four or five inches. In regions where heavy snowfalls can be depended upon, it may not be necessary to protect any of the above-named plants, but here and elsewhere, where winters are severe and the snowfall light, it is of the utmost importance to provide protection, or no success need be expected. _Hammersmith_ is the best winter lettuce, and _Round Leaf_ and _Prickly Winter_ are two good varieties of spinach for fall sowing.

The beds of kale, corn salad, winter lettuce and winter spinach should be arranged side by side, and alongside of the parsnips and salsify, so as not to interfere with the plowing of the ground in fall and in spring. As some of the parsnips and salsify will be left in the ground to be dug at leisure in spring, it is best to have all these vegetables side by side, so that when the parsnips and salsify[29] are dug, and the crop of kale, corn salad, etc., harvested, the whole ground can be plowed at once.

Before closing, a few words in regard to watering and transplanting may not prove amiss.

The best time for watering is in the evening. Though water may be given to the roots at any time, it should never be sprinkled on the foliage in the hot sun, as that causes brown spots or blisters where it comes in contact with the leaves. More injury than good results from beginning to water a plant, and then not keeping it up till the necessity ceases. As soon as the ground begins to get dry after watering, the soil should be stirred with the hoe. When you start to water a plant, do it thoroughly, so as to give the roots a soaking at every watering, or else do not water at all.

The main points to be regarded in transplanting, are handling the plant carefully, so as to injure the roots as little as possible, planting firmly and shading to prevent the sun from withering or scorching the leaves. It should be borne in mind, that it is not nature's design that a plant should be transplanted, and we ought to show sympathy for a plant as well as for our fellow-creatures.

And now, having taken a walk with you through the kitchen garden, all I have further to say is, may you be favored with seasonable rain and sunshine, for, be it remembered, without the co-operation of the elements all our efforts are in vain.

INDEX.

Aromatic herbs, 176.

Artichoke, Globe, 175. Jerusalem, 175.

Asparagus, 40, 173. varieties of, 43. Barr's Mammoth, 43. Conover's Colossal, 43. Purple Top, 43.

Beans, 43. Bush Beans, 46, 180. Best of All Dwarf Bean, 46. Black Wax, 180. Burpee's Perfection Wax, 44. Champion Bush Bean, 48. Early Valentine, 180. Golden Wax, 46, 180. Limas, 50. Dreer's Improved Lima, 50. Extra Early Lima, 50. King of the Garden, 50. Pole Beans, Snap Varieties, 48, 185. Burpee's White Zulu, 48. Dutch Case Knife, 186. Golden Wax Flageolet, 48. Large White Lima, 185. Lazy Wife's, 48. Southern Prolific, 186. White Creaseback, or Best of All, 48, 186.

Beets, 51. varieties of, 52. Burpee's Improved Blood Turnip, 54. Eclipse, 52, 187. Edmand's Early Turnip, 52. Long Blood Red, 187.

Blackberries, 161. Gregg Black Cap, 161. Wilson, Jr., 161. Wilson's Early, 161.

Borecole, 192.

Cabbages, 54. Early or Summer, 54, 181. Early varieties of, 61. Early Flat Dutch, 181. Early Jersey Wakefield, 61, 181. Early Summer, 61. Extra Early Etampes, 61. Extra Early Express, 61. Fottler's Brunswick, 181. Vandergaw, 61. Late or Winter, 55. Late varieties of, 61. Burpee's Surehead, 61, 187. Danish Ball Head, 63. Large Late Drumhead, 187. Late Flat Dutch, 187. Short-stem

Drumhead, 63.

Cantaloupe, or Musk Melon, 69. varieties of, 72. Burpee's Netted Gem, 72. Emerald Gem, 72. Montreal Green Nutmeg, 74.

Carrots, 67. varieties of, 67. Danvers Half-long Orange, 67. Early Very Short Horn, or Golden Ball, 68. Ox Heart, 68. Red Saint Vallery, 69. Short Horn, 67.

Cauliflower, 65, 181. varieties of, 66. Burpee's Best Early, 67. Early Snowball, 66, 182. Extra Early Dwarf Erfurt, 66, 182.

Celery, 74, 189. varieties of, 80. Boston Market, 190. Crawford's Half Dwarf, 190. Crimson or Red Celery, 82. Dwarf Golden Heart, 81. Golden Self-blanching, 81.

Celery, White Plume, 82.

Chicorée, 191.

Chives, 175.

Cold frames and hotbeds, 21.

Compost, 166.

Corn Salad, 192.

Corn, Sweet, 83, 182. varieties of, 85. Amber Cream, 86. Crosby's Early Twelve-rowed, 86. Potter's Excelsior, 86. Stowell's Evergreen, 86, 182. The Cory, 85.

Cucumbers, 87. varieties of, 89. Burpee's Giant Pera, 89. Early Green Prolific, 89, 187. Early Russian, 89. Improved Early White Spine, 89, 187. London Long Green, 89, 187.

Currants, 159.

Dewberry, Lucretia, 161.

Diagram of the garden, 15, 16, 172. Key to the, 17.

Dwarf or Bush Beans, 180.

Early or Summer Cabbages, 54.

Egg Plant, 91, 183. varieties of, 94. Black Pekin, 184. Extra Early Dwarf Round Purple, 94. New York Improved Large Purple, 94, 184.

Endive, 191. Batavian, 191. Green Curled, 191.

Garden, diagram of the, 15, 16. laying out the, 12. planting the, 35. situation of the, 9. soil of the, 11.

Globe Artichoke, 175.

Gooseberries, 159.

Grapes, 163.

Gumbo, 188.

Hammond's Slug Shot, 91.

Hops, 95.

Horse Radish, 94, 174.

Hotbeds and cold frames, 21.

Jerusalem Artichoke, 175.

Kale, or Borecole, 192. Dwarf German Greens, 192.

Key to diagram, 17.

Kohl Rabi, 181, 189. Early White Vienna, 181.

Late or Winter Cabbages, 55.

Laying out the garden, 12.

Leeks, 188, 189.

Lettuce, 96, 178, 193. varieties of, 100. Burpee's Golden Heart, 179. Burpee's Hard-Head, 100. Burpee's Silver Ball, 101. Burpee's Tomhannock, 100. Cos, 179. Hammersmith, 193. New York, 179. Perpetual, 179. Philadelphia White Cabbage, 102. Stonehead Golden Yellow, 101. The Deacon, 102. The Hanson, 102, 179. The Tennis Ball, 102.

Lucretia Dewberry, 161.

Manure, 167.

Musk Melon, 69.

Okra, 102, 189.

Onions, 103, 180. varieties of, 108. Large Red Wethersfield, 109, 181. White Globe, 109. White Silverskin, or White Portugal, 109. Yellow Globe Danvers, 108, 181. Italian varieties of, 110, 181. Burpee's Mammoth Silver King, 112. Earliest White Green, 111. Giant Red Rocca, 110. Giant Yellow Rocca, 111.

Parsley, 112, 176. Extra Curled Dwarf, 113.

Parsnips, 113, 178.

Parsnips, varieties of, 115. Improved Guernsey, 115.

Peas, 115, 179. varieties of, 117. American Wonder, 118, 180. Burpee's Extra Early, 117. Burpee's Quality, 120. Burpee's Quantity, 120. Champion of England, 120. Extra Early Premium Gem, 118. Laxton's Earliest of All, 118. Laxton's Evolution, 119. Philadelphia Extra Early, 180. Pride of the Market, 118. Telephone, 180. The Stratagem, 119.

Peppers, 121, 188. varieties of, 122. Bull Nose and Golden Dawn, 123, 189. Burpee's Golden Upright, 123. Burpee's Ruby King, 122, 189. Celestial Pepper, 124. Long Narrow Cayenne, 124. Procopp's Giant, 124. Red Cluster, 123. Spanish Monstrous, 124.

Pie Plant, 174.

Planting the garden, 35.

Pole Beans, 185.

Potatoes, 133, 183. Early Ohio, 183. Sweet, 135, 188.

Procuring the seeds and plants, 15.

Pumpkins, 125. varieties of, 126. Golden Marrow, 126. Quaker Pie, 126. Saint George or Old Negro, 126. Small Sugar, 126.

Radishes, 126, 178, 191. varieties of, 128. Burpee's Earliest, 128. California Mammoth White Winter, 128, 192. Chinese Rose Winter, 128, 192. Earliest Carmine, Olive-shaped, 130. Early Long Scarlet Short Top. 129. Early Oval Dark Red, 130. Early Round Dark Red, 130. Early White Turnip, 130. French Breakfast, 130, 179. Half Long Scarlet, 130. Round Black Spanish Winter, 128, 192. White-tipped Turnip, 130. Wood's Early Frame, 130. Summer varieties of, 131. Burpee's Surprise, 132. Chartiers or Shepherd, 132, 179. Giant White Stuttgart, 131, 179, 192. Golden Globe, 131, 179. Long White Globe, 132. Long White Vienna, 131. White Strasburg, 132. Winter varieties of, 132. California Mammoth White, 132, 192. Chinese Rose, 133. White Spanish, 192.

Raspberries, Black Cap and Red, 161. Philadelphia and Cuthbert, 161.

Rhubarb, 159, 174.

Sage, 136, 176.

Salad, Corn, 193.

Salsify, 178.

Saving seeds, 167.

Seeds and plants, procuring the, 15.

Situation of the garden, 9.

Slug Shot, Hammond's, 91.

Small Lima, or Sieva Bean, 186.

Soil of the garden, 11.

Spinach, 136, 178, 193. varieties of, 137. New Long Standing, 138. New Thick-leaved Round, 137, 193. Norfolk Savoy-leaved, 137. Prickly Winter, 193.

Squashes, 138. Summer varieties of, 140. Brazil Sugar, 187. Early White Bush, or Patty-Pan, 140. Golden Summer Crookneck, 140. White Pineapple, or White Turban, 140, 187. Winter varieties of, 141. Essex Hybrid, 141, 187. Hubbard, 142, 187.

Strawberries, 164.

Summer Cabbages, 54.

Sweet Corn, 83, 182.

Sweet Herbs, 176. Anise, 176. Caraway, 176. Coriander, 176. Dill, 176. Sage, 176. Summer Savory, 176. Sweet Basil, 176. Sweet Fennel, 176. Sweet Marjoram, 176. Thyme, 176.

Sweet Potato, 135, 188.

Tomatoes, 142, 183. varieties of, 146. Burpee's Cardinal, 146. Burpee's Climax, 148. Essex Early Hybrid, 148. Extra Early Advance, 146. Golden Queen, 149. Livingston's Perfection, 184. Mikado, 184, 185. Pear-shaped Yellow, 151. Red Cherry, 157. Turner Hybrid, 149, 185. Victoria, 151. White Apple, 151.

Tools, 29. Cultivator, 31. Fire-fly hand plow, 33. Hand hoes, 35. Harrow, 30. Plow, 29. Roller, 31. Seed drill, 34. Shovels, 35. Spades, 35. Steel rakes, 35. Trowels, 35. Wheel hoe, 32.

Turnips, 151, 191. varieties of, 153. Early Red, or Purple Top Strap-leaved, 153, 192. Early White Flat Dutch, 153. Extra Early Purple Top Milan, 154. White Egg, 154.

Vetticost, 192.

Watermelons, 154. varieties of, 156. Burpee's Mammoth Ironclad, 156. Cuban Queen, 158. Hungarian Honey, 156. Ice Cream, 159. Icing, or Ice Rind, 157. Jordan's Gray Monarch, 159. Kolb's Gem, 158. Phinney's Early, 159.

Winter Cabbages, 55.

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FOOTNOTES:

[1] Miss Moll says that this rusting can be prevented by only hoeing the beans when the soil is dry. We would also particularly recommend _Burpee's Perfection Wax_, a fine new variety, that has so far proved free from rust.--ED.

[2] See the method of covering the seed of Lima beans described by Miss L. M. Moll, and our note on the same.--ED.

[3] We would also particularly recommend _Burpee's White Zulu_, a new variety of 1888. It is one of the earliest of pole beans, immensely productive, and the broad, handsome, white pods, eight to ten inches long, are of the choicest quality.--ED.

[4] The _Extra Early Express_, a new variety, just introduced from France, and seed of which we distributed for trial this year, has proved _eight to ten days earlier_ than the Etampes. The heads do not average quite as large as the Etampes, but are of equally as good quality and of the shape shown in the illustration on page 60.--ED.

[5] For years, Mr. Vandergaw, a large cabbage grower of Long Island, has had a _second-early_ cabbage fully as early as Early Summer and with much larger heads. This is known as _the Vandergaw Cabbage_, and is only now being generally introduced. The heads are very large and solid, of the shape shown in the illustration on page 64; it is a good keeper, and altogether a good variety, also, for winter use.--ED.

[6] Other distinct and good varieties of American onions are _Southport Yellow Globe_ and _Large Red Globe_, _Yellow Strasburg or Dutch_, and the _Extra Early Red_. For more complete information, invaluable to all who propose growing onions on a large scale for market, see the new book, "HOW TO GROW ONIONS, WITH NOTES ON VARIETIES," an exhaustive treatise written by T. Greiner, of New Jersey, Col. A. H. Arlie, of Oregon, and W. Atlee Burpee.--ED.

[7] Equally as early is _Laxton's Earliest of All_, which is a blue-seeded variety, of very fine quality and handsome appearance.--ED.

[8] The _Stratagem_ is also a remarkably fine pea, of the same type as _Pride of the Market_, except that the large, handsome peas are _wrinkled_.--ED.

[9] Mr. Darlington's remarks on the varieties of peas would be incomplete without reference to two remarkable new peas, obtained by crosses made some years since, but only now (1888) being introduced. These peas have been called _Burpee's Quantity_ (which is illustrated above), and _Burpee's Quality_,--the former because it is the most productive of all, as many as ninety pods having been counted upon a single vine--the latter, because, while also very productive, it excels other varieties in its peculiarly rich, sugary flavor. Both varieties grow two and a half feet high, but will well repay brushing, and both are main-crop peas,--Burpee's Quantity being ready for the table in about two months, and Burpee's Quality in seven weeks from planting.

Probably no one in America is better posted as to the relative value in the garden of the different peas than MR. WILLIAM FALCONER, Glen Cove, N. Y., the well-known writer on garden topics. A few peas of Burpee's Quantity (then known as No. 75) were sent to Mr. Falconer for trial. On Oct. 28th, 1887, he writes, "The pea, No. 75, I had from you this year has given me much satisfaction; indeed, so well pleased am I with it that I wish to grow it next year as a main crop. Season medium to late, grows two and a half feet, and in the way of Abundance; peas large, closely packed together in tight pods, and, when cooked, of capital quality. _Without any exception, the heaviest cropper among all my peas this year._"--ED.

[10] A very distinct and novel variety has just been introduced from China, under the name of _Celestial Pepper_. The small, nearly heart-shaped fruits are produced in great abundance, growing upright, and are of a beautiful creamy yellow color until fully ripe, when they turn coral red: the plant is handsome enough for the flower garden. Among the largest of the sweet, mild red peppers are _Spanish Monstrous_ and _Procopp's Giant_, while among the hottest of all peppers is the _Long Narrow Cayenne_.--ED.

[11] While both of the varieties named are excellent for pumpkin pies, a new variety from Washington County, New York, is of superlatively fine quality. It is known as _The Quaker Pie Pumpkin_, as it had been kept for many years in a family of "Quakers," or Friends, whose pumpkin pies became famous throughout the neighborhood.

The _Saint George_ or _Old Negro_ pumpkin of New England is also a great favorite, from the choice quality of its fine-grained flesh.--ED.

[12] We must differ with Mr. Darlington as to the usefulness of the winter radishes. Their fresh, pungent taste is very refreshing in winter, when there is such a scarcity of vegetables. The most popular varieties are the _California Mammoth White Winter_, _Chinese Rose Winter_ and the _Round Black Spanish Winter Radish_.--ED.

[13] For forcing, _Wood's Early Frame_ is preferred to the Long Scarlet; it is of same shape, but not so long, and has less foliage. Other good early radishes besides those named are _Early Round Dark Red_, _Half Long Scarlet_, _Early Oval Dark Red_, _Early White Turnip_, _French Breakfast_ and the _White Tipped Turnip Radishes_. A variety of these handsome little radishes on the table is both attractive and appetizing.--ED.

[14] In addition to the varieties named, the _White Strasburg_, _Burpee's Surprise_ and _Chartiers or Shepherd_ radishes are particularly valuable for summer use. The latter is very handsome, of large shape, clear rose color, shading off into pure white; it is also remarkable from the fact that it retains its fine quality, even when grown to an extraordinary size.--ED.

[15] Mr. Darlington has only named some of the best of the large varieties of tomatoes. The very small tomatoes, such as _Victoria_, _Red Cherry_, _Pear-shaped Yellow_ and _White Apple_, will be found useful and ornamental for preserving.--ED.

[16] In addition to the varieties named, we would recommend _Phinney's Early_, as probably the best early melon of good size; also the _Ice Cream_ and _Jordan's Gray Monarch_, as very choice melons of oblong shape.--ED.

[17] While, as stated, a well-drained soil is most desirable for the garden, and its value is not to be underrated, yet success in gardening can be had on almost any soil. The more unfavorable the circumstances, the greater credit is due the gardener, and many cannot afford expensive underdraining.--ED.

[18] The suggestion as to applying manure in the spring is good, as far as the well-drained land is concerned; where the land is not well-drained, however, more of the good properties of the manure are retained by applying the coarse manure in the fall, as it then fills the soil with decomposing vegetable matter.--ED.

[19] The parsley seed will germinate quickly if soaked in tepid water for twenty-four hours before planting. We must also take exception to the statement that the plain-leaved sorts are superior to the curled varieties for seasoning purposes.--ED.

[20] The reason here presented for not growing late cabbage, because the worms might damage some of them, is quite original, and about equal to not planting any potatoes, because the bugs might eat the tops. We can hardly conceive of a garden, however small, without late cabbage. For the prevention of the ravages of this pest we would suggest the use of alum water, as being sure, easily applied and entirely harmless to the user.--ED.

[21] It is the extreme richness of the soil, which is claimed by Miss Moll to be requisite to the growth of the Tomato, that, in her case, renders the use of the trellis and pruning necessary, as it induces too rank a growth of vine, covering the ground so that the sun and air cannot penetrate unless the vines are tied up. We can hardly see any _degradation_ in allowing the plant liberty to grow in the manner intended by nature. More than this, as seedsmen, we pride ourselves on the new and improved varieties of Tomatoes that we have introduced, and the finest we have ever grown--finest alike for size, color, quality and productiveness--have been grown on poor clay soil, that looked fairly yellow when at all dry, and we have never been able to equal them on either rich heavy loam, or on light soils. We would not undervalue the tying up of a few plants for early use, but claim that it is unnecessary for the general crop.--ED.

[22] As stated, these Tomatoes were undoubtedly originated from the same stock. We received the Turner Hybrid in the spring of 1884, a small packet of seed being sent us by one of our customers--Mr. J. W. Turner, of Iowa. This seed we had planted, and were surprised at the wonderful growth, size and quality of the variety, but unfortunately there were two distinct colors: some were a rich deep red and some a pale pink, of a not very attractive shade. So we grew it carefully for another season before sending out, that we might have them all of the best color. This, we believe, is not the case with the _Mikado_, as in our trial the two colors were present, although they both are evidently of the same origin.--ED.

[23] This idea of a mulch of light material to cover the freshly planted beans in a wet season is a very good one; but we would think that saving and applying _Coffee Grounds_ for a bean patch of the size it should be in a garden of one acre, would be a good deal like “emptying a hogshead of water with a teaspoon.” We would suggest the use of sand, sifted coal ashes, chaff or buckwheat hulls, as answering the purpose equally well, and as being much more readily obtained.--ED.

[24] We think that the melons, cucumbers, etc., get a better start (and we would include the pole beans) when the hill for seed is raised slightly above the surface, as it greatly lessens the danger of the young seedlings “damping off,” and instead of the watering, which is here claimed to be necessary, we would suggest a thorough loosening of the soil around the roots.--ED.

[25] Leek is both wholesome and palatable. We heartily endorse the words of recommendation, and trust that many readers will include it in their gardens. Kohl Rabi is another vegetable but little known in America, and which Miss Moll is also fully warranted in recommending.--ED.

[26] The plan here described involves much unnecessary labor. It takes considerable time to dig the trenches, and, unless the soil of the garden were unusually deep, this depth of trench, fourteen inches, would bring up and mix with the surface a great deal of very poor subsoil. As rich soil cannot be found at this depth, a liberal supply of manure must be put down, for the roots to feed upon, where it will not be available for any future crop, unless the trenches were located in exactly the same spot each year. The increase in the labor of digging for storage would be considerable over the plan of surface culture as recommended in Mr. Darlington’s treatise. Miss Moll gives as a reason the greater heat in her locality, to overcome which we would suggest planting between rows of tall-growing sweet corn, and also recommend the use of some of the self-blanching varieties of celery.--ED.

[27] Endive, commonly known in restaurants as _Chicorée_, is one of the most attractive and refreshing of salads. It is particularly appetizing when served mixed with lettuce, with plain French dressing.--ED.

[28] This is also sown at the same time as late cabbage, and grown in the same manner, being used as a fall and winter supply of greens, and we think is most palatable in this way.--ED.

[29] In this locality (Philadelphia), parsnips and salsify will start into growth, and become worthless for the table if left in the ground after it has become possible to work it in the spring. For a late supply, the roots should be dug and stored in a very cool cellar. This method does not interfere with the garden being all thoroughly plowed in the spring.--ED.

Transcriber's Notes:

1. Obvious printers', punctuation and spelling errors have been corrected silently.

2. Some hyphenated and non-hyphenated versions of the same words have been retained as in the original.

3. Superscripts are represented using the caret character, e.g. D^r. or X^{xx}.

4. Italics are shown as _xxx_.

5. Bold print is shown as =xxx=.

==========

The laws of contrast of colour

M. E. Chevreul

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Underscores "_" before and after a word or phrase indicate _italics_ in the original text. Equal signs "=" before and after a word or phrase indicate =bold= in the original text. Small capitals have been converted to SOLID capitals. Illustrations have been moved so they do not break up paragraphs. Deprecated spellings have been preserved. Typographical and punctuation errors have been silently corrected. For the lines 788 to 888, the quote marks have been replaced with the actual text so that the lines can be broken up to fit within the 72 column width requirement.

[Illustration: PLATE IX.]

THE LAWS OF CONTRAST OF COLOUR:

AND THEIR APPLICATION TO THE ARTS OF PAINTING, DECORATION OF BUILDINGS, MOSAIC WORK, TAPESTRY AND CARPET WEAVING, CALICO-PRINTING, DRESS, PAPER-STAINING, PRINTING, MILITARY CLOTHING,

Illumination, Landscape, and Flower Gardening, &c.

BY M. E. CHEVREUL,

DIRECTOR OF THE DYE WORKS OF THE GOBELINS, ETC. ETC.

TRANSLATED FROM THE FRENCH BY JOHN SPANTON.

NEW EDITION,

With Illustrations printed in Colours.

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1861.

CONTENTS.

PAGE INTRODUCTION 1

PART THE FIRST.

SECTION I.—ON THE LAW OF SIMULTANEOUS CONTRAST OF COLOURS, AND OF ITS DEMONSTRATION BY MEANS OF EXPERIMENT 4 CHAP. I.—Manner of observing the Phenomena of the Simultaneous Contrast of Colours. Definition of Simultaneous Contrast 4 CHAP. II.—The Law of the Simultaneous Contrast of Colours, and the Formula which represents it 8 CHAP. III.—The Law of Simultaneous Contrast of Colours demonstrated by the Juxtaposition of a certain Number of Coloured Bodies 10 CHAP. IV.—On the Juxtaposition of Coloured Surfaces with White 18 CHAP. V.—On the Juxtaposition of Coloured Bodies with Black 19 CHAP. VI.—On the Juxtaposition of Coloured Bodies with Grey 21 CHAP. VII.—On the Juxtaposition of Coloured Bodies belonging to the Colours of the same Group of Coloured Rays 24 CHAP. VIII.—On the Application of the Law of Contrast to the Hypothesis that Red, Yellow, and Blue are the only Primary Colours; and that Orange, Green, Indigo, and Violet are Secondary or Composite Colours 25

SECTION II.—ON THE DISTINCTION BETWEEN SIMULTANEOUS, SUCCESSIVE, AND MIXED CONTRAST OF COLOURS, AND ON THE CONNEXION BETWEEN THE EXPERIMENTS MADE BY THE AUTHOR, AND THOSE PREVIOUSLY MADE BY OTHER OBSERVERS. DISTINCTION BETWEEN SIMULTANEOUS, SUCCESSIVE, AND MIXED CONTRAST OF COLOURS 29

PART THE SECOND.

ON THE APPLICATION OF THE LAW OF SIMULTANEOUS CONTRAST OF COLOURS 34 Introduction 34 Definition of the words Tones, Scales, and Hues 34 Of Diagrams designed to represent and define Colours and their Modifications 36 Harmony of Colours 46 Assortments of Red, Orange, Yellow, Green, Blue, and Violet with White, Black, and Grey 49 Colours with White 50 Colours with Black 54 Colours with Grey 58

FIRST DIVISION.—IMITATION OF COLOURED OBJECTS WITH COLOURED MATERIALS IN A STATE OF INFINITE DIVISION 68 Introduction 68 Painting on the System of Chiaro-'scuro 69 Painting on the System of Flat Tints 81

SECTION III.—ON COLOURING IN PAINTING 82 CHAP. I.—On Colouring 82 Of Aërial Perspective 83 Of Colouring in respect to the Harmony of the Colours of the various Objects composing the Picture 85 CHAP. II.—Utility of the Law of Simultaneous Contrast of Colours in the Art of Colouring 87 Utility of this Law in order to imitate promptly and surely the Modification of Light on the Model 89 Utility of the Law in order to Harmonize those Colours of a Composition which are inherent to the Nature of the Object represented 95

SECOND DIVISION.—IMITATION OF COLOURED OBJECTS BY MATERIALS OF A DEFINITE SIZE, AS THREADS, &C. 102 CHAP. I.—On the Elements of Gobelins Tapestry 104 RULE I.—The Binary Mixture of Primary Colours 104 RULE II.—The Mixture of Complementary Colours 105 RULE III.—The Mixture of the Three Primary Colours in such proportions that they do not become neutralized, because one or the other of them is in excess 108

THIRD DIVISION.—COLOUR PRINTING 118 On Calico-Printing, and printing Paper-hangings 118 False Judgment of the Value of Recipes for Colouring Compositions 119 CHAP. II.—On the Law of Simultaneous Contrast of Colours in relation to Paper-hangings with Figures, Landscapes, or large Flowers of varied Colours 121 On the Law of Simultaneous Contrast of Colours relatively to the Borders of Paper-hangings 123 Printed or written Characters on Papers of different Colours 136 On the Assortment of Colours for reading by diffused Daylight 138

FOURTH DIVISION.—EMPLOYMENT OF COLOURS IN ARCHITECTURE 138 1. On the Employment of Colours in Egyptian Architecture 138 2. On the Employment of Colours in Greek Architecture 139 3. On the Employment of Colours in Gothic Architecture 141 Application to the Interior of Edifices 143 On the Assortment of Stuffs with the Wood of Seats 143 On the Selection of Frames for Pictures and Engravings 145 On the General Decoration of the Interiors of Churches 147 On the Decoration of Museums and Galleries 149 Decorations of the Interior of Houses 152 On the Assortment of Colours in Interiors, the Walls of which are panelled or covered with Marble, Stucco, or Painted Wood 163

FIFTH DIVISION.—CLOTHING 165 I. MEN'S CLOTHING 165 Of the Advantages of Contrast, considered with regard to the apparent Cleanliness of Cloth for Clothing 165 II. FEMALE CLOTHING 167 Colours for the Dress of Women with White Skins 167 Of the Colours of the Hair and Head-dress 168 Of the Colours of the Complexion and the contiguous Drapery 169 The Head-dress in relation to the Coloured Rays which it may reflect upon the Skin 171 Fair-haired Type 175 Type with Black Hair 176 On the Assortment of Colours in the Dress of Women with Copper-coloured Skins 177 On the Assortment of Colours in the Dress of Women with Black or Olive Skins 177

APPLICATIONS TO HORTICULTURE.

On the Art of arranging ornamental Plants in Gardens, so as to derive the greatest possible advantage from the Colours of their Flowers 180 Assortments of Flowers where the Plants are apart 181 Assortments relating to the Harmonies of Contrast of Hues 182 Assortments as to Harmony of Analogy 182 On the Art of assorting Ligneous Plants in Gardens, so as to derive the best possible advantage from the Colour of their Foliage 184 On the Distribution and Planting of Trees, &c., in Masses 185 Chap. I. Of Lines of Plants 187 Of the Lines of Plants called Screens 188 Of Lines of Plants considered as Elements of Masses 188 Of Homogeneous Masses 189 Of Heterogeneous or Varied Masses 190 Isolated 190 Contrast of Colours 194 Repetition 194 Symmetry 196 General Harmony 196

SIXTH DIVISION.—INTERVENTION OF THE PRECEDING PRINCIPLES IN THE JUDGMENT OF COLOURED OBJECTS, RELATIVELY TO THEIR COLOURS, CONSIDERED INDIVIDUALLY, AND TO THE MANNER IN WHICH THEY ARE ASSOCIATED 197 On the Connexion of the Law of Simultaneous Contrast of Colours with the Judgment we form upon all Coloured Bodies, under the relations of the respective Beauty or Purity of their Colours, and of the Equality of the Distance of their Tones if these bodies belong to the same scale 205 On the Comparison of two Samples of the same Colour 206 Influence of a Surrounding Colour upon one Colour when compared with another 206 On the Effect of Contrast upon the Browns and the Lights of

most of the Scales of Wood and Silk employed in Tapestry and Carpets 208 Means afforded by Contrast for ascertaining whether the Tones of a Scale of Colour are equidistant 209 Of the Binary Associations of Colours, critically considered 210 Of the Complex Association of Colours, reviewed critically 214 Of the Arts which address the Eye by employing Coloured Materials of a certain size, considered relativelyto the Physical Condition of these Materials, and to the Peculiarity of the Art employing them 218 Tapestries, Carpets, Mosaics, and Coloured Glass Windows, corresponding to Paintings in Chiaro-'scuro 219 Of the Disposition of the Mind of the Spectator in respect to the Judgment he forms of an Object of Art which attracts his eye 225

ON THE COLOURS OF MILITARY UNIFORMS 227

INDEX 235

LIST OF ILLUSTRATIONS.

ENGRAVED AND PRINTED IN COLOURS BY EDMUND EVANS.

In referring to the illustrations, it will be necessary to cover with white paper all but the example immediately under notice.

NOTE.—In Plates 8, 9, and 10, the examples are in rows of 13 circles arranged lengthwise.

PLATE PAGE 1. DIAGRAMS, VARIOUS 4 2. EXPERIMENTAL DEMONSTRATIONS OF CONTRAST OF COLOUR 7 3.} MODIFICATIONS WHICH THE PRINCIPAL COLOURS 4.} INDUCE IN CONTIGUOUS COLOURS 17 5.} 6. SIMPLE AND COMPOUND COLOURS 26 7. CHROMATIC DIAGRAM 36 8. ASSORTMENTS OF COLOURED CIRCLES:— COLOURS WITH WHITE 51 9. DO. DO. BLACK 54 10. DO. DO. GREY 58 11. ELEMENTS OF GOBELINS TAPESTRY:— THE BINARY MIXTURE OF PRIMARY COLOURS 104

12. DO. THE MIXTURE OF COMPLEMENTARY COLOURS 105 13. BLACK ORNAMENTS ON VARIOUS COLOURED GROUNDS 120 14. GREY DO. DO. DO. 123 15. METALLIC GILT ORNAMENTS ON DO. 124 16. BORDER OF BLUE FLOWERS ON DO. 130 17. BORDER OF ROSES AND LEAVES ON DO. 131

PREFACE TO THE THIRD EDITION.

The present edition has been entirely revised; some obscurities cleared up, and a chapter on Military Clothing added. The application of Chevreul's reasoning will doubtless tend to a rational view of this much debated question. It affords much satisfaction to all concerned in the diffusion of the principles enunciated in this work, to observe that they are being generally applied in this country, thus realizing the hopes originally expressed by the translator.

TRANSLATOR'S PREFACE.

Colour, a universal source of enjoyment, so essential an element of decorative art, has not been hitherto the subject of such investigations as to place its powers, harmonies, and discordances among matters of scientific certainty. A few traditionary dogmas have been the only guide of ordinary workmen, while success in design, as well as in the higher regions of art, has been dependent upon that rare union of faculties vaguely denoted by the indefinite, unsatisfactory term, "taste."

The arrangement of colours in manufactures of English design—since the decline of mediæval art—has commonly been condemned as notoriously arbitrary, destitute of any reference to principle, and deficient in that satisfying richness and beauty which result from harmonious combinations. Although often overcharged with colour, and of costly elaboration, our manufactures have too often proved that the designer—in ignorance of a true, infallible standard—has mistaken gaudiness for splendour, and capricious strangeness for improvement; and, for want of a better claim to popular favour, has constantly sought it by "leaning on novelty, his fickle, frail support."

The established preference of French designs was shown, by the Great Exhibition of 1851, to be, in the main, well-founded; and one of the leading causes of the perfect success of some objects was found in the fact, that they had been designed and executed in accordance with a well-defined set of principles, extensively taught in France to designers, workmen, and others. These principles it is the purpose of this book to set forth, to illustrate, and to apply to every art of which the choice and arrangement of colours is an element.

The author, M. Chevreul, before the publication of this work, had gained high reputation by his researches in organic chemistry. In his "Considerations sur l'Analyse Organique," he enunciated principles which, carried into practice in his "Recherches sur les Corps Gras d'origine animal," opened the path which has been rendered illustrious by Liebig and others. But, being appointed Director of the Dye Works of the Gobelins, he was compelled to abandon these researches—the field in which, "having sown, he had, as it were, only to reap,"—that he might fully investigate the principles involved in the assortment of colours.

M. Chevreul's earnest attention to this inquiry was continued during ten years, with ample opportunities for investigation. For twenty-five years he has been in the habit of lecturing to workmen, artists, &c. The undisputed superiority of those French manufactures in which these instructions have been fully carried out, has evinced his success and rewarded his exertions.

Aware of the important influence of such knowledge, the Chamber of Commerce of Lyons solicited and obtained from the French Government permission for M. Chevreul to lecture there to the artisans especially, to whom printed copies of the lectures were afterwards gratuitously distributed.

As the present Work contains the substance of these instructions, we may hope that our own industrious countrymen may not long be without a similar advantage.

The value of this book has been universally recognised, and it has already been translated into several languages, although but recently into our own. A recent critic has said, with equal truth and eloquence,—"Rarely has a subject of inquiry, so fraught with beautiful and ready applications, been presented to us. To be familiar with this book is to possess a new sense. Every object in art and nature speaks a new and exciting language. Colour becomes music to the eye. We become impatient of any violent infringement of the principles of harmony, and seek every opportunity of putting our newly-acquired knowledge into practice. The minuteness of investigation, and the copiousness of illustration which characterize this volume are truly remarkable; the most untutored mind cannot fail to understand it, if steady attention be given. As a preparation for a course of scientific study, it is invaluable, for it is an excellent example of the Baconian method of investigation."

EXTRACTS FROM THE AUTHOR'S PREFACE.

In seeking to discover the causes of the complaint made of the quality of certain colours prepared in the dyeing laboratory of the Gobelins, I was at once convinced, that, although the complaints concerning the instability of the light blues, greys, and browns, might be well founded, there were others, especially those of a want of vigour in the blacks employed for the shadows of blue and violet draperies, which were not so; for, having procured black-dyed wools from the most celebrated dye works in France and other countries, and having found that they were not superior to those of the Gobelins, I saw that the want of vigour alleged against the blacks was owing to the colours contiguous to them, and that the matter was involved in the phenomena of _the contrast of colours_.

It was thus demonstrated to me that I had two absolutely distinct subjects to investigate, in order to fulfil my duties as Director of the Dye Works; the first being the contrast of colours, considered in the most general manner, both in relation to science and to its applications: the second—the chemistry of dyeing. These are the two centres around which have converged all my researches during the last ten years.

In fact, numerous observations made during several months, on the view of coloured objects, which were verified by my pupils and others, much accustomed in their profession to judge of colours and to appreciate the least differences between them, have been collected and described as well-known facts. Upon reflecting on the mutual relations of these facts, and in seeking the principle of which they were the results, I was led to the discovery of that which I have named the "Law of Simultaneous Contrast of Colours." Thus this work is the fruit of the method _à posteriori_: facts are observed, defined, described, then generalized in a simple expression, which has all the characters of a law of nature. This law, once demonstrated, becomes a means, _à priori_, of assorting coloured objects so as to obtain their best possible effect, according to the taste of the person who arranges them; it becomes also a means of estimating whether the eyes are well organized for seeing and judging of colours; and whether painters have copied exactly the colours of known objects.

In reviewing the Law of Contrast with regard to its application, and in submitting to experiment all the laws which appear to me to result from it, I have been led to extend it to the arts of tapestry, to the various sorts of painting and printing, to illuminating, horticulture, &c. But, in order to anticipate the judgments of some readers, upon the value of the opinions I have advanced (2nd part, 2nd division) respecting the Gobelins and Beauvais tapestry and the Savonnerie carpets, I must state, that, being an entire

stranger to the inspection and direction of the works which are executed in the Royal manufactories, as well as to the choice of models, my views and opinions should be regarded only as those of an individual who has had frequent occasion to see and examine various artistic productions, on the preparation of which he could exercise no influence, the duties which attach me to the Gobelins being exclusively those of Director of its Dye Works.

THE LAWS OF

Harmony and Contrast of Colours.

INTRODUCTION.

1. A ray of solar light is composed of an indeterminate number of variously coloured rays, which are distributed into groups, termed _red rays, orange rays, yellow rays, green rays, blue rays, indigo rays, violet rays_.

2. But all the rays comprised in the same group, the red for example, are not identical in colour; on the contrary, they may be considered as differing more or less among themselves, although we recognise the impression they produce separately, as comprised in that which we ascribe to red light.

3. When light is reflected by an opaque white body, it is not modified in proportion to the variously coloured rays which constitute white light; but, 1. _If the body is not polished_, every point of its surface is to be considered as dispersing the white light which falls upon it, in all directions, into the surrounding space; so that the point becomes visible to an eye placed in the direction of one of its rays. We may easily conceive that the image of the body, in a given position, is composed of the sum of the physical points, which send to the eye so placed, a portion of the light which each point radiates. 2. _If the body is polished_, as, for example, the surface of a mirror, a portion of the light is irregularly reflected, as in the preceding case; while another portion is regularly reflected, giving to the mirror the property of presenting to an eye, suitably placed, the image of the body which sends its light to the reflector. One consequence of this distinction is, that if we regard two plane surfaces which reflect white light, and differ from each other only in polish, it will happen that where the unpolished surface is visible, all its parts will be equally, or almost equally, illuminated; while the eye, when in a position to receive only the light which it reflects irregularly, will receive very little light from the polished surface; but it will receive much more light when in a position to receive that which is regularly reflected.

4. If the light which falls on a body is completely absorbed by that body, so that it disappears from sight, as in falling into a perfectly dark cavity, then the body appears to us black; and it becomes visible only because it is contiguous to surfaces which reflect or transmit light. We know of no bodies which are perfectly black, and it is only because they reflect a little white light that we judge they have relief, like other material objects.

5. When light is reflected by an opaque coloured body, there is always a reflection of white light, and a reflection of coloured light; the latter is owing to the fact that the body absorbs or extinguishes within itself some of the coloured rays, and reflects the others. It is evident that the _absorbed_ coloured rays are of a different colour from the _reflected_ coloured rays; and farther, that if these be reunited with the former, white light will be reproduced. It is evident, also, that unpolished opaque bodies reflect irregularly white light, and the coloured light which makes them appear coloured; and that those which are polished reflect irregularly a portion only of these two lights, while they reflect regularly the other portion.

6. It thus appears, by what has been said concerning the physical composition of solar light, that if the whole of the coloured light which is absorbed by a coloured body were reunited with the whole of the light which it reflects, white light would result. Now, it is this property of two variously coloured lights, taken in a certain proportion, to reproduce white light, that we express by the words _coloured lights complementary to each other_, or _complementary colours_. It is in this sense that we say,

Red is complementary to Green, and _vice versâ_. Orange " " Blue, " " Greenish-Yellow " Violet, " " Indigo " " Orange-Yellow, "

7. It must not be supposed that a red body, a yellow body, &c. reflects, besides white light, only the red rays or yellow rays, &c., each of these bodies reflects also every sort of coloured rays; but, the rays which cause us to judge it to be red or yellow, &c., being more numerous than the others, produce more effect than they; yet, the latter have an undoubted influence in modifying the action of red and yellow rays upon the organ of sight. This explains the innumerable diversities of colour observable among various red bodies, various yellow bodies, &c. It is difficult not to admit that among these diversely coloured rays reflected by bodies, there are a certain number which, complementary to each other, must reproduce white light upon reaching the retina.

PART THE FIRST.

SECTION THE FIRST.

OF THE LAW OF SIMULTANEOUS CONTRAST OF COLOURS, AND OF ITS DEMONSTRATION BY MEANS OF EXPERIMENT.

CHAPTER I.

Manner of observing the Phenomena of the Simultaneous Contrast of Colours.—_Definition of Simultaneous Contrast._

8. If we look at the same time at two stripes of unequal tints of the same colour, or at two stripes of equal tints of different colours, in juxtaposition, that is to say, contiguous by one of their edges, the eye will perceive, if the stripes be not too wide, certain modifications; in the first case affecting the intensity of the two tints, in the second, the optical composition of the two colours so placed. Now as these modifications cause the colours to appear, when looked at together, more different than they really are, I have given to them the name of the _simultaneous contrast of colours_. The modification which affects the intensity of colour, I term _contrast of tone_; and the modification which affects the optical composition of the contiguous colours, I term _contrast of colour_.

The twofold phenomena of contrast of colour and contrast of tone may be readily shown by the following.

Experimental Demonstration of Contrast of Tone.

Plate A A■.

9. Let the two halves of a sheet of unglazed paper, about twenty inches square, be coloured clear grey, by a mixture of chalk and black; fix them, in any way, upon a piece of unbleached linen, placed across a window, at the distance of twelve inches asunder. Take two halves of another piece of similar paper B B■, but of a darker grey, and coloured with the same substances. Fix A next to B and place B■ twelve inches from B. (See Fig. 1.)

[Illustration: PLATE I.]

Upon looking at the four half-sheets for a few seconds, it will be seen that A contiguous to B will be lighter than A■, while B will seem darker than B■.

10. It is easy to demonstrate that the modification is not equally intense over the whole of the surfaces A A■ and B B■, but that it becomes gradually feebler from the line of contact. This may be proved by placing a card, so cut, that O and P may each present three grey stripes, as shown in Fig. 2, Plate 1. The stripes 1 1 are more modified than the stripes 2 2, and these are more so than the stripes 3 3. However, in order that this modification may be effected, it is not absolutely necessary that O and P should touch; for if the stripes 1 1 be covered, the stripes 2 2, 3 3 will be modified.

11. The following experiment, which is simply the result of the two preceding (9 and 10), is well suited to demonstrate the extent of contrast of tone. Upon a sheet of cardboard divided into ten stripes, each about a quarter of an inch broad, lay a uniform tint of Indian ink. As soon as it is dry, lay a second tint on all the stripes except the first. As soon as the second is dry, lay a third on all the stripes except the first and second, and so on of all the rest, so as to have ten flat tints, gradually increasing in depth from the first to the last. (See Fig. 3.) If ten strips of paper of the same grey, but each of a different tone, be laid upon a cardboard, in the preceding gradation, it will serve the same purpose.

Upon looking at the cardboard, it will be seen that the strips, instead of presenting flat tints, will each appear of a tone diminishing in intensity from the edge _a a_ to the edge _b b_. In the stripe 1, the contrast is produced simply by the contiguity of the edge _b b_ with the edge _a a_ of the stripe 2; in the stripe 10, it is simply by the contiguity of the edge _a a_ with the edge _b b_ of the stripe 9. But in each of the intermediate stripes 2, 3, 4, 5, 6, 7, 8, 9, the contrast is produced by a double cause; partly by the contiguity of the edge _a a_ with the edge _b b_ of the stripe which precedes it, partly by the contiguity of the edge _b b_ with the edge _a a_ of the darker tint which follows it. The first cause tends to raise the tone of the half of the intermediate stripe; while the second cause tends to lower the tone of the other half of the same stripe.

In consequence of this contrast, the stripes seen from a proper distance, resemble channels rather than flat surfaces. For, in the stripes 2 and 3 for instance, the grey is weakened from the edge _a a_ to the edge _b b_, presenting to the eye the same effect as if the light fell upon a channelled surface; there is however this difference, that in the real channelling the enlightened part would throw a reflection upon the dark portion.

12. Contrast of tone occurs with colours so called as well as with grey; thus to repeat the experiment (9), fig. 1, with the halves _o o_ of a sheet of paper of a light tint of a certain colour, and the two halves _p p_ of a sheet of paper of a darker tint of the same colour, it will be seen that _o_ contiguous to _p_ will be lighter than _o■_, and _p_ darker than _p■_. In short, it may be demonstrated as has been done (10) that the modification of colours in juxtaposition becomes weaker in proportion to their distance from the line of contact; and in order to observe this effect in bodies which are not contiguous, it is only necessary to experiment as described in (10).

[Illustration: PLATE II.]

The colours experimented upon must be as nearly as possible of equal intensity.

13. _Experimental Demonstration of Contrast of Colour._—If we arrange as before, the two halves of an unglazed coloured sheet of paper, and two halves of another sheet of a different colour, but as nearly as possible of equal intensity, or rather of _tone_ (8), upon looking at the four half-sheets _o o■, p p■_ for a few seconds, we shall see that _o_ differs from _o■_ and _p_ from _p■_; consequently the two half-sheets, _o p_, seem to undergo a reciprocal modification of tint, which is rendered apparent by comparing their colours with those of _o■_ and _p■_.

14. No 1. { Red inclines to Violet. { Orange " Yellow. 2. { Red " Violet. { Yellow " Green. 3. { Red " Yellow. { Blue " Green. 4. { Red " Yellow. { Indigo " Blue. 5. { Red " Yellow. { Violet " Indigo. 6. { Orange " Red. { Yellow " Bright Green. 7. { Orange " Bright Red. { Green " Blue. 8. { Orange " Yellow. { Indigo " Blue. 9. { Orange " Yellow. { Violet " Indigo. 10. {Yellow " Bright Orange. { Green " Blue. 11. { Yellow " Orange. { Blue " Indigo. 12. { Green " Yellow. { Blue " Indigo. 13. { Green " Yellow. { Indigo " Violet. 14. { Green " Yellow. { Violet " Red. 15. { Blue " Green. { Indigo " Deep Violet. 16. { Blue " Green. { Violet " Red. 17. { Indigo " Blue. { Violet " Red.

15. It thus appears from the experiments described in this chapter that two coloured surfaces in juxtaposition, viewed simultaneously, present to the eye two modifications—one relative to the depth of tone of their respective colours, and the other relative to the physical composition of those colours.

CHAPTER II.

The Law of the Simultaneous Contrast of Colours, and the Formula which represents it.

16. After I had assured myself that the preceding phenomena were constant for my sight when it was not fatigued, and that many persons, accustomed to judge of colours, saw them as I did, I sought to reduce them to an expression sufficiently general to render it possible to predicate the effect which would be produced upon the organ of vision by the juxtaposition of two given colours. All the phenomena that I have observed seem to depend upon a very simple law, which in its most general sense may be enunciated in these terms: When two contiguous colours are seen at the same time, they appear as dissimilar as possible, both with regard to their optical composition and their depth of tone. Therefore there may be at once simultaneous contrast of colour, properly so called, and simultaneous contrast of tone.

17. Now two colours in juxtaposition, _o_ and _p_, will differ from each other in the greatest possible degree when the complementary of _o_ is added to _p_, and the complementary of _p_ is added to _o_; indeed by the juxtaposition of _o_ and _p_, the rays of the colour _p_, which _o_ reflects when it is seen alone, and which are active in that case, cease to be so when _o_ and _p_ are in juxtaposition. Now under these circumstances, each of the two colours, losing what it has analogous to the other, must be so much more different from it.

18. The following formulæ will illustrate this:—

Let us represent—

The colour of the stripe O by the colour _a plus_ white B, " " P " _a■ plus_ white B■, the complementary colour of _a_ by C, " " _a■_" _c■_, the colours of the two stripes seen separately are— Colour of O = _a_ + B; colour of P = _a■_ + B■; by juxtaposition they become—

Colour of O = _a_ + B + _c■_, P = _a■_ + B■ + _c_.

We will now show that this expression amounts to taking away the rays of _a■_ from the colour _a_ of O (15), and to taking away the rays of the colour _a_ from _a■_ of P.

For let us suppose—

B reduced into two portions, white = _b_ + white = (_a_■ + _c_■),

B■ reduced into two portions, white = _b_■ + white = (_a_ + _c_).

The colours of the two stripes seen separately are—

The colour of O = _a_ + _b_ + _a_■ + _c_■, and the colour of P = _a_■ + _b_■ + _a_ + _c_.

By juxtaposition they become—

The colour of O = _a_ + _b_ + _c_■, and the colour of P = _a_■ + _b_■ + _c_.

An expression which is evidently the same as the former, except for the values of B and B■.

19. I have said that simultaneous contrast may at the same time affect the optical composition of colours, and the depth of their tone; consequently, when colours are not of the same depth, that which is deep appears deeper, and that which is light appears lighter; that is to say, the former appears to lose white light, while the latter seems to reflect more of it. Thus _there may be, in looking at two contiguous colours, simultaneous contrast of colours and simultaneous contrast of tone_.

CHAPTER III.

The Law of Simultaneous Contrast of Colours demonstrated by the Juxtaposition of a certain Number of Coloured Bodies.

20. Let us now apply the above formula to the seventeen observations of Chapter I., and we shall see that the modifications of contiguous colours are precisely those which would result from the addition to each of them of the complementary of the contiguous colour (18). The rank these colours occupy in Chapter I. may be readily noted, as I have attached to each the number applied to it in that chapter. And for the complementary of each colour see (6). (See Plate II.)

Orange and Green, 7. 21. Orange, the complementary of Blue, being added to Green, makes it Bluer or less Yellow. Green the complementary of Red being added to Orange makes it Redder less Yellow.

Orange and Indigo, 8. 22. Orange, the complementary of Blue, being added to Indigo, makes it Bluer or less Red. Green the complementary of Red being added to Orange makes it Redder less Yellow.

Orange and Violet, 9. 23. Orange, the complementary of Blue, being added to Violet, makes it Blue or less Red. Violet the complementary of Orange-yellow being added to Orange makes it Yellower less Red.

Green and Indigo, 13. 24. Green, the complementary of Red, being added to Indigo, makes it Redder or more Violet. Indigo the complementary of Orange-yellow being added to Green makes it Yellow.

Green and Violet, 14. 25. Green, the complementary of Red, being added to Violet, makes it Redder. Violet the complementary of Green-yellow being added to Green makes it Yellower.

Orange and Red, 1. 26. Orange, the complementary of Blue, being added to Red, makes it Violet or Crimson. Red the complementary of Green being added to Orange makes it Yellower.

Violet and Red, 5. 27. Violet, the complementary of Green-yellow, being added to Red, makes it Orange-yellow. Red the complementary of Green being added to Violet makes it Indigo.

Indigo and Red, 4. 28. Indigo, the complementary of Orange-yellow, being added to Red, makes it Orange. Red the complementary of Green being added to Indigo makes it Blue.

Orange and Yellow, 6. 29. Orange, the complementary of Blue, being added to Yellow, makes it Greener. Yellow the complementary of Indigo being added to Orange makes it Redder.

Green and Yellow, 10. 30. Green, the complementary of Red, being added to Yellow, makes it Orange. Yellow the complementary of Indigo-violet being added to Green makes it Blue.

Green and Blue, 12. 31. Green, the complementary of Red, being added to Blue, makes it Indigo. Blue the complementary of Orange being added to Green makes it Yellower.

Violet and Blue, 16. 32. Violet, the complementary of Greenish-yellow, being added to Blue, makes it Greenish. Blue the complementary of Orange being added to Violet makes it Redder.

Indigo and Blue, 15. 33. Indigo, the complementary of Orange-yellow, being added to Blue, makes it Green. Blue the complementary of Orange being added to Indigo makes it Violet.

Red and Yellow, 2. 34. Red, the complementary of Green, being added to Yellow, makes it Green. Yellow the complementary of Indigo-violet being added to Red makes it Violet.

Red and Blue, 3. 35. Red, the complementary of Green, being added to Blue, makes it Green. Blue the complementary of Orange being added to Red makes it Orange.

Yellow and Blue, 11. 36. Orange-yellow, the complementary of Indigo-violet, being added to Blue, makes it Indigo. Blue the complementary of Orange being added to Yellow makes it Orange.

Indigo and Violet, 17. 37. Indigo, the complementary of Orange-yellow, being added to Violet, makes it Red. Violet the complementary of Greenish-yellow being added to Indigo makes it Bluer.

38. It is evident that, all other things being equal, the modifications of contiguous colours will be so much the more marked, as the complementary colour C or C■, which is added to each of them, differs more from them; for the complementary C■ which is added to the colour O, is identical with it, as the complementary C is identical with the colour P to which it is added; and the modifications of O and P will simply augment the intensity of their colours. But are there yet any two bodies known which present to the observer two pure colours perfectly complementary to each other? Certainly not; all those which are coloured by reflection reflect (7), besides white light, a great number of rays of various colours. We cannot instance a _red_ body and a _green_ body, or an _orange_ and a _blue_, or an _orange-yellow_ and an _indigo_, or a greenish-yellow and a _violet_, which reflect pure or mixed colours, absolutely complementary to each other. So that the juxtaposition of these colours produces only a simple _augmentation of their intensity_. Hence, although it is less easy to verify the law of contrast with respect to red and green, or orange and blue, &c., than with respect to those which are the object of the seventeen experiments just described (15), yet, upon applying it to the former, it will be seen that their colours acquire a most remarkable brilliancy, strength, and purity. This result, perfectly conformable to the law, may be easily understood: for example, an orange-coloured object reflects blue rays, as a blue object reflects orange rays (7). Hence, when a blue stripe is put in contact with an orange stripe, although it is admitted that the first appears to the eye to receive blue from the orange of the second, as this appears to receive orange from the blue of the blue stripe; or what is the same thing, that the blue stripe appears to destroy the effect of the blue rays of the second stripe, as these appear to destroy the effect of the orange rays of the blue stripe—it is evident that the two colours so contrasted must purify each other, and become more intense. But the blue may incline to green or violet, and the orange to yellow or red; that is to say, the modification may not only affect the intensity of the colour, but also its physical composition. However, if this latter effect take place, it is always much more feeble than the first. Besides, if you look several times at the same coloured stripes, you will see that the blue which at first had appeared to you greenish will afterwards appear inclining to violet; and that the orange, which had appeared at first yellowish, will incline to red; so that the phenomena of modification, as it affects the physical composition of colour, will not have the constancy of those which are the subject of the preceding seventeen observations (15). I now proceed to state the observations I have made on colours which are most nearly complementary to each other.

Red and Green.

39. _Red,[1] the complementary of Green, placed by the side of Green, increases its intensity._

Green, the complementary of Red, placed by the side of Red, increases its intensity.

[1] In the original French Edition there is evidently a confusion of terms in this and the two following articles (39, 40, 41, 42). The Red is there represented as placed in juxtaposition with _red_, and green with _green_, and so on with the other instances; orange and blue; orange-yellow and indigo; greenish-yellow and violet; instead of being made by contrast with their respective complementaries to intensify each other.

Such is the theoretical result, the experimental result entirely agrees with it. When we place a green, inclining more to yellow than to blue, side by side with, 1st, a slightly orange-red, 2nd, a slightly crimson-red, and 3rd, an intermediate red, and repeat our observations several times on each of these assemblages of colour, we shall observe different results; that is to say, in one case the red will appear more orange and the green yellower, and in another the red will appear more violet and the green bluer. We shall find also that the change may be attributed as much to a difference in the intensity of the light upon the colours as to fatigue of the eye.

When we place a green, inclining rather to blue than to yellow, side by side with, 1st, a slightly orange-red, 2nd, a slightly crimson-red, and 3rd, an intermediate red, the results are the same as with the first green, but with this difference,—that in the assemblage of bluish-green and of slightly crimson-red, observed several times, the green and the red appear almost constantly yellower than they are separately. A result very easily understood.

Orange and Blue.

40. _Blue, the complementary of Orange, placed by the side of Orange, increases its intensity._

Orange, the complementary of Blue, placed by the side of Blue, increases its intensity.

Upon repeating these observations with a deep blue and an orange which is not too red, the two colours appear commonly to become redder.

Orange-Yellow and Indigo.

41. _Orange-yellow, the complementary of Indigo, placed by the side of Indigo, increases its intensity._

Indigo, the complementary of Orange-yellow, placed by the side of Orange-yellow, increases its intensity.

[Illustration: PLATE III.]

Greenish-Yellow and Violet.

42. _Greenish-yellow, the complementary of Violet, placed by the side of Violet, increases its intensity._

Violet, the complementary of Greenish-yellow, placed by the side of Greenish-yellow, increases its intensity.

The result of observation is almost always in conformity with this law.

43. According to the law of the simultaneous contrast of colours, and the insensible gradation of modification, beginning at the contiguous edges of the colours in juxtaposition (11), we may show, by means of coloured circular spaces, the modifications which the principal colours induce in those which are contiguous to them.

Place wafers, circular pieces of paper, or any other convenient material about an inch and a half in diameter, coloured red, green, orange, blue, greenish-yellow, violet, indigo, and orange-yellow, each separately upon a sheet of white paper; then tint the white paper around the circle with its complementary colour, gradually softening it off from the coloured circle, when it will be found that

The Red circle tends to colour the surrounding space with its complementary Green. Green ” ” Red. Orange ” ” Blue. Blue ” ” Orange. Greenish-yellow ” Violet. Violet ” ” Greenish-yellow. Indigo ” ” Orange-yellow. Orange-yellow ” Indigo.

These figures are designed to exhibit the effects of contrast to those persons who, not having studied physical laws, are, notwithstanding, desirous of understanding these effects.

CHAPTER IV.

On the Juxtaposition of Coloured Surfaces with White.

44. When white bodies are viewed simultaneously with coloured bodies contiguous to them, they are sensibly modified. I confess that the modification is too feeble to be determined with absolute certainty while we are ignorant of the law of contrast; but, understanding that, and knowing the modifications that white undergoes in connexion with certain colours, we shall not fail to recognise this modification in special cases, provided the colours opposed to the white be not too deep.

Red and White.

45. Green, complementary to Red, being added to White, the Red appears more brilliant and deeper.

Orange and White.

46. Blue, complementary to Orange, being added to White, the Orange appears more brilliant and deeper.

Greenish-Yellow and White.

47. Violet, complementary to Greenish-yellow, being added to White, the Yellow appears more brilliant and deeper.

Green and White.

48. Red, complementary to Green, being added to White, the Green appears more brilliant and deeper.

Blue and White.

49. Orange, complementary to Blue, being added to White, the Blue appears more brilliant and deeper.

[Illustration: PLATE IV.]

Indigo and White.

50. Yellowish-orange, complementary to Indigo, being added to White, the Indigo appears more brilliant and deeper.

Violet and White.

51. Yellowish-green, complementary to Violet, being added to White, the Violet appears more brilliant and deeper.

Black and White.

52. Black and white, which may be considered in some respects complementary to each other, become, conformably to the law of contrast of tone, more different than when seen separately. This results from the effect of the white light, which is reflected by the black (4), being more or less destroyed by the light of the white stripe. By an analogous action, the white heightens the tone of the colours to which it is contiguous.

CHAPTER V.

On the Juxtaposition of Coloured Bodies with Black.

(See Plate 9, Page 54.)

53. A black surface being deeper than that which is contiguous to it, the contrast of tone tends to deepen it still more, while it tends to lower the tone of the contiguous colour; as on the other hand white, placed in juxtaposition with it, would heighten it. So much for contrast of tone.

54. Black surfaces reflect a small quantity of white light (4), and this falling upon the retina simultaneously with the coloured light of a contiguous body, it is evident that the black surface must appear tinted with the complementary of the coloured light; but it will be a weak tint, since it is displayed upon a ground which has but a feeble power of reflecting light. So much for the contrast of colour.

55. The lowering of the tone of the colour contiguous to the black is constantly observed; but a very remarkable fact is the weakening of the black itself, when the contiguous colour is deep, and of a nature to give a luminous complementary, as orange, orange-yellow, greenish-yellow, &c.

Red and Black.

56. Green (the complementary of Red), when placed by the side of Black, makes it appear Reddish. The Red looks clearer, partaking less of Orange.

Orange and Black.

57. A Blue (the complementary of Orange), when placed by the side of Black, causes it to appear less brilliant, or somewhat rusty, while Orange by the side of Black appears more brilliant in colour.

Greenish-Yellow and Black.

58. Greenish-yellow (the complementary of Violet), when placed by the side of Black, gives it a Violet tint, whilst the Greenish-yellow becomes clearer and more Green; but there are some kinds of Yellow which are weakened by the side of Black.

Green and Black.

59. Red (the complementary of Green), when placed by the side of Black, causes the Black to appear more Violet or Reddish; whilst Green by the side of Black becomes slightly Yellower.

[Illustration: PLATE V.]

Blue and Black.

60. Orange (the complementary of Blue), when placed by the side of Black, causes it to appear brighter, while the Blue becomes clearer and somewhat Greener.

Indigo and Black.

61. Orange-yellow (the complementary of Indigo), placed by the side of Black, causes it to look much brighter. The Indigo also appears brighter.

Violet and Black.

62. Violet (the complementary of Greenish-yellow), when placed by the side of Black, lightens it up; whilst the Violet becomes more brilliant and clear, and somewhat Reddish.

CHAPTER VI.

On the Juxtaposition of Coloured Bodies with Grey.

(See Plate 10, Page 58.)

63. As the brilliancy of the light reflected by white bodies is one of the principal causes which render the sight insensible to the modifications produced in white by the juxtaposition of coloured bodies; and, on the other hand, as the feeble light reflected from black bodies is unfavourable to our perception of the modifications which they sustain from the proximity of coloured bodies, especially when the complementary of the colour of these bodies is but slightly luminous, it may be conceived that grey bodies, judiciously selected with regard to their depth of tone, would, by contiguity to coloured bodies, exhibit the phenomena of contrast of colour in a more striking manner than either black or white bodies would.

Red and Grey.

64. Grey appears Greenish by receiving the influence of its complementary Red.

The Red appears purer, less Orange perhaps.

Orange and Grey.

65. Grey appears Bluer by receiving the influence of its complementary Orange.

The Orange appears purer, more brilliant, Yellower perhaps.

Yellow and Grey.

66. Grey appears to incline to Violet by receiving the influence of its complementary Yellow.

The Yellow appears more brilliant, and yet less Green.

Green and Grey.

67. Grey appears to incline to Red by receiving the influence of its complementary Green.

The Green appears more brilliant, Yellower perhaps.

Blue and Grey.

68. Grey appears to incline to Orange by receiving the influence of its complementary Blue.

The Blue appears more brilliant, Greener perhaps.

Indigo and Grey.

69. Grey appears to incline to Orange by receiving the influence of its complementary Blue.

The Blue appears more brilliant, Greener perhaps.

Violet and Grey.

70. Grey appears Yellowish by receiving the influence of its complementary Violet.

Violet appears fresher, less dull.

70_a_. The grey, which was the subject of the above experiments, was as free as possible from every colouring matter foreign to black; it belonged to the scale of normal black (see Part II., 164)—that is to say, it resulted from a mixture of the purest possible black and white materials. By juxtaposition with white, it appeared deeper, and the white appeared more pure; while by juxtaposition with black, it appeared lighter and more rusty, and the black appeared deeper.

70_b_. One result of the complementaries of colours in juxtaposition with grey being more perceptible than when these colours are juxtaposed with white or black, is, that if instead of a _normal grey_, we juxtapose a _grey, tinted_ either with _red, orange, yellow_, &c., these tints will be greatly heightened by the complementaries added to them. For example, a bluish grey will receive a very perceptible increase of blue from its proximity to orange, and a yellowish-grey will take a perceptible green tint from the same proximity.

NOTE.—_The chemical nature of coloured substances has no influence upon the phenomena of simultaneous contrast._

71. The chemical nature of coloured bodies in juxtaposition has no influence upon the modifications of their colours. Whatever may happen to be the chemical composition of the coloured bodies, provided they be identical to the sight, they yield the same results. I need only cite the following examples:—Indigo, Prussian blue, cobalt, ultramarine, as nearly alike as possible, gave the same sort of modification; orange prepared from red lead, annotto, or a mixture of woad and madder, caused the same modification of the colours to which they were adjacent.

CHAPTER VII.

On the Juxtaposition of Coloured Bodies belonging to the Colours of the same Group of Coloured Rays.

72. Whenever there is a great difference between two contiguous colours, the difference becomes still more appreciable by putting the same colour successively in juxtaposition with the various colours belonging to the same group. For example, _orange and red_.

Orange being placed beside scarlet-red, pure red and crimson-red, it will be seen that the red acquires a purple and the orange a yellow tint.

Violet being placed beside scarlet-red, pure red and crimson-red, gives analogous results: the violet always appears bluer, and the red yellower or less purple.

73. These observations explain why we obtain results in accordance with the formula, even when such coloured substances are used as are far from exhibiting pure colours, namely, stained papers or stuffs.

74. The juxtaposition of coloured stripes is a means of demonstrating the difficulty of determining the types of pure colours by common pigments; at least, if we do not take into consideration the law of simultaneous contrast. For instance—

1. Place red in contact with orange-red; the first will appear purple and the second yellower, as above; but if the first red be placed beside purplish-red, the latter will appear bluish, and the former more yellow or orange; so that the same red will be purple in one case and orange in the other

2. Place yellow beside orange-yellow, the former will appear greenish and the latter redder; but if you put the first yellow beside a greenish-yellow, the last will appear greener, and the yellow more orange; so that the same yellow will incline to green in one case, and to orange in the other.

3. Place blue beside greenish-blue, the former will incline to violet, and the second will appear yellower. Put the same blue beside a violet-blue, the former will incline to green, and the second will appear redder; so that the same blue will be violet in one case and greenish in the other.

75. Hence we see that the colours which painters term simple—red, yellow, and blue—pass insensibly by juxtaposition into the condition of compound colours, since the same red is purple or orange; the same yellow is orange or green; and the same blue is green or violet.

CHAPTER VIII.

On the Application of the Law of Contrast to the Hypothesis that Red, Yellow, and Blue are the only Primary Colours; and that Orange, Green, Indigo, and Violet are Secondary or Composite Colours.

76. The experiments to which I have just applied the principle of the modification which colours undergo by juxtaposition, and the explanation consequent upon the manner in which white light has been considered, are also clearly explained in the language of painters and dyers, who admit of only three primary colours—red, yellow, and blue. As there are persons who, while they hold this opinion, desire, notwithstanding, to give a reason for the phenomena resulting from the juxtaposition of colours, I will explain them in accordance with this language; and, for greater clearness, I make five groups of juxtaposed colours, beginning with those which include the observations to which the preceding law is most easily applied. I shall presume that orange is composed of red and yellow, green of yellow and blue, indigo and violet of red and blue.

FIRST GROUP.—_Two Secondary Colours having a Simple Colour as a Common Element._

It is very easy to verify the law when we look at two colours which form part of the group: we see that by their reciprocal influence they lose more or less of the colour which is common to them. It is evident that they become more unlike each other in proportion to this loss.

1. _Orange and Green._—These colours having the element yellow in common, lose it by juxtaposition. _The orange appears redder, and the green bluer._

2. _Orange and Indigo._—These colours having the element red in common, lose it by juxtaposition. _The orange appears yellower, and the indigo greener._

3. _Orange and Violet._—Like the preceding.

4. _Green and Indigo._—These colours having the element blue in common, lose it by juxtaposition. _The orange appears yellower, and the indigo bluer._

5. _Green and Violet._—Like the preceding.

SECOND GROUP.—_A Compound Colour, and a Simple Colour, which is found in the Compound._

Plate 6.

1. _Orange and Red._—The orange loses red, and appears yellower; the red becomes bluer, to differ as much as possible from the orange.

[Illustration: PLATE VI.]

2. _Violet and Red._—The violet loses red, and appears bluer; the red becomes yellower, to differ as much as possible from the violet.

3. _Indigo and Red._—Like the preceding.

4. _Orange and Yellow._—The orange loses yellow, and appears redder; the yellow becomes bluer, to differ as much as possible from the orange.

5. _Green and Yellow._—The green loses yellow, and appears bluer; the yellow becomes redder, to differ more from the green.

6. _Green and Blue._—The green loses blue, and appears yellower; the blue becomes redder, to differ as much as possible from the green.

7 _Violet and Blue._—The violet loses blue, and appears redder; the blue must become yellower to differ as much as possible from the violet.

8. _Indigo and Blue._—Like the two preceding.

THIRD GROUP.—_Two Simple Colours._ (See 6, 7.)

1. _Red and Yellow._—Red in losing yellow appears bluer; and the yellow losing red appears bluer; or, in other words, the red inclines to purple, and the yellow to green.

2. _Red and Blue._—The red in losing blue appears yellower; and the blue losing red appears yellower; or, in other words, the red inclines to orange, and the blue to green.

3. _Yellow and Blue._—The yellow in losing blue appears redder; and the blue losing yellow appears more violet; or, in other words, the yellow inclines to orange, and the blue to violet.

FOURTH GROUP.—_Two Compound Colours consisting of the same Simple Colours._

Indigo and Violet.—As indigo differs from violet only in containing more blue in proportion to red, it follows that the difference will be greatest when the indigo loses red and inclines to greenish blue, while the violet, by gaining red, inclines toward that colour. It is clear that, if the violet lost red, or if the indigo acquired it, the two colours would approximate; but, as they differ from each other, the first effect ensues.

We may further explain the preceding phenomena by considering indigo relatively to violet, as blue; then it will lose its blue, which is common to both colours, and incline to green; while the violet, also losing its blue, will appear redder.

FIFTH GROUP.—_A Compound Colour, and a Simple Colour, which is not found in the Compound._

1. _Orange and Blue._ 2. _Green and Orange._ 3. _Violet and Greenish Yellow._

Upon the hypothesis that orange, green, and violet are compound colours, and that red, blue, and yellow are simple, it follows that in opposing them in the order in which they are reciprocally complementary, and supposing also that the colours so juxtaposed are entirely free from any foreign colour, there appears no reason for the compound colour losing one of its elements rather than another, or for the simple colour being unlike one of the elementary colours rather than another. For instance, in the juxtaposition of green and red, we see no reason why green should pass into blue rather than into yellow, or why the red should incline to blue rather than to yellow.

SECTION II.

ON THE DISTINCTION BETWEEN SIMULTANEOUS, SUCCESSIVE, AND MIXED CONTRAST OF COLOURS, AND ON THE CONNEXION BETWEEN THE EXPERIMENTS MADE BY THE AUTHOR, AND THOSE PREVIOUSLY MADE BY OTHER

OBSERVERS. DISTINCTION BETWEEN SIMULTANEOUS, SUCCESSIVE, AND MIXED CONTRAST OF COLOURS.

77. Before speaking of the relation of my experiments to those made by others on the contrast of colours, we must distinguish three classes of contrast. The _first_ includes those relating to the contrast which I term _simultaneous_; the _second_ to that which I term _successive_; and the _third_ to that which I term _mixed_.

78. _Simultaneous contrast of colours_ includes that phenomena of modification which objects variously coloured seem to undergo in physical composition, and in the depth of tone of their respective colours, when seen at the same time.

79. _Successive contrast of colours_ includes the phenomena observed when the eyes having looked for some time at one or more coloured objects, perceive, after having ceased to look at them, images of those objects, presenting the colour complementary to that of the actual object.

80. This distinction also facilitates the understanding of the phenomena which maybe called _mixed contrast_; for, the retina having seen a certain colour for some time, has an aptitude to see for a further time the complementary of that colour, as well as any new colour presented by an external object; the sensation perceived being the result of this new colour, and the complementary of the first.

For want of this distinction, one of the branches of optics most fertile in applications, has not been treated with the clearness and precision which are necessary to show its importance to those who have not experimented upon it.

81. The following is a simple mode of observing _mixed contrast_:—Having closed one eye, the right for example, look steadily with the left at a sheet of paper of a colour A; when this colour seems to become dull, look immediately at a sheet of paper of the colour B, the eye then has the impression produced by the mixture of this colour B with the complementary (C) of the colour A.

82. To be convinced of this mixed sensation, it is only necessary to shut the left eye, and to look at the colour B with the right eye; when the sensation perceived is not only that of the colour B, but it may appear modified in the contrary way to that of the mixed sensation C + B, or what is the same, it appears to be rather A + B.

83. Upon shutting the right eye, and looking again at the colour B with the left eye, and that many times in succession, different sensations are successively perceived, but more and more feebly, until at length the left eye returns to its normal state.

84. I advise any person who thinks that one of his eyes is more able to perceive colours than the other, to look at a sheet of paper alternately with the right and left eye; if the sensations of each are identical, he may conclude that he has deceived himself. And even if the sensations be different, the experiment should be repeated several times, successively, for the difference observed in a single experiment might be occasioned by one of the eyes having been previously modified or fatigued.

85. This practice appears to me especially useful to painters. I now give some examples of mixed contrast.

86. The left eye, having looked for some time at red, has an aptitude to see afterwards green, the complementary of red. If then it be attracted by yellow, it perceives a sensation resulting from the mixture of green and yellow. The left eye being shut, and the right eye, which has not been modified by the sight of red, being opened, it sees yellow, and it is possible that this yellow may appear more orange than it is really.

87. _If the left eye_ | _and had_ | _the latter would_ _had first seen_ | _afterwards seen_ | _have seemed_ Yellow Red Violet. 88. Red Blue Greenish. 89. Blue Red Orange-red. 90. Yellow Blue Blue-violet. 91. Blue Yellow Orange-yellow. 92. Red Orange Yellow. 93. Orange Red Red-violet. 94. Red Violet Deep blue. 95. Violet Red Orange-red. 96. Yellow Orange Red. 97. Orange Yellow Greenish-yellow. 98. Yellow Green Bluish-green. 99. Green Yellow Orange-yellow. 100. Blue Green Yellow-green. 101. Green Blue Blue-violet. 102. Blue Violet Reddish-violet. 103. Violet Blue Greenish-blue. 104. Orange Green Bluish-green. 105. Green Orange Reddish-orange. 106. Orange Violet Bluish-violet. 107. Violet Orange Yellowish-orange. 108. Green Violet Red-violet. 109. Violet Green Yellow-green. 110. Red Green Bluer. 111. Green Red Tinted-violet. 112. Yellow Violet A little bluer. 113. Violet Yellow Greenish. 114. Blue Orange Yellower. 115. Orange Blue More violet.

116. I should observe that all these colours, at least to my eyes, did not undergo equally intense or equally continuous modifications. For instance, the modification produced by the successive view of yellow and violet, or of violet and yellow, is stronger and more durable than that produced by the successive view of blue and orange, and still more than that of orange and blue. The modification produced by the successive view of red and green, of green and red, is but slight, and not enduring.

I may also add that the depth of tone exercises some influence on the modification; for, if after looking at orange, we look at dark-blue, the latter will appear greenish rather than violet, a result contrary to that afforded by a light blue.

117. I have thought it the more necessary to mention under a special name the phenomenon which I call _mixed contrast_, as it explains certain facts remarked by dealers in coloured fabrics, as well as the inconvenience felt by painters, who, wishing to produce an exact imitation of their models, look at them so long as to be unable to perceive their tones and modifications. I will mention two facts which have been communicated to me by manufacturers, referring the reader to Part II. for the application of the study of mixed contrast to painting.

118. First Fact. When a purchaser has looked a long time at a yellow cloth, and he is then shown an orange, orange-red, or scarlet one, he finds it dull, and judges it to be a dark or crimson-red; because the retina affected by the yellow has a tendency to see violet; and hence all the yellow of the orange colour disappears, and the eye sees it as a red, or a red inclining to violet.

119. Second Fact. If there be presented to a purchaser, one after another, fourteen pieces of a red fabric, he judges the six or seven last pieces to be less beautiful than the first, although they may be all identical. What is the reason of this false judgment? It is, that the eyes which have seen six or eight red pieces in succession, are in the same condition as if they had looked steadily for the same length of time at a single red stuff,—having a tendency to see the complementary of red, that is green. This tendency necessarily enfeebles the brilliancy of the red of the last pieces. The dealer, therefore, that he may not be a sufferer from the fatigued eyes of his customer, after showing him a few red pieces, should present some green ones, to restore the eyes to their normal state. If the view of the green were sufficiently prolonged to pass the normal state, the eyes would acquire a tendency to see red, and then the pieces seen last would appear more beautiful than the rest.

PART THE SECOND.

ON THE APPLICATION OF THE LAW OF SIMULTANEOUS CONTRAST OF COLOURS.

INTRODUCTION.

120. Before entering into the details of these applications, I think it necessary to offer some considerations which will enable me to establish some propositions or principles, to which I shall have frequent occasion to refer. I propose to give—

121. 1. Definitions of several expressions applicable to colours and their modifications. 2. The means of representing and defining colours and their modifications by the aid of diagrams. 3. A classification of the harmonies of colours. 4. A view of some arrangements of the primary colours with white, black, and grey.

SECTION I.

Definition of the words Tones, Scales, and Hues.

122. The words _Tones_ and _Hues_ recur continually, both in common language and in that of artists; yet they are not so well defined as to be free from ambiguity, or to be well understood.

123. The word TONE of a colour will be employed exclusively to designate the various modifications which that colour, in its greatest intensity, is capable of receiving from white, which _lowers_ its tone, or of black, which _heightens_ it.

124. The word SCALE will be applied to the assemblage of tones of the same colour, thus modified. The pure colour is the normal tone of the scale, if the normal tone does not belong to a broken or reduced scale—_i.e._, to a scale, of which all the tones are made dull with black (149).

125. The word HUE will be applied exclusively to the modifications which a colour receives from the addition of a small quantity of another. We shall speak, for example, of the _tones_ of the blue scale, the _tones_ of the red scale, &c. We say the _hues_ of blue to designate all the scales whose colours, still remaining blue, yet differ from pure blue; each hue comprehending the tones which constitute a scale more or less allied to the blue scale.

126. I have defined the tones of a colour to be the various modifications, which that colour at its maximum of intensity is capable of receiving from black and white; it must be observed that the condition “maximum of intensity for receiving black,” is absolutely essential to this definition; for if black be added to a tone below the maximum, it would pass into another scale. Artists distinguish

colours as _pure, broken, reduced, grey_, or _dull_.

127. Pure colours are those termed _simple_, red, yellow, blue, and those which result from their binary compounds, orange, green, violet, and their _hues_. (150.) _Broken_ colours are the pure colours mixed with black, from the tone of the lightest to the deepest. According to these definitions, it is evident that in all the scales of simple and binary colours, the tones which are above the pure colour are _broken_ tones.

128. Artists, and especially painters and dyers, admit that the mixture of three primary colours, in a certain proportion, gives black; hence, when these three colours are so mixed that two predominate, black will result, formed from the union of the whole of the colour, which is in small quantity, within suitable proportions of the two predominant colours. For example, if blue be mixed with red and yellow, a little black is produced, which reduces or _breaks_ the orange.

129. We must remember that the _primary colours_ of painters are not those of the prismatic spectrum, but substances employed by them, as red, yellow, and blue colours.

SECTION II.

Of Diagrams designed to Represent and Define Colours and their Modifications.

130. Various contrivances have been proposed under the titles of Tables, Scales, Colour-Circles, Chromatometers, &c., for representing either by numbers or a rational nomenclature, colours and their modifications. They are generally founded on these three propositions:—1. There are three primary colours. 2. Equal portions of these colours being mixed, produce pure secondary colours. 3. Equal portions of the three primary colours produce black.

131. But we know of no substance which exhibits pure colour; that is, which reflects only one kind of coloured rays, whether pure red, pure yellow, or pure blue. And since it is impossible to procure pure colouring matters, how can it be said that orange, green, and violet are composed of two simple colours mixed in equal proportions? Or that black consists of a mixture of equal parts of three simple colours?

[Illustration: PLATE VII.]

These chromatic tables, &c., point out mixtures which do not produce the results deducible from the principles on which they are said to be based.

132. But most of the blue, red, and yellow colours with which we are acquainted, give, by their binary compounds, violet, green, and orange inferior in brilliancy to the natural violet, green and orange colours of objects. This result would be explained by admitting that colours mixed two by two, reflect at least two kinds of coloured rays; and that where there is any mixture of colours which reflect separately red, yellow, and blue, there is produced a certain amount of black which reduces the brilliancy of the mixture.

133. Conformably with this view, the violet, green, and orange colours which result from a mixture of coloured matters, are most brilliant when the respective colours of these materials approach each other. For example, a mixture of blue and red inclines more to violet than a mixture of blue and yellow inclines to green, and that of red and yellow inclines still more to orange.

134. In order to represent all the modifications that I have called _tones_ and _hues_ of colours, as well as the relations which exist between those that are complementary to each other, I have devised the following diagram (Plate 7). From a centre, _c_, I describe two circumferences, _y_ Y. I divide each of these by means of three rays, _c a_, _c b_, _c d_, into arcs of 120 degrees each. I divide the portion of each ray comprised between the two circles _y_ Y into twenty parts, which represent as many tones of the colours red, yellow, and blue.

135. In each of the scales of these three colours there is one tone, which, when pure, represents the colour of the scale to which it relates. I therefore call it the _normal tone of that scale_. If we represent a unit of surface _s_, entirely covered by the pigment which reflects the normal colour, and if we suppose that this colouring matter is equally distributed over the surface _a_ 1, we shall represent the tones superior to the normal tone by the unit of surface covered with 1 of the normal colour, plus the quantities of black increasing with the number of tones; and we shall represent the inferior tones by the unit of surface covered with a fraction of the quantity 1, constituting the normal tone, mixed with (——) quantities of black, as the tone has a less elevated number. If the tone 15 of the red scale be the normal tone, the normal tone of the yellow scale will have a lower number, while the normal tone of the blue scale will have a higher number. This depends upon the unequal lightness of the colours.

136. If each arc of 120° be divided into two of 60° and if radii pass through the points of division, beginning at _y_, there will be represented twenty tones of the orange, green, and violet scales, the colours at the extremities of each diameter being complementary to one another. Each arc of 60° might be divided into arcs of 30°, and thus would be obtained radii representing twenty tones of scales, which I shall call orange-red, orange-yellow, greenish-yellow, greenish-blue, bluish-violet, and violet-red.

137. By dividing each arc into five, for example, by means of five radii, which I divide into twenty parts each, beginning at the circumference _y_, I shall obtain sixty new scales.

138. Beginning with red, I designate them as follows:—

_a_ Red _e_ Yellow _i_ Blue 1 Red 1 Yellow 1 Blue 2 Red 2 Yellow 2 Blue 3 Red 3 Yellow 3 Blue 4 Red 4 Yellow 4 Blue 5 Red 5 Yellow 5 Blue 139. _b_ Red-orange _f_ Yellow-green _k_ Blue-violet 1 Red-orange 1 Yellow-green 1 Blue-violet 2 Red-orange 2 Yellow-green 2 Blue-violet 3 Red-orange 3 Yellow-green 3 Blue-violet 4 Red-orange 4 Yellow-green 4 Blue-violet 5 Red-orange 5 Yellow-green 5 Blue-violet 140. _c_ Orange _g_ Green _l_ Violet 1 Orange 1 Green 1 Violet 2 Orange 2 Green 2 Violet 3 Orange 3 Green 3 Violet 4 Orange 4 Green 4 Violet 5 Orange 5 Green 5 Violet 141. _d_ Orange-yellow _h_ Green-blue _m_ Violet-red 1 Orange-yellow 1 Green-blue 1 Violet-red 2 Orange-yellow 2 Green-blue 2 Violet-red 3 Orange-yellow 3 Green-blue 3 Violet-red 4 Orange-yellow 4 Green-blue 4 Violet-red 5 Orange-yellow 5 Green-blue 5 Violet-red

I attach no importance to this nomenclature; I employ it only as the simplest to distinguish the seventy-two scales just described. The number may be increased indefinitely, by inserting as many as we choose between the above.

142. Let us now represent the gradations of each colour in the scales of the circle by the addition to it of black, progressively increasing till it becomes pure black. Imagine a quadrant whose radius is equal to that of the circle, and arranged so as to turn upon an axis perpendicular to the plane of the circle. Divide this quadrant, 1st, by concentric arcs _y y■_, which coincide with the circles denoted by the same letters; 2nd, by ten radii, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Divide each of these radii into twenty parts, representing twenty tones, corresponding to the tones of the scales represented on the circle.

143. I suppose that the tenth radius comprises the gradations of normal black, covering the half-circle described by the movement of the quadrant upon its axis; this black mixed in decreasing quantities, with increasing quantities of white, gives the twenty tones of normal grey, and ends by being lost in the white situated above the tone 1. I suppose, further, that the normal tone of each of the scales taken upon each of the radii of the quadrant 1, 2, 3, 4, 5, 6, 7, 8, 9, is formed of the mixture of black with the colour of any of the scales that the circle contains, and in such a proportion that the normal tone 15 of that scale is represented by the unit of surface covered with 1, or ¹■/■■ of red.

144. The tone 15 of the scale of the

1st Radius = ■/■■ of Red + ¹/■■ of Black. 2nd " = ■/■■ " + ²/■■ " 3rd " = ■/■■ " + ³/■■ " 4th " = ■/■■ " + ■/■■ " 5th " = ■/■■ " + ■/■■ " 6th " = ■/■■ " + ■/■■ " 7th " = ³/■■ " + ■/■■ " 8th " = ²/■■ " + ■/■■ " 9th " = ¹/■■ " + ■/■■ "

These proportions relate to the effect of the mixtures upon the eye, and not to the material quantity of the red and black substances.

145. We see then—1. That each of these _tones_, 15, composed of colour and black, reduced by white and deepened by black, gives a scale of twenty tones, so much the more broken as they are nearer the scale of normal black. 2. That the quadrant by its movement upon the axis of the circle, represents the scales of every colour except red, broken by black. These broken scales are equidistant, and are formed of equidistant tones. 3. That all the colours are thus contained in a circle, whose plan comprehends the pure colours; the central space, black; and the intermediate space the pure colours, broken by the various proportions of black.

146. The diagram, as just described, thus represents the lowering of pure colours by white, and their gradation by black; their modifications by their mutual mixtures, the modification of hues, and the modification of breaking. We will presently inquire into the possibility of realizing it by means of coloured materials.

147. We have presumed—1. That the normal tone of each of the scales is as pure as possible. 2. That the tones bearing the same number in all the scales,—both those of the pure colours and those of the broken colours,—are, to the sight, of equal depth. 3. That if three tones, of the same number, be taken in three consecutive scales, the tone of the intermediate scale is the mean between the colours of the extreme scales. It is thus easy to explain the modifications of a pure colour commencing with its normal tone.

148. These modifications are so produced that—1. _The Pure Colour never leaves its Scale._—The modification is in the direction of the radius of the circle—proceeding from the normal tone towards the centre, it gains white; while proceeding from the normal tone towards the circumference, it gains black.

149. 2. _The Pure Colour leaves its Scale by the addition of Black._—In this case the various scales comprised in the quadrant perpendicular to the circle, begin at the normal tone of one of the pure scales of the circle with which the quadrant coincides. This normal tone, resulting from a quantity of colour represented by unity, covering a unit of surface _s_, the normal tones of the quadrant result from the mixture of black and a fraction of unity of the colour. These mixtures constitute broken colours, each covering a unit of surface _s_, and are of the same depth as the normal tone of the pure colour. The fraction of the quantity of colour is, in the broken normal tones, so much less, as the scales, to which these tones belong, approximate to the vertical axis of the semicircle.

Besides, each normal tone of the scales of the quadrant is modified, like the normal tones of the scales of the circle, by increasing quantities of white towards the centre, and of increasing quantities of black towards the circumference.

150. 3. _A Pure Colour is modified by the addition of another Pure Colour._—In this case hues are formed so much more resembling each other, as the quantities of the second colour are smaller. These modifications are made circularly, so that the tones retain their numbers. Thus admitting, with painters and dyers, that there are only three primary colours, and that by combining these two by two, we obtain all the pure complex colours; and by combining them in threes, all the broken colours; we find that it is possible to represent by this hypothesis, all the modifications of colours.

151. Another advantage of this construction is that of giving to all artists who may make applications of the law of simple contrast, the complementaries of all the pure colours; since the colours of the circular plan which are found at the extremities of the same diameter are complementary to each other. For example, not only are red and green, blue and orange, yellow and violet on the same diameter, but it is so with orange-red and bluish-green, and yellowish-green and violet-red; of red No. 1 and of green No. 1; so that all the colours opposed to each other are mutually complementary.

152. The complementary of a colour contiguous to another being once known, it is easy, according to the principles of combination, to determine the modification that the second must receive from the first; since this modification is the result of the mixture of the complementary with the contiguous colour. In fact, if there is no difficulty when the result is that of the non-complementary mixture with a simple colour, red, yellow, and blue, with a binary colour, orange, green, violet (using the language of painters, 76), there is no greater difficulty when the result is that of the mixture of two binary colours. For, the complementary being much less intense than the colour with which it is mixed, the result will be found by subtracting from the last binary colour the portion of its simple colour, which with the complementary forms white, or in other words, neutralises it.

153. _Examples._—1. Orange being added as a complementary to green, neutralises a portion of its blue, and consequently makes it appear less blue or more yellow.

2. Orange being added as complementary to violet, neutralises a portion of its blue, and consequently makes it appear less blue or more red.

3. Green being added as complementary to violet, neutralises a portion of its red, and consequently makes it appear less red or more blue.

154. These three examples are easily explained by subtracting from the binary colour a portion of its simple colour which is identical with that contiguous to it. Thus:—

1. Blue subtracted from Green, makes it appear more Yellow. 2. Blue " " Violet " " Red. 3. Red " " Violet " " Blue.

155. To put the diagram into practice we must adopt invariable types of colour, either in the solar spectrum, or in polarized light, or coloured rings, or colours developed in a constant manner, by any process whatever; then imitate them with the utmost fidelity, by means of colouring matters which should be applied to the circular plan of our chromatic diagram.

These types must be sufficiently numerous to reproduce the principal colours, in order that a practised eye may without difficulty insert all the tones of the same scale and all the hues of which types are wanting. In fact the diagram thus established, should present terms so near that the various colours of the natural bodies might be referred to them.

156. 1. _That it represents all the Modifications resulting from the Mixture of Colours._—Thus any colour lowered by white and deepened with black may, retaining its place in the scale, give rise to an infinite variety of tones; infinite, inasmuch as an unlimited number may be inserted from tone 1 to tone 20.

157. 2. Pure colours, by their mutual modifications, may produce an infinite variety of hues; for between two adjacent hues we may insert as many as we desire.

158. 3. The normal tone of a pure colour represented by a quantity equal to 1, covering the unit of surface, is the commencement of the normal tones and scales proceeding towards black; these normal tones being represented by black and a quantity of colour less than unity, constituting the mixtures which cover a unit of surface s, and colour it of a tone which has the same number as the normal tone of the pure scale to which it relates. It is understood that in proceeding from this tone to the corresponding tone of normal black, we may insert an unlimited number of mixtures of colour and black.

159. The modifications of colours, thus indicated by the diagram, render it extremely easy to understand the definitions given above (123) of the words, scales, tones, hues, pure and broken colours.

160. 2. _It affords the means of knowing the complementaries of every colour, since the names written at the two extremities of any one diameter indicate the colours complementary to each other._

161. EXAMPLES.—_a._ Suppose it be required to know the mutual influence of _blue and yellow_; at one extremity of a diameter we read the word _blue_, and at its opposite end, the word _orange_; showing that blue tends to give orange to yellow. Again, at the end of another diameter we read the word yellow, and at its opposite, the word violet; by which we see that yellow tends to give violet to blue.

162. _b._ Suppose _green and blue_ be contiguous; at one extremity of a diameter we read the word green, and at its opposite end, red; showing that green tending to give red to blue, must render it more violet. Again, at one end of a diameter we read the word blue, and at its opposite end, orange. But what arises from the mixture of green and orange? The orange will tend to neutralize its complementary, blue, in the green; and as it is always too feeble to neutralize all the blue, its influence will be limited to neutralizing a portion of it; whence it results that green, contiguous to blue, will appear more yellow than it really is.

163. _c._ Let _green and yellow_ be contiguous, we shall see in like manner that the green, by imparting red to the yellow, will render it orange; and that violet, the complementary of yellow, by neutralizing some yellow in the green, will make the green appear bluer, or less yellow.

164. 3. _A third advantage of this diagram, which distinguishes it from other chromatic diagrams, is, that it affords the preceding advantages, without being coloured._

165. 4. _A fourth advantage is that of its manifesting to all artists who use coloured materials of a definite size, especially the workers of tapestry, carpets and the like, the relation of number which must exist between the tones of the various scales which they work together._

SECTION III.

Harmony of Colours.

166. The eye has an undoubted pleasure in seeing colours, independently of the design and every other quality of the object which displays them. A suitable example to demonstrate this, is the wainscoting of an apartment in one or more flat tints which only attract the eyes and affect them more or less agreeably, as the colours are well or badly chosen.

167. First Case. _Agreeable Colour._—Every one, whose eyes are well organized, derives pleasure from looking at the coloured rays transmitted through a coloured glass, whether it be red, orange, yellow, green, blue, or violet.

168. Second Case. _Different Tones of the same Scale of Colour._—The simultaneous view of the series of tones of the same scale, which commences with white and ends with dark brown, gives undoubtedly an agreeable sensation, especially if the tones have equal and sufficiently numerous intervals; for example, from eighteen to thirty.

169. Third Case. _View of Different Colours, belonging to adjacent Scales, assorted conformably to Contrast._—The simultaneous view of different colours, belonging to scales more or less allied to each other, may be agreeable; but the assortment of scales

producing this effect is very difficult to obtain, because the more nearly the scales approach, the more frequently it happens that one of the colours injures that which is adjacent to it, and even both are reciprocally injurious. The painter may, however, take advantage of this harmony, by sacrificing one of the colours, which he subdues, to make the other more brilliant.

170. Fourth Case. _View of very different Colours, belonging to very distant Scales, arranged conformably to Contrast._—The simultaneous view of complementary colours, or of binary assemblages of colours, which, without being complementary, are yet very different, is also an undoubtedly agreeable sensation.

171. Fifth Case. _View of various Colours, assorted more or less according to the Law of Contrast_, being seen through a glass of a colour not deep enough to allow all the colours peculiar to the glass to be visible, afford a spectacle which is not without its charm, and which is placed between that produced by the tones of the same scale, and that which is produced by various colours; for it is evident, that if the glass were of a deeper colour, it would cause objects to be seen of the colour peculiar to it.

172. Hence we infer that there are six distinct harmonies of colour, comprised in two species.

FIRST SPECIES—HARMONIES OF ANALOGY.—1. _The harmony of scale_, produced by the simultaneous view of different tones of the same scale, more or less approximating. 2. _The harmony of hues_, produced by the simultaneous view of tones of the same, or nearly of the same depth, belonging to neighbouring scales. 3. _The harmony of a dominant coloured light_, produced by the simultaneous view of various colours assorted according to the law of contrast, but one of them predominating, as would result from the view of these colours through a slightly-coloured glass.

173. SECOND SPECIES—HARMONIES OF CONTRAST.—1. _The harmony of contrast of scale_, produced by the simultaneous view of two very distant tones of the same scale. 2. _The harmony of contrast of hues_, produced by the simultaneous view of tones of different depths, belonging, to neighbouring scales. 3. _The harmony of contrast of colours_, produced by the simultaneous view of colours, belonging to very distant scales, assorted according to the law of contrast. The difference in the depth of the adjacent tones may further augment the contrast of colours.

SECTION IV.

Assortments of Red, Orange, Yellow, Green, Blue, Violet with White, Black, and Grey.

174. It will not be useless to the object of this work to introduce some observations relative to the degree of beauty of certain arrangements of the primitive colours with black, white, and grey. But I cannot too strongly insist upon the fact, that they are not given as a rigorous deduction from scientific rules, for they are only the expression of my particular taste; yet I hope that many classes of artists, especially dressmakers, decorators of all kinds, designers of patterns for woven fabrics, paper-hangings, &c., will find advantage in consulting them.

175. The _ground_, as well as the interval between the colours, having influence upon their effect, all my observations were made with white, black, grey, and coloured circles, ■/■■ of an inch in diameter, separated by intervals of ■/■■ of an inch; thirteen circles arranged in a straight line forming a series.

176. The series designed to show the effect of white were on a ground of normal grey; those to show the effect of black and of grey were upon a white ground, slightly tinged with grey. It is necessary to remark that the _coloured_ circles placed apart, were upon black grounds, which must have exercised some influence.

177. The colours which have been under my notice are red, orange, yellow, green, blue, violet. Their differences in regard to brilliancy are so great as to admit of their being divided into two groups, one comprising red, orange, yellow, and bright green, the other blue and violet, which, with the same depth of tone, have not the brilliancy of the former. I shall call the first group _luminous colours_, and the second _sombre colours_. But the deep and broken tones of the _luminous scales_ may in many cases be assimilated to the sombre group, as the light tones of blue and violet may sometimes be employed as _luminous_ colours.

ARTICLE I.

Colours with White.

Plate 8.

A. _Binary Assortments._

178. All the primary colours gain by their juxtaposition with white, but the binary arrangements which result from them are not equally agreeable; and it is to be remarked that the depth of tone of a colour has a great influence upon the effect of its assortment with white.

The binary assortments in the order of their greatest beauty, are as follows:—_light blue_ and white, _rose_ and white, _deep yellow_ and white, _bright green_ and white, _violet_ and white, _orange_ and white.

Dark blue and dark red produce, with white, too strong a contrast of tone to allow of their assortment being as agreeable as that of their light tones. On the contrary, yellow being a light colour, we must take the normal or deepest tone of yellow to produce its most beautiful effect. Dark green and violet contrast too much in tone with white for their combination to be as agreeable as those which are made with the light tones of these colours. The objection which can be made to the combination of orange and white is that of too much brilliancy; yet I should not be surprised to find that many persons preferred it to that of violet and white.

B. _Tertiary Assortments of Colours complementary to each other with White._

179. It is to me impossible to establish an order of beauty among binary combinations of primary complementary colours. I shall therefore only describe the effect of white interposed between the binary complementary assortments, or between each of the complementary colours.

[Illustration: PLATE VIII.]

180. 1. _Red and Green_ are of all complementary colours the most equal in depth; for red, as regards its brilliancy, is midway between yellow and blue; and in green these two extremes are united. 2. The arrangement, white, red, green, white, &c., is not decidedly superior to the preceding, at least when the colours are not deep. 3. The arrangement white, red, white, green, white, &c., seems to me inferior to the preceding.

181. 1. _Blue and Orange_ are more opposed to each other than red and green, because the least brilliant colour blue, is separated, while the most brilliant are combined in orange. 2. The arrangement, _white, orange, blue, white_, &c., is agreeable. 3. The arrangement, _white, orange, white, blue, white_ &c., is also agreeable.

182. 1. _Yellow and Violet_ form an arrangement which, as regards depth of tone, is most distinct, since the least intense or lightest colour, the yellow, is separated from the others. Because of this great contrast of tone, the deep, but pure, greenish-yellow combines better with light violet, than light yellow and deep violet. 2. The arrangement, _white, yellow, violet, white_, &c., appears to me inferior to the preceding arrangement (1). 3. The arrangement, _white, yellow, white, violet, white_, &c., seems to me inferior to 2.

C. _Ternary Assortments of Colours not complementary with White._

183. 1. Red and orange do not accord well. 2. The arrangement, _white, red, orange, white_, &c., is scarcely preferable. 3. The arrangement, _white, red, white, orange, white_, &c., is not so bad as the preceding, because white being favourable to all the colours, its interposition between the colours which injure each other, can only produce an advantageous effect.

184. _Red and Yellow_ accord pretty well, especially if the red is purple-red rather than scarlet, and the yellow rather greenish than orange. 2, The arrangement, white, red, yellow, white, is preferable to the preceding. 3. The arrangement _white, red, white, yellow, white_, is still better.

185. 1. _Red and Blue_ accord passably, especially if the red incline rather to scarlet than to crimson. Deep tones are preferable to light ones. 2. The arrangement _white, red, blue, white_, &c., is preferable to 1. 3. The arrangement _white, red, white, blue, white_, is preferable to the second.

186. 1. _Red and Violet_ do not accord well, yet they are found in some natural productions, as the sweet pea. 2. The arrangement _white, red, violet, white_, is not so bad as the preceding. 3. The arrangement _white, red, white, violet, white_, is preferable.

187. 1. _Orange and Yellow_ accord incomparably better than red and orange. 2. The arrangement _white, orange, yellow, white_, is agreeable. 3. The arrangement _white, orange, white, yellow, white_, is not so good as 2, and perhaps 1, because there is too much white.

188. 1. _Orange and Green_ do not accord well. 2. The arrangement _white, orange, green, white_, is preferable to 1. 3. The arrangement _white, orange, white, green, white_, is perhaps preferable to 2.

189. 1. _Orange and Violet_ accord passably, yet not so well as orange and green; the contrast, in the latter case, is greater than in the arrangement orange and violet. 2. The arrangement _white, orange, violet, white_, &c., is preferable to the preceding. 3. The arrangement _white, orange, white, violet, white_, &c., is preferable to 2.

190. 1. _Yellow and Green_ form an agreeable combination. 2. The arrangement _white, yellow, green, white_, &c., is still more agreeable. 3. The arrangement _white, yellow, white, green, white_, &c., is inferior to the preceding, and perhaps to the first. The inferiority of 3 seems to me to be caused by too much light for the _green_.

191. 1. _Yellow and Blue._ The arrangement of _yellow_ and _blue_ is more agreeable than that of _yellow_ and _green_, but it is less lively. 2. The arrangement _white, yellow, blue, white_, &c., is perhaps preferable to the preceding. 3. The arrangement _white, yellow, white, blue_, &c., is perhaps inferior to the preceding.

192. 1. _Green and Blue_ produce an indifferent effect, but better when the colours are deep. 2. The arrangement _white, green, blue, white_, &c., is preferable. 3. The arrangement _white, green, white, blue, white_, &c., has a still better effect, because the light is more equally distributed.

193. 1. _Green and Violet_, especially when light, form a combination preferable to the preceding, _green_ and _blue_. 2. The arrangement _white, green, violet, white_, &c., is not decidedly superior to the preceding. 3. The arrangement, _white, green, white, violet, white_, &c., is not decidedly superior to it.

194. 1. _Blue and Violet_ accord badly. 2. The arrangement, _white, blue, violet, white_, &c. is scarcely preferable to the preceding (1). 3. The arrangement _white, blue, white, violet, white_, &c., is not so bad as the preceding (2).

ARTICLE II.

Colours and Black.

Plate 9. (Frontispiece.)

195. I do not know whether the use of black for mourning, prevents the use of it, in numberless cases, where it would produce excellent effects; it may be combined most advantageously, not only with sombre colours to produce the harmony of analogy, but also with light and brilliant colours to produce the harmony of contrast.

196. Chinese artists appear to have made excellent use of it, for I have often seen furniture, painting, ornaments, &c., where it has been most judiciously employed. I recommend those artists for whom this paragraph is particularly designed, to attend to the following observations, not doubting that many will be profitable to them.

A. _Binary Combinations._

197. No combination of primary colours with black is disagreeable, but there exists among these a generic difference of harmony, which is not shown, at least to nearly the same degree, in the binary combinations of white with the same colours. In fact the brilliancy of white is so predominant, that whatever may be the difference of lightness or brilliancy observed between the various associated colours, there will always be the harmony of contrast, according to what has been said (44-52) of the influence of white in raising the tone and augmenting the intensity of the colour adjacent to it.

198. If the binary combinations of black be examined in this point of view, it will be seen that the deep tones of all the scales, and even of the blue and violet scales (which are not, properly speaking, deep), form with it harmonies of analogy and not of contrast. So likewise do the unbroken tones of the _red, orange, yellow-green_ scales, and the very light tones of the violet and blue scale. We may add, according to what has been said (55), that the combinations of _black_ with sombre colours, such as _blue_ and _violet_, whose complementaries, orange and _greenish-yellow_, are luminous, may diminish the contrast of tone if the colours be juxtaposed with _black_ or one not far from it, and in this case the _black_ loses much of its vigour.

199. _Blue_ and _Black, Violet_ and _Black_, make combinations which may be employed successfully when only dark colours are required. The first is superior to the second.

200. Light combinations which exhibit the harmonies of contrast, appear to me in the order of beauty thus:—

Red or _Rose_ and _Black_, _Orange_ and _Black, Yellow_ and _Black_, lastly, _Bright Green_ and _Black_. As to yellow, I repeat that it must be brilliant and intense, inasmuch as black tends to impoverish its tone.

B.—_Ternary Combinations of Colours mutually Complementary with Black._

201. 1. _Red, Green_, &c. 2. _Black, Red, Green, Black_, &c. This arrangement being quite different from the former, it is difficult to decide respecting their comparative beauty. 3. _Black, Red, Black, Green, Black_, &c., appear to me inferior to the preceding, because there is too much black.

202. 1. _Blue, Orange_, &c. 2. _Black, Blue, Orange, Black_. I prefer the first to the second; the proportion of dark colour being too strong relatively to the _orange_. 3. _Black, Blue, Black, Orange, Black_, &c. This pleases me less than the first.

The effect of _black_ with _blue_ and _orange_ is inferior to that of _white_.

203. 1. _Yellow, Violet_, &c. 2. _Black, Yellow, Violet_, &c. 3. _Black, Yellow, Black, Violet, Black_, &c. The second is superior to the third, because the proportion of sombre colours with the _yellow_ is too strong in the latter. The first appears to me superior to the second.

C.—_Ternary Combinations of Colours not Complementary with Black._

204. 1. _Red, Orange_, &c. 2. _Black, Red, Orange, Black_, &c. 3. _Black, Red, Black, Orange, Black_, &c. As orange and red injure each other, there is an advantage in separating them by black. The third arrangement is preferable to the second; and both are preferable to those in which _black_ is replaced by _white_.

205. 1. _Red, Yellow_, &c. 2. _Black, Red, Yellow, Black_. 3. _Black, Red, Black, Yellow, Black_, &c. The two last arrangements appear to me superior to the first, and many persons would prefer them to the arrangement in which _white_ replaces _black_. I cannot too strongly recommend the arrangement 2 and 3 to artists, for whom these observations are especially designed.

206. 1. _Red, Blue_, &c. 2. _Black, Red, Blue, Black_. 3. _Black, Red, Black, Blue, Black_, &c. No. 2 is preferable to No. 3, because there are too many sombre colours in the latter, and because these differ too much from the _red_. The effect of _black_ upon the binary arrangement, _red_ and _blue_, is inferior to that of _white_.

207. 1. _Red, Violet_, &c. 2. _Black, Red, Violet, Black_, &c. 3. _Black, Red, Black, Violet, Black_, &c. The _red_ and _violet_ injure each other, it is therefore advantageous to separate them by _black_; but the latter does not produce so good an effect as _white_. It is difficult to say whether No. 3 is preferable to 2; because, if there be in the latter _red_ near _violet_, this defect is more than compensated in 3, by the predominance of sombre colours over the _red_.

208. 1. _Orange-Yellow_, &c. 2. _Black, Orange-Yellow_, &c. 3. _Black, Orange, Black, Yellow, Black_, &c. The _orange_ and _yellow_ being very luminous, the _black_ allies itself to them very well in the arrangement 2 and 3; and if the arrangement, _white, orange, yellow, white_, be preferred to No. 2, I think that in the arrangement 3, the _black_ produces a superior effect to the _white_.

209. 1. _Orange, Green_, &c. 2. _Black, Orange, Green_, &c. 3. _Black, Orange, Black, Green, Black_, &c. _Black_ combines well with _orange_, and with _bright green_. In like manner it combines well with _orange_ and _yellow_. If, in the arrangement 2, _white_ be preferred to _black_, I think it cannot be in 3. I recommend to artists the combination of _black_ with the binary arrangements _orange_ and _yellow, orange_ and _green_.

210. 1. _Orange, Violet_, &c. 2. _Black, Orange, Violet, Black_, &c. 3. _Black, Orange, Black, Violet, Black_, &c. _Black_ does not combine so well as _white_ with _orange_ and _violet_, because the proportion of dark colours relatively to _orange_, a very vivid colour, is too great.

211. 1. _Yellow, Bright Green_, &c. 2. _Black, Yellow, Green, Black_, &c. 3. _Black, Yellow, Black, Green, Black_, &c. _Yellow_ and _light green_ being luminous colours, _black_ combines very well with them; and if in the arrangement 2 the effect of _white_ be preferred to that of _black_, I think that it cannot be in the arrangement 3.

212. 1. _Yellow, Blue_, &c. 2. _Black, Yellow, Blue, Black_, &c. 3. _Black, Yellow, Black, Blue, Black_, &c. If the arrangement 2 be preferable to 3, I think it inferior to 1. The _black_ does not appear to combine so well as the white in the group _yellow_ and

blue.

213. 1. _Green, Blue_, &c. 2. _Black, Green, Blue, Black_, &c. 3. _Black, Green, Black, Blue, Black_, &c. Although _green_ and _blue_ do not well accord, yet the combination with _black_ is not decidedly advantageous. Because of the augmentation of the proportion of sombre colours, the _white_ has a superior effect to the _black_.

214. 1. _Green, Violet_, &c. 2. _Black, Green, Violet, Black_. 3. _Black, Green, Black, Violet, Black_, &c. If the _black_ unite better with _green_ and _violet_ than with _green_ and _blue_, yet these ternary combinations are inferior to the binary combinations; and inferior to the ternary combination where it is replaced by _white_.

215. 1. _Blue, Violet_, &c. 2. _Black, Blue, Violet, Black_, &c. 3. _Black, Blue, Black, Violet, Black_, &c.

216. Although _blue_ and _violet_ are colours which do not accord well, and although there is an advantage in separating them, yet it must be remembered that _black_ in isolating them, does not relieve their sombre colour, but, on the other hand, the harmony of the arrangements of 2 and 3 is more agreeable as a harmony of analogy than the harmony of contrast presented by _white_ with the same colours. Thus there are cases in which the assemblage of _black, blue_, and _violet_, may be advantageous, when it is desired to produce diversified, but not striking effects.

ARTICLE III.

Colours with Grey.

Plate 10.

[Illustration: PLATE X.]

217. All the primary colours gain purity and brilliancy by the proximity of grey; yet the effects are far from being like or even analogous to those which result from the proximity of the same colours with white. This will not create surprise, if it be remembered that while white preserves the character of each colour and exalts it by contrast, it can never be taken for a colour properly so called; grey, on the contrary, may be; it happens that the latter makes with the most sombre colours, as blue, violet, and deep tones in general, assortments which belong to the harmonies of analogy; while, with colours naturally brilliant, such as red, orange, yellow, and the light tones of green, they form analogies of contrast. But, although white contrasts more with sombre colours than with those that are naturally luminous, there is not observed between white and those two kinds of colours the difference observable between grey and the same colours. This result confirms what I have said of the binary combinations of black. (203.)

A.—_Binary Combinations._

218. _Grey and Blue, Grey and Violet_, form arrangements of which the harmony of analogy is agreeable, yet less so than that of _black_ with the same colours.

219. _Grey and Orange, Grey and Yellow_, _Grey and Bright Green_, form equally agreeable arrangements of harmony of contrast; perhaps they are less so than those in which _grey_ is replaced by _black_.

220. _Grey and Rose_ are a little dull and inferior to _Black and Rose_. All the binary arrangements of _grey_, except, perhaps, that of _orange_, are inferior to those of _white_.

B.—_Ternary Combinations of Complementary Colours with Grey_.

221. _Red_, _Green_, _&c_.—1. _Red, Green_, &c. 2. _Grey, Red, Green, Grey_, &c. 3. _Grey, Red, Grey, Green, Grey_, &c. If it be doubtful whether the binary assortment of _grey, red, and green_, be favourable, it cannot be called injurious. The third assortment is, perhaps, inferior to that in which the grey is replaced by _black_.

222. _Blue and Orange._—1. _Blue, Orange_, &c. 2. _Grey, Blue, Orange, Grey_. 3. _Grey, Blue, Grey, Orange, Grey_, &c. I prefer the first arrangement to the two others.

223. _Yellow and Violet._—1. _Yellow, Violet_, &c. 2. _Grey, Yellow, Violet, Grey_, &c. 3. _Grey, Yellow, Grey, Violet, Grey_, &c. Although the arrangements 2 and 3 are lighter than the arrangements in which _grey_ is replaced by _black_, yet the binary arrangement appears to me preferable to the ternary.

C.—_Ternary Assortments of Colours not Complementary to each other with Grey._

224. _Red and Orange._—1. _Red, Orange_, &c. 2. _Grey, Red, Orange, Grey_, &c. 3. _Grey, Red, Grey, Orange, Grey_, &c. The arrangements 2 and 3 are preferable to the binary. The third is preferable to the second. In short, the grey produces, with _red_ and _orange_, a better effect than _white_, but the effect is inferior to that of _black_.

225. _Red and Yellow._—1. _Red, Yellow_, &c. 2. _Grey, Red, Yellow, Green_, &c. 3. _Grey, Red, Grey, Yellow, Grey_, &c. Although the grey combines well with the _red_ and the _yellow_, it has not so decidedly advantageous an effect as _black_ in the binary arrangement.

226. _Red and Blue._—1. _Red, Blue_, &c. 2. _Grey, Red, Blue, Grey_, &c. 3. _Grey, Red, Grey, Blue, Grey_, &c. The arrangement 2 is preferable to 3. I dare not say to 1. The effect of grey is inferior to that of _white_.

227. _Red and Violet._—1. _Red, Violet_, &c. 2. _Grey, Red, Violet, Grey_, &c. 3. _Grey, Red, Grey, Violet, Grey_, &c. The assortment 3 appears to me superior to 2, and the second to the first; but it is difficult to say whether _grey_ is superior to _black_. I am certain it is superior to _white_.

228. _Orange and Yellow._—1. _Orange, Yellow_, &c. 2. _Grey, Orange, Yellow, Grey_, &c. 3. _Grey, Orange, Grey, Yellow, Grey_, &c. The assortment 3 appears to me preferable to 2; the harmony of contrast is less intense than with _black_. The assortment 3 is, perhaps, superior to the assortment of _white, orange, white, yellow, white_.

229. _Orange and Green._—1. _Orange, Green_, &c. 2. _Grey, Orange, Green, Grey_, &c. 3. _Grey, Orange, Grey, Green, Grey_, &c. Grey combines well with _orange_ and _green_, but it does not contrast so agreeably as _black_ or _white_.

230. _Orange and Violet._—1. _Orange, Violet_, &c. 2. _Grey, Orange, Violet, Grey_, &c. 3. _Grey, Orange, Grey, Violet, Grey_, &c. The binary assortment appears to me preferable to the other two. The assortment 2 is preferable to 3. If the _grey_ is a little dull with _orange_ and _violet_, it has not the same disadvantage as _black_, in causing too great a predominance of sombre colour.

231. _Yellow and Green._—1. _Yellow, Green_, &c. 2. _Grey, Yellow, Green, Grey_, &c. 3. _Grey, Yellow, Grey, Green, Grey_, &c. _Grey_ combines well with _yellow_ and _green_, but the assortments 2 and 3 are a little dull, and inferior to those in which _black_ replaces _grey_.

232. _Yellow and Blue._—1. _Yellow, Blue_, &c. 2. _Grey, Yellow, Blue, Grey_, &c. 3. _Grey, Yellow, Grey, Blue, Grey_, &c. The two assortments, two and three, are inferior to the first. The _grey_ is heavy to _yellow_ and _blue_; its effect is inferior to that of _white_, and perhaps also to that of _black_.

233. _Green and Blue._—1. _Green, Blue_, &c. 2. _Grey, Green, Blue, Grey_, &c. 3. _Grey, Green, Grey, Blue, Grey_, &c. _Grey_, in its combination with _green_ and _blue_, has not the same objection as _black_, but it has an inferior effect to _white_.

234. _Green and Violet._—1. _Green, Violet_, &c. 2. _Grey, Green, Violet, Grey_, &c. 3. _Grey, Green, Grey, Violet, Grey_, &c. _Grey_ is not employed advantageously with _green_ and _violet_, it is inferior to _white_ in the ternary arrangements, and perhaps I should also give preference to _black_.

235. _Blue and Violet._—1. _Blue, Violet_, &c. 2. _Grey, Blue, Violet, Grey_, &c. 3. _Grey, Blue, Grey, Violet, Grey_, &c. The remarks made (218) in the assortment of _black_ with _blue_ and _violet_ are applicable to the arrangement with grey, taking into account the difference of tone which exists between _grey_ and _black_.

Recapitulation.

236. I will now give a summary of the observations which appear the most striking on reading the foregoing paragraphs, premising, however, that I do not pretend to establish laws fixed upon scientific principles, but to state general propositions which express my own peculiar taste.

237. 1st. _In the harmony of contrast the complementary arrangement is superior to every other._

The tones must be as nearly as possible of the same depth to produce the finest effect. The complementary arrangement in which white associates most advantageously, is that of blue and orange, and that of yellow and violet is the least advantageous.

238. 2nd. _The Primaries, Red, Yellow, and Blue associated in pairs assort better together, as a harmony of contrast, than an arrangement formed of one of these primaries, and of a binary colour in juxtaposition with it, having the same primary as one of its elements._

Examples.

Red and Yellow accord better than Red and Orange. Red and Blue " " Red and Violet. Yellow and Red " " Yellow and Orange. Yellow and Blue " " Yellow and Green. Blue and Red " " Blue and Violet. Blue and Yellow " " Blue and Green.

239. 3rd. _The arrangement of Red, Yellow, or Blue with a binary colour containing the former, contrasts the better, as the simple colour is essentially more luminous than the binary._

Whence it follows, that in this arrangement, it is an advantage for the red, yellow, or blue to be of lower tone than the binary colour.

Examples.

Red and Violet accord better than Blue and Violet. Yellow and Orange " " Red and Orange. Yellow and Green " " Blue and Green.

240. 4th. _When two colours accord badly together, it is always advantageous to separate them by White._

In this case it is more advantageous to place each colour next to white, than in an assortment where the two colours are together beside white.

241. 5th. _Black never produces a bad effect when it is associated with two luminous colours. It is therefore often preferable to White, especially in an assortment where it separates the colours from each other._

Examples.

1. Red and Orange.

Black is preferable to white in the arrangements 2 and 3 of these two colours. 2. Red and Yellow. 3. Orange and Yellow. 4. Orange and Green. 5. Yellow and Green.

Black, with all these binary assortments, produces harmony of contrast.

242. 6th. _Black in combination with sombre colours, such as blue and violet, and with broken tones of luminous colours, produces harmony of analogy, which, in many instances, may have a good effect._

The harmony of analogy of black, associated with blue and violet, is preferable to the harmony of contrast of the assortment white, blue, violet, white, &c., the latter being too crude.

243. 7th. _Black does not accord so well with two colours, one of which is luminous, the other sombre, as when it is associated with two luminous colours. In the first instance the combination is so much the less agreeable as the luminous colour is more brilliant._

With all the following assortments Black is inferior to White. 1. Red and Blue. 2. Red and Violet. 3. Orange and Blue. 4. Orange and Violet. 5. Yellow and Blue. 6. Green and Blue. 7. Green and Violet.

With the assortment yellow and violet, if it is not inferior to white, it produces only a mediocre effect.

244. 8th. _Although Grey never produces exactly a bad effect in its association with two luminous colours, yet in most cases its assortments are dull, and it is inferior to Black and White_.

Among the assortments of two luminous colours, there are scarcely any besides those of red and orange with which grey associates more happily than white. But it is inferior to it, as also to black, in the arrangements red and green, red and yellow, orange and yellow, orange and green, yellow and green. It is also inferior to white, with yellow and blue.

245. 9th. _Grey, in combining with sombre colours, such as Blue and Violet, and with broken tones of luminous colours, produces harmonies of analogy, which have not the vigour of those with black; although the colours do not combine well together, it has the advantage of separating them from each other._

246. 10th. _When Grey is associated with two colours, one of which is luminous the other sombre, it will perhaps be more advantageous than White, if this produces too strong a contrast of tone; on the other hand, it may be more advantageous than Black, if that increases too much the proportion of sombre colours._

Examples.

Grey associates better than Black with—

1. Orange and Violet. 2. Green and Blue. 3. Green and Violet.

247. 11th. If, when two colours accord badly, there is in principle an advantage in separating them by White, Black, or Grey, it is important to the effect to take into consideration—1. The height of tone of the colours. 2. The proportion of sombre to luminous colours, including, in the first, the broken brown tone of the brilliant scales, and in the luminous colours, the light tones of the Blue and Violet scales.

Consider the height of tone of the colours.

248. The effect of white with red and orange is inferior as their tones become higher, especially in the assortment white, red, orange, white, &c.; the effects of the white being too crude. On the contrary, black unites very well with the normal tones of the same colours, that is to say, the highest tones without any mixture of black. Although grey does not associate so well as black with red and orange, it has the advantage of producing a less crude effect than white.

Consider the proportion of sombre to luminous colours.

249. Whenever colours differ very much, either in tone or in brilliancy, from the black or white with which we wish to associate them, that arrangement where each of the two colours is separated from the other by black or white, is preferable to that in which the black or the white separate each pair of colours. Thus the assortment white, blue, white, violet, white, &c., is preferable to the assortment white, blue, violet, white, &c., because the separation of the brilliant from the sombre is more equal in the first than in the second. I should add that this is somewhat more symmetrical as to the position of the two colours, and the principle of symmetry influences our judgment of things more than is generally recognised. It is also in conformity with the above, that the assortment black, red, black, orange, black, &c., is preferable to the assortment black, red, orange, black, &c.

250. Some remarks appear to me also necessary to prevent false deductions from the above propositions. In the preceding examples, the colours, including white, black, and grey, are supposed to occupy an equal extent of surface, and to be placed at equal distances apart, for without these conditions the results will be different; for example, I have preferred the assortment white, red, white, yellow, white, to the assortment white, red, yellow, white. There are some cases in which the latter is preferable to the former, as in the arrangement of flowers in gardens, especially yellow and rose flowers, which present less coloured surface than the white flowers with which they are associated.

251. I have spoken of the good effects of black and green separated, and I may add that green designs upon a black ground are also agreeable; but it does not follow that black lace upon a green stuff will have a good effect, at least on the optical quality of black, for this acquires a rusty tint, which resembles a faded colour.

252. The more colours are opposed, the easier it is to assort them; because they do not experience by their mutual juxtaposition, any modification which renders them disagreeable, as generally happens to colours which are very nearly alike. Must we then conclude that with two colours which have in this case been indicated to an artist to be employed, with some liberty to modify them, he should endeavour to increase the effect of contrast rather than that of analogy? Certainly not; for frequently the latter is preferable to the former. For example:—Take orange-red and a pure red, instead of increasing the yellow in the orange-red, or of giving a violet hue to the red, it sometimes will be preferable to incline towards the harmony of scale or of hue, by endeavouring to make the orange one of the light tones of a scale whose red will be brown.

253. In conformity with this manner of observing, when we would avoid the bad effect of two adjacent colours by white, black, or grey, we must see whether, instead of a harmony of contrast, it may not be better to obtain the harmony of analogy.

254. Finally, when we bring into combination not normal grey, but a coloured grey, we are always sure of obtaining an effective harmony of contrast by taking a grey coloured with a complementary of that opposed to it. Thus an orange-grey or carmelite-brown or maroon has a good effect with light blue.

FIRST DIVISION.—IMITATION OF COLOURED OBJECTS WITH COLOURED MATERIALS IN A STATE OF INFINITE DIVISION.

INTRODUCTION.

255. Coloured materials, such as Prussian blue, chrome-yellow, vermilion, &c., are infinitely divided, so to speak, either when ground pure, or mixed with a white material, in a gummy or oily liquid.

The reproduction of the images of coloured objects with these pigments is called the _Art of Painting_.

256. There are two systems of Painting—the one consists in representing as accurately as possible upon a flat surface an object in relief in such a way that the image makes an impression upon the eye of the spectator similar to that which the object itself would produce. This is termed the _Art of Chiaro-'scuro_.

257. There is a means of imitating coloured objects much simpler in its facility of execution than the preceding. It consists in tracing the outline of the different parts of the model, and in colouring them uniformly with their peculiar colours. There is no relief, no projection; it is the plane image of the object, since all the parts receive a uniform tint: this system of imitating is _Painting in Flat Tints_.

PAINTING ON THE SYSTEM OF CHIARO-'SCURO.

258. Are the modifications perceived in a single coloured object, for example, in a blue or red stuff, &c., indeterminable, when these draperies are seen as draperies of a vestment or furniture, with more or less distinct folds, or are they determinable, in given circumstances? This is a question of which I am about to attempt a solution.

259. Firstly, let us distinguish three circumstances in which modifications of colours may be observed:—

1. Modifications produced by coloured lights falling upon the model.

2. Modifications produced by two different lights—as, for example, the light of the sun and diffused daylight—each illuminating different parts of the same object.

3. Modifications produced by diffused daylight.

260. We will suppose that in the two first cases the lighted surfaces are plane, and that all their superficial parts are homogeneous, and in the same conditions, except that of light. In the third case, we shall consider the position of the spectator viewing an object lighted by diffused daylight, the surface of which is not so disposed as to act equally in all its parts upon the light which it reflects to the eye of the spectator.

261. Modifications produced by coloured lights.

Red rays falling on Black make it appear Purple-black. " White " Red. " Red " Redder. " Orange " Redder. " Yellow " Orange. " Deep Green " Red-black. " Light Green " Reddish-grey. " Light Blue " Violet. " Violet " Purple.

262. Modifications produced by Orange light.

Orange rays falling on— Black make it appear Maroon, or Carmelite-brown. White " Orange. Orange " More vivid. Red " Scarlet. Yellow " Yellow-orange. Light Green " Yellow-green. Deep Green " Rusty-green. Light Blue " Orange-grey. Deep Blue " Grey, slightly Orange-grey. Indigo Blue " Orange-maroon. Violet " Red-maroon.

263. Modifications produced by Yellow light.

Yellow rays falling on— Black make it appear Yellow-olive. White " Light Yellow. Yellow " Orange-yellow. Red " Orange. Orange " Yellower. Green " Greenish-yellow. Light Blue " Yellow-green. Deep Blue " Green-slate. Indigo " Orange-yellow. Violet " Yellow-maroon.

264. Modifications produced by Green light.

Green rays falling on— Black make it appear Greenish-brown. White " Green. Green " More intense and brilliant. Red " Brown. Orange " Faint Yellow, a little Green. Green " Greener, according to its depth. Indigo " Dull Green. Violet " Bluish-green Brown.

265. Modifications produced by Blue light.

Blue rays falling on Black make it appear Blue-black. Black " White " Blue. " " Blue " More vivid. " " Red " Violet. { Brown, having a " " Orange " { pale tint of Violet. Blue " Yellow " Green. " " Green " Blue-green. " " Indigo " Dark-blue Indigo. " " Violet " Dark-blue Violet.

266. Modifications produced by Violet light.

{Very faint Violet rays falling on Black make it appear {Violet-black. " " White " Violet. " " Violet " Deeper Violet. {Red-violet " " Red " {Purple. " " Orange " Light Red. {Brown, with a " " Yellow " {very slight tint {of Red. " " Green " Light Purple. {Fine Blue " " Blue " {Violet. {Deep Blue " " Indigo " {Violet.

267. It is understood that to represent the preceding phenomena exactly, we must take into account the facility with which coloured light penetrates every kind of glass, the more or less intense colour of the stuff, and the kind of scale to which the coloured stuff and that of the transmitted coloured light respectively belong.

268. These observations were made by partially exposing coloured stuffs to the sun's rays transmitted through coloured glasses. The portion of stuff not exposed to these rays, was lighted by the direct light of the sun. The portion of stuff which received the action of the coloured rays being exposed to diffused daylight, reflected also rays of that light which it would have reflected in case it had been protected from the influence of the rays transmitted to it through coloured glasses.

269. II. Modifications produced by two lights of different intensity.

270. 1. The modification by the light of the sun falling upon one part of the surface of a coloured body, while the other part is enlightened by diffused daylight.

2. The modification produced when two parts of the same object are unequally illuminated by diffused daylight.

An object lighted partly by the sun, and partly by diffused daylight.

271. To observe this kind of modification properly, let us expose to the sun a square piece of stuff A B, two and a half inches broad (Plate I., fig 4) and place in the middle a piece of black wire _f, f■_; then put parallel to this, and in the middle between A and B, two wires _e, e■_ and _g, g■_, of about three-tenths of an inch in width. The extremity _g■_ is fixed upon a perpendicular plane, so high, that all the part B _f, f■_ may be in shadow.

272. 1. _If the stuff is red_, the lighted portion A is more orange or less blue than the part B, which is in shade; and the portion _a_ is more orange than the portion _a■_, as the portion _b_ is bluer than the portion _b■_.

273. 2. _If the stuff is orange_, A is more orange or less grey than B; and the portion _a_ is deeper, more vivid than _a■_, as _b_ is more grey and duller than _b■_.

274. 3. _If the stuff is yellow_, A is more vivid, more orange than B; _a_ is more so than _a■_, as _b_ is duller than _b■_.

275. 4. _If the stuff is green_, A is less blue or more yellow than B; and _a_ is of a yellower green than _a■_, as _b_ is bluer than _b■_.

276. 5. _If the stuff is blue_, A is less violet and more green than B; and _a_ is greener than _a■_, as _b_ is more violet or less green than _b■_.

277. 6. _If the stuff is indigo_, A is redder or less blue than B; and _a_ is redder than _a■_, as _b_ is deeper or bluer than _b■_.

278. 7. If the stuff is violet, A is less blue than B; and _a_ is redder than _a■_ as _b_ is bluer than _b■_.

279. 2nd. Two contiguous parts of the same object unequally illuminated by the same light, when viewed simultaneously, differ from each other, not only in depth of tone, but also in optical composition of colour.

Place half-a-sheet of coloured paper (Plate I., fig. 5) upon the partition _b_, of a chamber receiving diffused daylight by a window _f_: place another half-sheet upon the partition _a_, in such a manner that it will be lighted directly by the diffused light, while the other is only indirectly lighted by reflection from the walls, floor, and ceiling: the diffused light thus reflected being only white light, then stand at _c_, so as to see both half-sheets at once. I shall designate that which is upon the partition _a_, and most lighted, by A, and the other, which is upon the partition _b_, and less lighted, by B.

These letters in the plate indicate the respective positions of the half-sheets.

280. The inference from these observations is, that the colour of the same body varies, not only in intensity of tone, but also of hue, according as it is lighted directly by the sun, by diffused daylight, or by diffused reflected light. This result must never be overlooked whenever we define the colours of material objects.

3rd. _Modifications produced by diffused daylight reflected by a surface all the parts of which are not in the same position relatively to the eye of the spectator._

281. Distant bodies are rendered perceptible to the eye only in proportion as they radiate or reflect, or transmit the light which acts upon the retina.

According to the laws of reflection, it happens that those portions of a surface which are in relief, or hollow, must reflect the light in such a manner, that the eye of the spectator, in a given position, will see these parts very variously lighted, in respect to the intensity of reflected light, so that the parts of this surface will be, relatively to the eye, in the same condition as the homogeneous parts of a plane surface, which are illuminated by lights of unequal intensity.

There will be this difference, however, that the parts of the surface of a body which appears to us hollow, and especially in relief, being but feebly varied in the greater number of contiguous parts, there will be generally a gradual diminution of the effects observed in the case in which we have studied the modifications of two plane homogeneous surfaces, lighted by diffused lights of unequal intensity. The sphere presents a remarkable example of the manner in which light is distributed over a convex surface, relatively to the eye of an observer, who views it from a given position.

282. I shall not occupy myself with this gradation of white light, from parts illuminated to those which do not appear so. I regard only the principal modifications, and take for examples the cases where they are as evident as possible. These modifications can be reduced to the four following:—

First modification, produced by the maximum of white light which the surface of a coloured body is capable of reflecting.

283. Other things being equal, the more highly the surface of a body is polished, the more it will reflect white and coloured light. If we observe the surface of a stick of sealing-wax, suitably placed, we shall perceive a white stripe parallel to the axis of the cylinder, produced by so large a quantity of colourless reflected light that the red light reflected from this stripe is not appreciable by the eye. Thus the white light reflected by a coloured body may be of sufficient intensity to render the colour of the body in some of its parts imperceptible.

Second modification, produced by those parts of a coloured surface which send to the eye, in proportion to the coloured light, less white light than the other parts differently lighted, or differently placed in relation to the spectator.

284. When the eye sees certain parts of the surface of a polished or uniformly coloured object which reflects to it proportionally to the coloured light less of white light than the other parts, the first parts will appear in most cases of a more intense tone of colour than the second. We will cite the following:—

Example 1.—A cylinder of red sealing-wax presents, proceeding from the white stripe mentioned above, a red colour deeper in proportion as less white light reaches the eye. Thus, in a certain position where the white stripe appears to be in the middle of the cylinder, the part most lighted will appear coloured, reflecting a red inclining to scarlet, while that which is the least lighted reflects a red inclining to crimson.

Example 2.—If the eye is directed into a gold vase of sufficient depth, the gold does not appear yellow as on the exterior surface, but of a red-orange; because less white light, in proportion to coloured light, reaches the eye in the first case than in the second. It is for this reason that the concave parts of gold ornaments appear redder than the convex.

Example 3.—The spiral thread of a piece of twisted silk or wool held perpendicularly before the eye, appears in the part opposite to the light, of a much more decided colour than on the rest of the surface.

Example 4.—The folds of bright draperies present the same modification to an eye properly placed; the effect is particularly remarkable in yellow silk stuffs, and in sky-blue; for we can easily understand that it is less marked when the stuffs are less bright and of dark colours.

Example 5.—There are some stuffs which appear to be of two tones of the same scale of colour, and sometimes also of two tones of two contiguous scales, although the weft and the warp of these stuffs are of the same tone and the same colour. The cause of this appearance is very simple; the threads which, parallel to each other, form the designs, are in a different direction to the threads which constitute the ground of the stuff. Hence, whatever may be the position of the spectator with regard to the stuff, the threads of the design will always reflect coloured and white light in a different proportion to that reflected by the threads of the ground, and, according to the position of a spectator, the design will appear to be lighter or darker than the ground.

Third modification.—The colour complementary to that of a coloured object developed in one of its parts, in consequence of simultaneous contrast.

285. A natural consequence of the law of simultaneous contrast in general, and of the effect of a colour upon grey and black in particular, is, that since the same object presents some parts more or less dark, contiguous to some parts where we see the colour peculiar to the object, the first parts will appear tinted with the complementary to this colour. But to observe this effect, it is necessary that the grey part should reflect to the eye white light, and little or none of the coloured light which the object naturally reflects.

Fourth modification, in a single coloured stuff.

286. For example, if the eye is directed towards a window which admits daylight, and a person clothed in a new blue coat, dyed with indigo or Prussian blue, be at the window, the eye will see one part of the coat will appear different from the other part, because the nap of the cloth is disposed in a contrary direction; one being of a fine blue, while the other is of an orange-grey, by the effect of contrast of the blue part with a part that reflects very little white light to the eye, without, or almost without, blue light.

287. But as the pile of the nap loses its regular position by wear, the cloth becoming dull and soiled, the coloured light is reflected irregularly from all points; and the effect is either absolutely destroyed or much weakened.

If the garment be of a deep green, the grey part will appear reddish; if it be of a violet, maroon, or claret, the grey part will appear yellow.

288. The complementary is only developed upon cloths of dark and sombre colours; thus red, scarlet, orange, yellow, and light blue garments do not exhibit it, because they have always too much of the essential colour which is reflected. The modification occurs only when one of the parts is more strongly illuminated than the other by diffused light (279).

289. There is also one circumstance where the fourth modification will appear evident; it is when we look at a series of light tones—blues, rose, &c. (belonging to the same scale)—of a skein of silk or wool, placed upon an easel, that one-half of the same skein presents to the eye the threads disposed in a contrary direction to those of the other half. The half of the skein which does not reflect coloured light to the eye, appears tinted with the complementary of the other half which does reflect it.

290. Fourth modification in a stuff presenting a dark and a light tone belonging to the same scale.

If we place in juxtaposition a dark tone and a light tone of the same scale, well assorted, the light tone will appear of the colour complementary to the scale to which it belongs. This modification is too important to allow me to pass it over hastily.

291. When we look for several seconds on a fabric dyed with a coloured ground, and on which therefore patterns intended to be white, but which, owing to the imperfection of the process employed, have received a light tone of the colour of the ground, the patterns will appear of the colour complementary to the latter. Thus, upon a ground of yellow-chromate of lead, they will appear violet; upon a ground of orange-chrome, they will appear blue; upon a green ground, rose, &c. To dispel the illusion, and to recognise the true tint of the pattern, it is only necessary to cover the ground with a white paper so perforated as to leave visible only the pattern coloured like the ground. The influence of a dark tone upon a feeble tone is such, that not only is the latter neutralized, but the place it occupies upon the cloth appears also tinted with its complementary colour.

292. From the preceding observations it follows that there may be a printed cotton, the design of which, although coloured, will appear to most eyes white, and not of the complementary of the ground. For those eyes which see it thus, the perception of the phenomenon of contrast will correct the imperfection of the art of the calico-printer.

293. In the Lectures upon Contrast, which I delivered in 1836, at the Gobelins, I remarked, that in applying paper (cut for the purpose) upon the lights of a blue drapery of the Virgin in a tapestry representing the Holy Family, after Raphael, they appeared of

a light blue, although, when they were seen surrounded with darker tones, they appeared of an orange tint.

294. We can conceive without difficulty that if the modification is not manifested with monochromous objects of vivid colours, as yellow, scarlet, &c., it is because that part of the surface of these objects which reflects the least light to the eye, always reflects enough of its peculiar colour to neutralize the complementary which the coloured light of the illuminated portion tends to develop. I believe that this effect tends to enfeeble the coloured light of the shaded part.

295. Although, in this chapter, I do not propose to treat of the modifications shown by coloured stuffs with white designs; yet, as it is a case so connected with the preceding considerations, I cannot avoid mentioning them in this place.

296. If we observe a sky-blue silk with white flowers, the weft of which is in an opposite direction to the weft of the blue ground, we shall see the flowers white, if they are placed in the most favourable manner to receive the white light reflected by them; while, in the contrary position, we shall see these flowers absolutely orange. There is still much white light reflected, but it is not sufficiently vivid to neutralize the development of the complementary of the ground.

PAINTING ON THE SYSTEM OF FLAT TINTS.

297. In painting by flat tints, the colours are neither shaded, blended together, nor modified by the coloured rays coming from the surrounding parts of the picture.

In pictures which belong to this kind of painting, the representation of the model is reduced to the observance of linear perspective, to the employment of vivid colours in the nearer parts, and of pale and grey colours in the more distant.

If the choice of contiguous colours has been made conformably to the law of simultaneous contrast, the effect of the colour will be greater than if it had been painted on the system of chiaro-'scuro.

298. In every instance where painting is an accessory, and not a principal feature, painting in flat tints is in every respect preferable to the other kind.

299. The essential qualities of painting in flat tints necessarily reside in the good choice of colours and well drawn outlines. These outlines contribute to render the impressions of colours stronger and more agreeable, when, circumscribing forms clothed in colours, they concur with them in suggesting to the mind a graceful object, when even the imitation of it does not give a faithful representation.

300. We may, in conformity with what has been said, consider that painting in flat tints may be advantageously employed,

1. When the objects represented are at such a distance that the finish of an elaborate picture would disappear.

2. When a picture is an accessory, decorating an object whose use would forbid too elaborate finish, and which would also be too costly. Such are the paintings which ornament screens, work-boxes, tables, &c.; in this case the objects preferable as models, are those whose beauty of colours and simplicity of form are so remarkable as to attract the eye by simplicity of outline, and by vivid colours: such are birds, insects, flowers, &c.

SECTION III.

ON COLOURING IN PAINTING.

CHAPTER I.

On Colouring.

301. _True or absolute colouring_ is the faithful reproduction in painting of the modifications that light enables us to perceive in the objects taken for models.

302. In the ordinary use of the word _colouring_, we allude to the more or less perfect manner in which the painter has complied with the rules,

1. _Of aërial perspective._

2. _Of the harmony of local colours, and of the colours of the different objects composing the picture._

ARTICLE I.

Of Aërial Perspective.

303. We must not believe that the employment of many colours in a composition is indispensable to give the epithet of _colourist_ to the artist, for in pictures painted in one colour only, the simplest of all, in which we only distinguish two colours including white, the artist may be honoured with the title of _colourist_, if his work presents lights and shades distributed as they are upon the model. To convince ourselves of the justice of the expression, it will suffice to remark that the model might very well appear to the painter coloured with a single colour, modified by light and shade. In the same sense this epithet may be applied to the engraver, who, by means of his burin, reproduces a picture as faithfully as possible, in respect both to the aërial perspective of its different planes, and to the relief of each particular object.

304. A painter who has faithfully reproduced the aërial perspective, with all its modifications of white and coloured light and of shades, has effected a _true or absolute colouring_, which, however, may not be universally deemed as perfect as that in which this quality of absolute colouring is not found, at least in the same degree of perfection.

Imperfectly faithful imitation.

305. _A painter may have perfectly seized upon all the modifications of white and coloured light, but in his imitation, some of these modifications are more strongly marked than in nature._

It almost always happens that _true but exaggerated colouring_ is more agreeable than absolute colouring; and that many persons who experience pleasure in seeing the modifications of exaggerated coloured light which a picture may exhibit, do not feel the same pleasure from the sight of a model, because the modifications corresponding to those which are imitated in excess are not sufficiently prominent to be evident to them. Besides the relish of the eye for an excess of an exciting cause, is essentially analogous to the inclination we have for food and drink of a pungent flavour and odour.

306. A painter may have perfectly seized all the modifications of light which bring forward the planes and the relief of objects; the modifications of the coloured light of his picture may be true, but the colours may not be those of his model. As in pictures in which there is a dominant colour, not found in the model, which is often called _the tone of such a picture, and the tone of such a painter_, if he uses it habitually.

307. We may form a very just idea of these pictures, by supposing the artist to have painted them while looking at his model through a glass of precisely the colour, to enable him to see the tint which predominates in his imitation. We may mention as an example, of this kind of imitation, a landscape painted from its reflection in a black mirror, the effect of which is very soft and harmonious. Thus we speak of brilliant or warm, cold or dull colouring.

Of Colouring in respect to the Harmony of the Colours of the various objects composing the Picture.

308. The colouring of the picture may be _true or absolute_, and yet not agreeable in effect because the colours of the objects are not harmonious. On the contrary, a picture may please by the harmony in the local colours of each object, and by that of the colours of objects contiguous to each other, and yet may offend in its gradation of lights and shades, and by the _fidelity_ of its colours. In a word, it offends by _true or absolute_ colouring, while a picture in flat tints, the colours of which are perfectly assorted for the eye, although not those which belong to the objects imitated, produces, with regard to general harmony of colours, an extremely agreeable effect.

309. The general conclusion resulting from the analysis just made of the word colouring, is, that the epithet _colourist_ may be applied to painters endowed, in very different degrees, with the faculty of imitating coloured objects by means of painting.

310. They who know the difficulties of _chiaro-'scuro_ and drawing, may give the name of colourists to painters remarkable for the skill with which they bring out objects placed upon the different planes of their pictures, by means of correct drawing and a skilful gradation of light and shade, even when their pictures do not exactly produce every modification of coloured light, and have not this harmony of different colours properly distributed to complete the effects of perfect colouring.

311. Persons unaccustomed to judge of painting, or _chiaro-'scuro_, are generally inclined to refuse the title of colourist to such painters, while they unhesitatingly accord it to others who reproduce the modifications of coloured light, and who tastefully distribute the different colours of their pictures. Besides, the eye is so powerfully influenced by colour, that frequently those who are strangers to painting can only conceive a colourist to be skilful whose tints are vivid, although his works may evince a want of observation.

312. We see by this how judgments will differ according to the importance respectively attached to one quality of colouring rather than to another.

313. For a painter to be a perfect colourist, he must not only imitate the model by reproducing the image faithfully, with respect to the variously coloured light, but also with regard to harmony of tints in the local colours, and in the colours of the different objects imitated. And although there are colours inherent to the model, which the painter cannot change without being unfaithful to nature, yet, in every composition, there are also colours at his disposal which must be chosen so as to harmonize with the rest. We shall return to this subject in the next chapter.

314. It is thus evident, that when a change in the colours of a picture has been effected by time, it is impossible to decide whether the artist who painted it should be called a _perfect_ colourist (310). But if we refer to what I have said of the painter who has correctly seized all the modifications of light adapted to bring out the distances and relief of objects, who has truly represented the modifications of coloured light, but which are not those of the model (312), we may very easily conceive how, at the present day, after the lapse of centuries, we may apply the name of _colourist_ to Albano, Titian, Rubens, and others. In fact, the pictures of these great masters now present to us gradations, more or less perfect, of light and shade, and such harmonies of colours, that it is impossible to mistake or not to admire them; and the idea that many pictures, not more than twenty or five-and-twenty years old, painted by artists of undoubted ability, have failed in colour more than the preceding, also increases our admiration of the latter.

CHAPTER II.

Utility of the Law of Simultaneous Contrast of Colours in the Art of Colouring.

315. As to the advantages the painter will find in it when it is required,—

1. To perceive and to imitate promptly and surely the modifications of the light on the model.

2. To harmonize those colours of a composition which are essentially inherent to the nature of the objects to be produced.

316. We learn by the law of _simultaneous contrast of colours_, that when we regard attentively two coloured objects at the same time, neither of them appears of the colour peculiar to it; that is to say, such as it would appear if viewed separately, but of a tint resulting from the peculiar colour and the complementary of the colour of the other object. On the other hand, if the colours of the objects be not of the same tone, the lightest tone will be lowered, and the darkest tone will be heightened.

317. The first conclusion from this is, that the painter will rapidly appreciate in his model the colour peculiar to each part, and the modifications of tone and of colour which they receive from contiguous colours. He will also perceive and be prepared to imitate modifications in them, which, if they had not always escaped him because of their feeble intensity, might have been disregarded, because the eye is peculiarly susceptible of fatigue when it seeks to disentangle modifications, the cause of which is unknown, and which are not very prominent.

318. Let us now return to _mixed contrast_ (77 _et seq._), in order to make it evident that the painter is liable to see the colours of his model inaccurately. As the eye, after observing one colour for a certain time, has acquired a tendency to see its complementary, and as this tendency is of some duration, it follows, not only that the eyes of the painter thus affected cannot see correctly the colour which he had for some time looked at, but also whatever colour he sees while this modifying influence lasts. So that, conformably to what we know of mixed contrast, he will see,—not the colour which is before him,—but the result of this colour, and of the complementary of that seen previously. It must be remarked, that besides the want of clearness of view which will arise, in most cases, from the want of exact coincidence of the second image with the first—for example, when the eye has seen a sheet of green paper A (Plate III., fig. 4), in the first place, and, in the second place, a sheet of blue paper, B, of the same dimensions, but placed differently, this second image, not being coincident in all its surface with the first, A, as represented in the figure, the eye will see the sheet B violet only in the part where the two images coincide. Consequently, this defect of perfect coincidence of images will affect the outline of the second image, as well as the colour which it really possesses.

319. We can establish three conditions in the appearance of the same object relatively to the state of the eye; in the first, the organ simply perceives the image of the object without taking into account the distribution of colours, light, and shade; in the second, the spectator, seeking to understand this distribution, observes it attentively, when the object presents to him all the phenomena of simultaneous contrast of tone and colour that it is capable of exciting in him. In the third case, the organ, from the prolonged impression of the colours, possesses in the highest degree a tendency to see the complementary of these colours; these different states of the organ being continuous.

I have no doubt that the dull colouring with which many artists of merit have been reproached is partly due to this cause, as I shall show more minutely hereafter.

Utility of this Law to facilitate the prompt Imitation of Modifications of Light on the Model.

320. The painter, knowing that the impression of one colour beside another is the result of the mixture of the first with the complementary of the second, has only to estimate mentally the intensity of the influence of this complementary, to reproduce faithfully in his imitation the complex effect which he has before his eyes.

321. A painter wishing to imitate a white stuff with two contiguous borders, one red, the other blue, perceives each of them changed by the influence of their reciprocal contrast; thus the red becomes more and more orange, in proportion as it approaches the blue, as this latter becomes more and more green as it approaches the red. The painter, therefore, making the borders of a single red and a single blue, reduced in some parts by white or by shade, will reproduce the effects he wishes to imitate. Whenever it is found that the painting is not sufficiently marked, he is sure of what he must add without departing from the truth, farther than by exaggerating a little (305).

2. A grey pattern drawn upon a yellow ground: the ground may be of paper, silk, cotton or wool; according to its contrast, the design will appear of a lilac or a violet colour (66).

The painter who would imitate this object, can reproduce it faithfully with grey. But if a painter, ignorant of the reciprocal influence of blue and red, convinced that he must represent what he sees, adds green to his blue, and orange to his red; as in the second example, he will trace a pattern more or less violet upon the yellow ground. Now, supposing that the painter had perfectly seized the modifications of the model, and, subsequently, had retouched his copy sufficiently to produce a perfectly faithful effect, it is evident it would have been perfect only after a number of trials, since he must have effaced what was first done.

3. I cite a third example of the influence of contrast, not relating to colours, like the two preceding, but to the different tones of the same colour, contiguous to each other.

Suppose several bands in juxtaposition, 1, 2, 3, 4, (Plate 1, fig. 3), of different tones in flat tints of the same scale, to form part of an object: to imitate it perfectly, it is evident that it must be painted in flat tints; but this object will appear to the eye a channeled surface, the lines where the two bands touch will appear like a relief by the effect of contrast of tone (9-11); therefore, if the painter is ignorant of this, he will reproduce, not an absolute copy of the model, but an exaggerated one. I the more willingly cite this example, because it gave me an opportunity of enabling a most skilful paperstainer to appreciate the utility of the law of simultaneous contrast. In going with him over his factory, he showed me a chimney-board representing a child whose figure stood out from a ground formed of two circular bands in grey flat tints; 1 and 2 (Plate I., fig. 7); the first was higher than the second; the phenomenon of contrast of tone was manifested at the borders, _a a_, of the two bands, so that the part of the band 2, contiguous to the band 1, was darker than the rest, as the part of the band 1, contiguous to 2, was lighter than the rest, conformably to what has been stated above (11). This effect, not being what the skilful artist wished to obtain, he inquired of me how it was to be avoided. I replied, that the grey of the band 2 must be reduced with white, in proportion as it approached the border _a a_; and, on the contrary, the grey of the band 1 must be strengthened with black, in proper gradations, beginning at the same border. And I proved to him, _that to imitate the model faithfully, we must copy it differently from what we see it_.

322. From the above we educe the six following principles:—

1. Put a colour upon a canvas, it not only colours that part of the canvas to which the pencil has been applied, but it also colours the surrounding space with the complementary of that colour.

Thus, a red circle is surrounded with a green areola, becoming weaker as it extends from the circle:—

A green circle is surrounded with a red areola. An orange " " blue " A blue " " orange " A yellow " " violet " A violet " " yellow "

(See Plates 3, 4, 5.)

2. White placed beside a colour heightens its tone; it is as if we took away from the colour the white light which enfeebled its intensity (44-52).

3. Black placed beside a colour weakens, and in some cases impoverishes, its tone, as upon certain yellows (55). It is, in fact, adding to black the complementary of the contiguous colour.

4. Put grey beside a colour, the latter is rendered more brilliant, and at the same time it tints this grey with its complementary (63).

323. From this principle it results that in many cases where grey is near to a pure colour in the model, the painter, if he wishes to imitate this grey which appears to him tinted with the complementary of the pure colour, need not use a coloured grey, as the effect will be produced in the imitation by the juxtaposition of the colour with the grey contiguous to it.

Besides, the importance of this principle cannot be doubted, when we consider that all the modifications which a monochromous object presents (excepting those which result from the reflections of coloured lights emanating from neighbouring objects,) arise from the different relations of position between the parts of the object and the eye of the spectator; so that it is strictly true to say that, to reproduce by painting all these modifications, it suffices to have a colour exactly identical to that of the model, with black and white. In fact, with white we can reproduce all the modifications due to the weakening of the colour by light, and with black, those which are due to the height of its tone. If the colour of the model in certain parts gives rise to the manifestation of its complementary, because these parts do not return to the eye enough colour and white light to neutralize this manifestation, the modification may be imitated by the employment of a normal grey tone, properly surrounded with the colour of the object.

It is necessary, in many cases, to employ with the colour of the object the colours which are near it; that is to say, the hues of the colour. For example; in imitating a rose, we can employ red shaded with a little yellow, and a little blue, or, in other terms, shaded with orange and violet; but the green shadows which we perceive in certain parts arise from the juxtaposition of red and normal grey.

5. To put a dark colour near a different, but lighter colour, is to heighten the tone of the first, and to lower that of the second, independently of the modification resulting from the mixture of the complementaries. An important consequence of this principle is, that the first effect may neutralize the second, or even oppose it. For example; a light blue placed beside a yellow tinges it orange, and consequently heightens its tone; while there are some blues, so dark relatively to the yellow, that they weaken it so much as not only to hide the orange tint, but even to cause sensitive eyes to feel that the yellow is rather green than orange. A very natural result, if we consider that the paler the yellow, the greener it appears.

6. Put beside each other two flat tints of different tones of the same colour, chiaro-'scuro is produced, because, in setting out from the line of juxtaposition, the tint of the band of the highest tone is insensibly enfeebled, while, setting out from the same line, the tint of the band of the lowest tone becomes heightened; thus there is a true gradation of light.

The same gradation takes place in all the juxtapositions of colours distinctly separated.

I believe that attention to these principles, and especially a perfect knowledge of the consequences of the last three, exercises a very happy influence upon the art of painting, giving to the artist such a knowledge of colours as he cannot possess before the law of their simultaneous contrast and its consequences have been developed.

Among the details which the painter endeavours to render, there are many which, due to contrast, either of colour or of tone, must be produced spontaneously. I presume that the Greek painters, whose palette was composed only of black, white, red, yellow, and blue, and who executed so many pictures which their contemporaries have spoken of with intense admiration, painted conformably to the simple method of which I speak; _devoting themselves to great effects_, _many small ones resulted from them_.

Utility of the Law in order to Harmonize those Colours of a Composition which are Inherent to the Nature of the Object represented.

324. In all, or nearly all, compositions of painting, we must distinguish the colours which the painter is under the necessity of using, and those which he may choose, because, unlike the former, they are not inherent to the model (313). For example, in painting a human figure, the colour of the flesh, the eyes, and the hair, are fixed by the model; but the painter has a choice of draperies, ornaments, background, &c. In an historical picture, the flesh colours are, in the majority of the figures, at the choice of the painter,

as are also the draperies and all the accessories, which can be placed and imagined according to his judgment.

In a landscape, the colours are determined by the subject, yet not so arbitrarily but that we can substitute for the true colour that of a neighbouring scale; the artist may choose the colour of the sky, imagine numerous accidental effects, introduce into his composition animals, draped-figures, carriages, &c., of which the form and colour may be so selected as to produce the best possible effect with the actual objects of the scene.

325. A painter may also choose a dominant colour which produces, on every object in his composition, the same effect as if they were illuminated by a light of the same colour, or as if they were seen through a coloured glass (259).

326. Although the law of contrast affords different methods of imparting value to a colour, genius alone can indicate the mode in which this idea should be realized in a painting.

327. Whenever the artist would attract the eye by colours, doubtless the principle of _harmony of contrast_ must be his guide. The law of _simultaneous contrast_ indicates the means of giving value to the pure colours by each other; means which, although spoken of, are but little known, as may be commonly seen in portraits of vivid colours, badly assorted; and in those numerous small compositions in tints broken with grey, where we look in vain for a pure tone; which, however, from the objects represented in them, are eminently adapted to receive all vivid colours.

328. The contrast of the most opposite colours is as agreeable as possible, when they are of the same tone. But if crudity or too great intensity of colours is feared, we must have recourse to the light tones of their respective scales.

329. When the painter breaks tones with grey, and wishes to avoid monotony, or when on the planes which are more remote, yet not so remote as to render their differences of colour inappreciable, he wishes every part to be as distinct as possible, he must have recourse to the principle of _harmony of contrast_, and mix his colours with grey.

330. This method of bringing out a colour by contrast, in using either light tones complementary or more or less opposed, or broken tones more or less grey, and of tints complementary to each other; or, in employing a broken tone, of a tint complementary to a more or less pure contiguous colour, ought especially to fix the attention of portrait painters. A portrait will have a very poor effect when neither the colour of the dress nor of the background have been well chosen.

331. The portrait-painter must endeavour to find the predominating colour in the complexion he has to paint; and this found and faithfully reproduced, he has to seek whatever accessories at his disposal will give value to it. It is a very common error to suppose that the complexion in women, to be beautiful, must consist only of red and white: if this opinion be true for most of the women of our temperate climate, it is certain that in warmer regions there are brown, bronzed, or even copper complexions endued with a brilliancy, I may say beauty, appreciated only by those who, in pronouncing upon a new object, lay aside habitual expressions, which (albeit unconsciously to most men), exercise so powerful an influence upon their judgment of objects seen for the first time.

See the section in which I have treated of _the application of the law of contrast to dress_. (Div. V.)

332. In order to make the best use of colours without being under the necessity of multiplying them, as, for example, in draperies of a single colour, recourse may be had to the coloured rays emanating from neighbouring bodies, whether visible to the spectator or out of sight. For example, a green or yellow light falling upon part of a blue drapery renders it green, and by contrast heightens the blue-violet tone of the rest; a golden yellow light falling on part of a purple drapery imparts to it a golden tint, which makes the purple of the rest come out, &c.

333. The principle of harmony of contrast then procures for the painter in chiaro-'scuro the means of realising, with respect to brilliancy of colours and distinction of parts, such effects as are produced in paintings of flat tints.

334. Having treated of the utility of the law of simultaneous contrast in the intelligent use of pure opposite colours, and of colours broken by grey similarly opposed when it is required to multiply pure and varied colours, it now remains for me to treat of those cases in which the painter, desiring less diversity in the object, less variety in the colours, employs sparingly the _harmony of contrast_, preferring the _harmony of scale_ and the _harmony of hues_.

335. The greater the variety of colours and accessories in a composition, the more the eyes of the spectator are distracted, and the more difficulty is experienced in fixing attention. If then, this condition of diversity of colours and accessories is obligatory on the artist, the more obstacles there are to surmount in drawing and fixing the attention of the spectator upon the physiognomy of the

figures, whether they represent the actors in a single scene, or whether they are simply portraits. In the latter case, if the model has such an ordinary physiognomy, as recommends itself neither by its expression nor its beauty, and still more, if he must conceal or dissemble a natural defect, all that is accessory to this physiognomy, all the resources of contrasted colours, well assorted, should come to his aid.

336. But if, fervently inspired, he appreciates the purity of expression, the nobility and loftiness of character pertaining to his model; or even if a physiognomy, to most eyes commonplace, strikes him by such an expression as he judges to belong only to men animated by noble ideas, it is to such a model that he will address himself and fix his chief attention; so that in giving it life upon his canvas, no one can mistake either the resemblance, or the sentiment which directed his pencil. Everything being accessory to the physiognomy, the draperies will be of black or of sombre colours; and if ornaments relieve them, they will be simple, and always in keeping with the subject.

337. When, in this point of view, we examine the masterpieces of Vandyke, and trace the beauty of their effect to the simplicity of the means which produce it,—when we consider the elegance of their attitudes, which always appear natural, the taste which presided over the selection of all the accessories, we are struck with admiration of the genius of the artist, who has not had recourse to those means, so much abused at the present day, of attracting attention, either by giving to the most vulgar person an heroic attitude, to the most commonplace physiognomy pretension to profound thought, or by seeking extraordinary effects of light, such as filling the figure with a strong light, while the rest of the composition is in shade.

338. These reflections indicate the course which an historical painter must take, when he would particularly fix the attention upon the physiognomy of the persons in a remarkable scene. The more he employs allied scales, the more care he must take to select such as do not lose too much by their mutual juxtaposition.

339. There is another important direction to give, which is to avoid as much as possible the same kind of images on different objects; thus figures clothed in draperies with large flower patterns, in a room where the carpet and porcelain vases repeat the same images, are never free from objection, for it is troublesome to the eye to distinguish those parts of the picture which the similarity of ornaments tends to confound. Upon the same principle, the painter must generally avoid placing beside the faithful copy of a model the copy of an imitation which repeats this model. For example, when, he paints a vase of flowers, the artist produces most effect, other things being equal, in painting a vase of grey or white porcelain, instead of a vase upon which a profusion of similar objects are its ornaments.

340. When it is required that a certain colour shall predominate in a composition, or to speak more correctly, when the scene is illuminated by a coloured light, shed over every object, we must not only take simultaneous contrast into consideration, but also the modification which results from the mixture of colours (172), comprising the recomposition of white light by means of a proper proportion of the differently coloured elementary rays.

341. We must here attentively study the article which treats of the principal cases of the modifications of light resulting from coloured rays falling upon bodies of various colours (261, _et seq._), when, although the coloured light chosen imparts value to certain colours of the objects upon which it falls, it also impoverishes and even neutralizes others. Consequently, in employing any predominant colour, we must renounce the advantages of others, or the effect produced will be false. For example: if orange colour predominates, for the colouring to be true it must necessarily follow—

1. That the purples must be more or less red. 2. That the reds must be more or less scarlet. 3. That the scarlets must be more or less yellow. 4. That the orange must be more intense, more vivid. 5. That the yellows must be more or less intense, and orange. 6. That the greens lose their blue, and consequently become yellower. 7. That the light blues become more or less light grey. 8. That the deep indigo becomes more or less maroon. 9. That the violets lose some of their blue.

Thus we see that orange light heightens all the colours which contain red and yellow, while, neutralizing a portion of blue in proportion to its intensity, it destroys wholly or partially this colour in the body which it illuminates, and consequently disturbs the greens and the violets.

342. With reference to the true imitation of colouring, it appears to me that painters of interiors, have, other things being equal, more skill than historical painters in faithfully reproducing the modifications of light. Historical painters, attaching more importance to the attitudes and physiognomy of their figures than to the other parts of their composition, attend less to small details, the faithful imitation of which is the essential merit of the painter of interiors. Besides, the historical painter is never in a position to see the

whole of the scene he would represent, while the painter of interiors, having constantly his model before him, sees it completely, as he imitates it upon the canvas. Hence, therefore, in every small composition the colours, as well as the objects represented, must be distributed with a kind of symmetry, so as to avoid being what I can best express by the term _spotty_. In fact, for want of a good distribution of objects, the canvas will not be filled in some parts, or, if it is, there will be, in many places, evident confusion; so also if the colours be not properly distributed, the picture will be spotty, because they are too far isolated from the others. (See 249-251.)

343. I believe that those painters who will study the mixed and simultaneous contrasts of colours, in order to employ rationally the coloured elements of their palette, will perfect themselves in _absolute colouring_ as by studying the principles of geometry they perfect themselves in linear perspective. I have no doubt but that the difficulty encountered by painters ignorant of the law of contrast, of faithfully imitating their model, has been with many the cause of a colouring dull and inferior to that of artists, who, less careful than they in the fidelity of imitation, or not so well organized for seizing all the modifications of light, have worked more by their first impressions, or, in other words, seeing the model more rapidly, their eyes have not had time to become fatigued; and thus, content with the imitation which they have made, they have not returned to their work too often to modify, to efface, and afterwards to reproduce it upon a canvas soiled by the colours first put on. There are, indeed, many painters, to whom the maxim, "Let well alone," is peculiarly applicable.

SECOND DIVISION.

Imitation of Coloured Objects by Materials of a Definite Size, as Threads, &c.

344. The tapestries of Gobelins and of Beauvais, and also the carpets of Savonnerie, and certain very elaborate mosaics, may all be considered as works which resemble the method of painting in _chiaro-'scuro_; while the windows of Gothic churches correspond more or less exactly to painting in _flat tints_; so also with tapestries for furniture and carpets, which, instead of being fabricated with scales of at least sixteen or eighteen tones, as they are in the royal manufactories, are composed with scales consisting of three or four tones only, and, far from imitating the effects of _chiaro-'scuro_, the coloured objects produced present to the eye only small monochromous bands of a single tone.

345. There are also some works whose coloured designs are upon a kind of mixed system, being the result of the juxtaposition of monochromous single tinted parts, of a visible size, but in which the effects of _chiaro-'scuro_ are sought by using gradations of scale or a mixture of hues; such are ordinary mosaics, carpets, embroidered tapestries, &c.

346. In the patterns of tapestries and carpets, when the principal effects to be aimed at have been determined, it may be seen what points of ordinary painting may be sacrificed to obtain them, and what must be done for perfecting the _special portion of their imitation_. Beginning with the physical condition of the coloured elements the weaver employs, and the texture of the tapestry, we see the necessity of representing in this kind of work only large, well-defined objects, and especially such as are remarkable for the brilliancy of their colours. The patterns for hangings must recommend themselves more by the opposition of their colours than by the minute finish of their details. To pretend to rival painting in these manufactures is to establish a confusion most detrimental to the progress of arts, absolutely distinct from painting, both in their purpose and their means of execution.

347. The principles truly essential to these arts of imitation being once deduced from the peculiarities of each, it becomes easy to point out by what efforts we may hope to obtain true perfection.

CHAPTER I.

ON THE ELEMENTS OF GOBELINS TAPESTRY.

348. To make mixtures of coloured threads intelligently, we must be guided by the three following rules:—The first two resulting directly from observation of facts; the third being the natural deduction from the facts comprised in the two former.

RULE I.—THE BINARY MIXTURE OF PRIMARY COLOURS.

When we unite Red with Yellow, Red with Blue, Yellow with Blue, the threads must not reflect a perceptible quantity of the third primary colour, if we would have Orange, Violet, and Green as brilliant as it is possible, by this method, to obtain.

EXAMPLE A.—_Red and Yellow._

Plate 11.

3 Red threads with 1 Yellow thread, 2 " " 1 " " 1 " " 1 " " 3 Yellow " 1 Red " 2 " " 1 " "

yield mixtures which appear to the eye in proportion to the two colours mixed. There is no appearance of grey in any of these mixtures, when we employ a red more inclining to orange than to crimson, and a yellow more inclining to orange than to green.

[Illustration: PLATE XI.]

B.—_Red and Blue._

3 Red threads with 1 Blue thread, 2 " " 1 " " 1 " " 1 " " 3 Blue " 1 Red " 2 " " 1 " "

yield mixtures which appear to the eye in proportion to the two colours mixed. If we use a red and a blue inclining to violet, the mixture will contain no grey.

C.—_Yellow and Blue._

4 Blue threads with 1 Yellow thread, 3 " " 1 " " 2 " " 1 " " 1 " " 1 " "

give mixtures which appear to the eye in the proportions of the two colours mixed. If we use yellow and a blue inclining to green more than to red, the mixture will contain little or no grey.

Experiment on all the preceding mixtures demonstrates the rule above; or rather, this rule is but the expression of a generalization of facts.

RULE II.—THE MIXTURE OF COMPLEMENTARY COLOURS.

349. _When we mix Red with Green, Orange with Blue, Yellow with Violet, the colours are more or less completely neutralized, according as they are more or less perfectly complementary to each other, and as they are mixed in proper proportions. The result is a grey, the tone of which is generally higher than that of the colours mixed, if the latter are of a suitably high tone._

EXAMPLES.—_Red and Green._

Plate 12.

3 Red threads with 1 Green thread give a dull Red.

2 Red threads with 1 Green thread give a duller and a deeper Red.

1 Red thread with 1 Green thread give a Reddish-grey.

The tone a little higher than the preceding.

3 Green threads with 1 Red thread give a Green Grey, the tone higher than the Green or the Red.

2 Green threads with 1 Red thread give a Grey, less Green, and of a higher tone than the two colours.

In repeating the same mixtures with higher tones of the same scales of Green and Red, the tone of the mixture of 2 Green with 1 Red is higher relatively to that of the colours mixed, than it is in the mixtures above.

1 Red thread and 1 Yellowish-green thread give a Carmelite-brown or an Orange-grey, the tone of which is equal to that of the colours mixed.

1 Red thread and 1 Bluish-green thread give a copper-coloured mixture or catechu-brown of a higher tone than that of the colours mixed.

Hence we may conclude that red and green threads, properly assorted, and in suitable proportions, yield _Grey_.

Orange and Blue.

3 Orange threads with 1 Blue thread give a dull Orange. 2 Orange " 1 " " a duller Orange. 1 Orange " 1 " " Chocolate-grey. 3 Blue " 1 Orange " Violet-grey. 2 Blue " 1 Orange " Violet-grey. Redder than the preceding.

[Illustration: PLATE XII.]

The results are the same with deeper tones than the preceding, except that the corresponding mixtures are browner.

3 orange threads with 3 blue threads present a remarkable phenomenon, according to the intensity of the light and the position from which it is observed. The tapestry being placed in a vertical plane before the incident light when the warp is horizontal, we perceive _blue_ and _orange_ stripes; but if the warp is vertical, we may then see the upper part of each blue stripe _violet_, and its under part, as well as the upper part of each orange stripe _green_, while the rest of each of the latter will appear _red_, bordered on the lower part with _yellow_. We may also see the upper part of each blue stripe, _violet_, and its under part, as well as the upper part of each orange stripe, _green_, and the rest of each of these stripes _red_, bordered on the lower part with green, and in the upper part with yellow. We say that they may be seen in this manner, because if the light were strong enough for distinct vision, we should not see the horizontal blue and orange stripes.

Yellow and Violet.

3 Yellow threads with 1 Violet give a Greyish-yellow. 2 " " 1 Violet " Yellow-grey. 1 " " 1 Violet " Grey, much nearer _normal grey_ than the preceding.

3 Violet threads and 1 Yellow give a Greyish-violet. 2 " " 1 Yellow " dull Violet, greyer than the preceding.

It is remarkable that in the mixture of a yellow with a violet thread, seen from a greater distance than that at which they appear neutralized, the yellow is so much weakened in proportion to the violet, that the mixture appears of a dull violet.

Yellow and blue afford an analogous result.

RULE III.—THE MIXTURE OF THE THREE PRIMARY COLOURS IN SUCH PROPORTIONS THAT THEY DO NOT BECOME NEUTRALIZED, BECAUSE ONE OR THE OTHER OF THEM IS IN EXCESS.

350. _When Blue, Red, and Yellow are combined in such proportions that they do not neutralize each other, the result is a colour much greyer or more broken than if the proportion of complementary colour were more equal._

As Red mixed with a Greenish-yellow gives a _Carmelite_ mixture, I shall add the following:—

1. _Crimson-red and greenish-yellow_ give mixtures so much duller as these colours more nearly neutralize each other. A mixture of one crimson-red with one greenish-yellow thread produces a brick or copper-orange, the tone of which is higher than that of the colours mixed.

2. _Scarlet-red and greenish-blue_ give mixtures which are without vigour or purity, relatively to the corresponding mixtures made with crimson-red and violet-blue.

3. Red and blue-grey give violet mixtures, which are not so dull as the preceding, because the colours contain no yellow.

4. The red of the mixture 3, worked with a green-grey, gives mixtures much duller than the preceding, as might have been expected, on account of the yellow contained in the green-grey.

5. Orange and blue-violet give very dull mixtures.

6. Orange and red-violet give dull mixtures, but redder or less blue than the preceding.

ON THE PRINCIPLE OF CONTRAST IN CONNEXION WITH THE PRODUCTION OF TAPESTRY.

351. The tapestry-weaver should therefore thoroughly understand the effects of contrast, to know the influence which the part of the copy he proposes to imitate receives from the colours surrounding it, and so judge what coloured threads to choose. The following examples will explain better than the most profound reasoning the necessity for the tapestry-worker to possess a knowledge of the law of contrast.

First Example.

352. If there be two coloured stripes in a picture, one red the other blue, touching each other, the phenomenon of contrast between two contiguous colours would have arisen, had not the painter sustained the red by blue, and the blue stripe by making it red or

violet next to the red stripe (320).

353. Suppose a weaver wishing to imitate these two stripes, but ignorant of the law of contrast of colours, after choosing the wools or silks, he is sure to make two stripes, which will produce the phenomenon of contrast; for he will select his wools or silks of only one blue or one red, to imitate two stripes of different colours, each of which appears homogeneous throughout, but which the painter has only succeeded in making so by neutralizing the phenomenon of contrast, which would undoubtedly have resulted had each been painted of a uniform colour.

354. Suppose the painter has painted the stripes with uniform colours, then contrast will arise, so that the red contiguous to the blue will appear orange, and the blue contiguous to the red will appear greenish.

If the weaver be ignorant of the law of contrast, in attempting to imitate his model he will be sure to mix yellow or orange with his red, and yellow or green with his blue, in those parts of the stripes which come in contact. Hence the contrast will be more exaggerated than if he had worked the two stripes with homogeneous colours.

355. Suppose a weaver has to copy the series of ten grey stripes in flat tints (fig. 3, Plate 1) described (11), it is evident that if he is ignorant of such effects he will exaggerate it in the imitation; for instead of working ten tints of the same scale so as to produce ten bands in flat tints, he will make ten bands, each graduated conformably to what he sees; he will probably also have recourse to lighter and darker tones than those which correspond exactly to the model, and thus he will require a greater number of tones than would have been necessary had he been aware of contrast, rendering the copy an exaggeration of the model.

When we attentively observe the rosy flesh tints of many pictures, we perceive in the shadows a more or less apparent green tint, resulting from the contrast of rose with grey. (I presume that the painter has made his shadows without using green, and that he has not corrected the effect of contrast by using red.) Now a weaver, ignorant of the effect of rose upon grey, in imitating the shaded part will have recourse to a green-grey, which will exaggerate an effect that would have been produced naturally by employing a scale of pure, not of greenish grey.

QUALITIES WHICH PATTERNS FOR GOBELINS TAPESTRY MUST POSSESS.

356. To determine the qualities which model pictures for tapestry must possess, we must decide what are specific qualities peculiar to this kind of imitation.

The weaver imitates objects with coloured threads of a certain diameter. These threads are applied round the threads of the warp. Their surface is not uniform but furrowed, those which are parallel to the threads of the warp being lower than those which are perpendicular to it; the effect of these furrows being such as would be produced upon a picture, by a series of dark parallel lines, cut at right angles by another series of finer parallel lines, less dark than the preceding.

357. There are these differences then between tapestry and painting:—

1. Tapestry never presents those blended colours which the painter obtains so easily by indefinitely mixing or dividing his pigments.

2. The symmetry and uniformity of the furrows of tapestry prevent the lights being as vivid, and the shadows as vigorous, as in a painting; for though the furrows obscure the lights, the salient parts of the threads which are in the shades, have the ill effect of enfeebling the latter by the light they reflect.

3. The lines surrounding the different objects in a painting, although straight or curved in every direction, may be of extreme fineness without ceasing to be perfectly distinct, while the threads of the weft and the warp, always crossing at right angles, interfere with such a result whenever the lines of the pattern do not exactly coincide with these threads.

4. The painter has other resources, which are denied to the weaver, for increasing the brilliancy of the lights and the vigour of the shadows. For instance: he opposes opaque body-colours to glaring colours, he modifies an object of a single colour by varying the thickness of the layer of paint which he places on the canvas; and within certain limits he can produce modifications, by changing the direction of the strokes of his pencil.

358. Hence, to raise the effects of tapestry as nearly as possible to those of painting, it is requisite:—

1. That the objects be represented of such a size that the position of the spectator does not permit of his distinguishing either the coloured elements from each other, or the furrows which separate them; so that threads of two mixed scales (377), and the

hatchings of different scales, more or less distant, interwoven together (378), may be mingled into a homogeneous colour, and that the cavities and salient parts may appear as a uniform surface.

2. That the colours be as vivid and strongly contrasted as possible, so that the lines which surround the different objects be more distinct, and the lights and shadows be as different as possible.

359. Thus patterns for tapestry must not only recommend themselves by correct outline and elegant forms, but must also represent larger objects: figures draped rather than nude, vestments decorated with ornaments, rather than simple and uniform. Consequently, every thing allied to miniature, by minuteness or by finish in details, is foreign to its special object.

360. The elements of Beauvais tapestry for furniture are essentially the same as those of Gobelins tapestry; but with this difference, that the light and the middle tones are of silk, while in the Gobelins tapestry these tones are almost always of wool. The scales of Beauvais are less varied in colour than those of the Gobelins, and their tones are less numerous. But the working of the threads is the same in both kinds of tapestry; so that as to the employment of coloured threads, depending in like manner on the knowledge and observance of the principles of mixture and contrast of colours, I need not add to what I have already said on this subject in the preceding section.

361. The furrows caused by the weft and the warp have not the inconvenience they present in the Gobelins tapestry. In fact, the regular grain of the tapestry for furniture is so far from producing a bad effect in the image represented on it, that we are obliged to give the appearance of this grain to many paper-hangings by means of parallel lines cutting it, or by points symmetrically placed.

COLOURED GLASS WINDOWS IN LARGE GOTHIC CHURCHES.

362. I am about to examine, according to the preceding views, the coloured glass windows which concur so powerfully with architecture, in giving to vast gothic churches that harmony which we cannot fail to recognise whenever we enter them. These structures rank with those works of art which are most impressive by their size, the subordination of their various parts, and by their complete fitness for the purposes to which they are applied. The stained glass of gothic churches has always a most appropriate effect, intercepting the white light, which, by giving too vivid a glare, is less conducive to meditation than the coloured light which this glass transmits. We shall find its splendid effect to arise, not only from the contrast of colours, but also from the contrast of its transparency with the opacity of the surrounding walls, and of the lead which binds its parts together. The impression produced on the eye by this twofold cause becomes more vivid the more frequently it is repeated and the longer it is sustained, when yellow, blue, violet, orange, red, and green stained glass appears like most precious jewels.

363. The upright windows usually represent, within a border or a ground analogous to the rose windows, the figure of a saint in harmony with those which stand in relief about the portals of the edifice; and to be fully appreciated they must be judged of as _parts of a whole_, and not as a Greek statue which is intended to be seen isolated on all sides.

The glass is of two kinds, the one painted on its surface by pigments afterwards vitrified (glass painting); the other, melted with the material that colours it (glass staining); the first is generally used in the composition of the nude parts of the human figure, and the second in that of the drapery. All the pieces of glass are united by strips of lead. What has struck me as being most effective in windows with human figures, is the exact observance of the relations of size of the figures and of the intensity of the light which renders them visible, with the distance at which the spectator is placed; a distance at which the strips of lead surrounding each piece of glass appear only as lines or as small black bands.

364. It is not necessary, for an effective whole, that the _painted glass_, when viewed closely, should exhibit fine hatchings, careful stippling, or blended tints; for, with the coloured stained glass for draperies, they should compose a system which compares with painting in flat tints, and certainly we cannot doubt that a painting on glass, executed entirely according to the system of _chiaro-scuro_, not to speak of the cost of its execution, will have the disadvantage of the finish in its details entirely disappearing at the distance at which it must be viewed as a whole.

365. _The first condition, which must be fulfilled by every work of art, is, that it be presented without confusion and as distinctly as possible._ Let us add that paintings on glass, executed on the method of _chiaro-'scuro_, cannot receive the borders and grounds of rose windows which have such fine effects of colour, as they have less brilliancy and transparency than the glass in which the colouring material has been incorporated; they are also less capable of resisting the injuries of time.

Variety of colours in these windows is so necessary to attain the best possible effect, that those which represent figures entirely nude, edifices, or large objects of a single colour, or slightly tinted, whatever may be the perfection of their execution with regard to finish or truth of imitation, will have an inferior effect to windows composed of pieces of varied colours suitably contrasted; but a bad effect results from the mixture of coloured glass with transparent colourless glass, when the latter has a certain extent of surface in a window; yet a good effect is obtainable by mixing ground glass with coloured glass, and also of small pieces of colourless transparent glass, framed in lead, so that at the distance at which they must be viewed they produce the effect of a symmetrical juxtaposition of white parts with black parts.

366. I conclude that we must refer the causes of the beautiful effects of coloured glass of great churches—

1. To their presenting a very simple design, whose different well-defined parts may be seen without confusion at a great distance.

2. To their offering a union of coloured parts which are distributed with a kind of symmetry, but which are also vividly contrasted, not only among themselves, but also with the opaque parts which surround them.

367. Coloured windows appear to me to produce their utmost effect only in the vast edifices where the different-coloured rays reach the eye of the spectator on the floor of the church so much scattered that they impinge upon each other, whence results an harmonious mixture, not found in a small structure lighted by coloured windows. It is this intimate mixture of the coloured rays, transmitted into a vast edifice, which permits of tapestries placed on the ground floor. But when the lower walls have not colourless glass windows, it is evident that, if tapestries be placed too near coloured windows, the harmony of their colours must be lost, as when blue rays fall upon red draperies, yellow rays upon blue draperies, &c.

Thus, when coloured glass is to be put in a window, it is necessary to take into consideration, not only its beauty, but also the effect which the coloured light it transmits will have upon the objects illuminated by it.

368. The coloured windows of a large church may be regarded as real, transparent tapestries, intended to transmit light, and to ally themselves harmoniously with the sculptures on the exterior, which destroy the monotony of the high walls of the edifice, and with the different monuments of the interior, among which tapestries must be taken into account.

369. My ideas on the employment of stained glass for windows may be summed up in the following terms:—

1. They produce their utmost effect only in the rose windows, bay windows, or pointed windows of large Gothic churches.

2. Only when they present the strongest harmonies of contrast, not of colourless transparent glass with the black produced by the opacity of the walls, iron bars, and strips of lead, but of this black with the intense tones of red, blue, orange, violet, and yellow.

3. Their designs must always be as simple as possible, and admit of the harmonies of contrast.

4. While admiring painted windows, of which a large number consist of paintings of undoubted merit, especially in regard to the difficulties overcome, I confess that it is a kind of painting which should not be much encouraged, because it never has the merit of a picture properly so called, it is more costly, and will produce less effect in a large church than a stained window of much lower price.

5. Windows of a pale grey ground, with light arabesques, have a very poor effect wherever they are placed.

See the relations of the law of contrast with the decoration of the interiors of churches.

THIRD DIVISION.

Colour Printing.

ON CALICO-PRINTING, AND PRINTING PAPER-HANGINGS.

370. I propose to examine only the optical, not the chemical, effects produced by patterns printed upon woven fabrics.

Printing on textile fabrics was for a long time limited, so to speak, to cotton cloths. It is only of late years that it has been extended to fabrics of silk and wool, for furniture and clothing. This branch of industry has now undergone an immense extension, fashion having accepted these products with extreme favour; but, whatever may be the importance of the subject, in a commercial point of view, I must treat it briefly. This book is not directed exclusively to that branch of inquiry, and as all the preceding part is intimately

connected with it, I shall merely state some facts which show, that, in ignorance of the law of contrast, the manufacturers and printers of cotton, woollen, and silk stuffs are constantly exposed to error in judging the value of recipes or colours, or as to the true tint of the design applied upon grounds of a different colour.

FALSE JUDGMENT OF THE VALUE OF RECIPES FOR COLOURING COMPOSITIONS.

371. At a certain calico-printer's a recipe for printing green had always succeeded up to a certain period, when it began to give bad results. They were lost in conjectures upon the cause, when a person, who at the Gobelins had followed my researches on contrast, recognised that the green of which they complained, being printed on a ground of blue, inclined to yellow through the influence of orange, the complementary of the ground. She therefore advised that the proportion of blue in the colouring composition should be increased in order to correct the effect of contrast. The recipe, modified according to this suggestion, gave the beautiful green which they had obtained formerly.

372. Thus every recipe for colours to be applied upon a ground of another colour, must be modified conformably to the effect which the ground will produce. It is this great facility in correcting the ill effect of certain contrasts which explains why they so often succeed without being able to account for it. Here, notwithstanding their colour, the eye judges them to be colourless, or of the tint complementary to that of the ground. These appearances have been the subject of questions frequently addressed to me by the manufacturers of printed stuffs, and by drapers: they are due to the _law of simultaneous contrast of colours_. In fact, when the patterns appear white, the ground acts by contrast of tone (9); if they appear coloured (and this appearance generally succeeds to that where they appear white), the ground then acts by contrast of colour (13). The manufacturer of printed stuffs therefore will not seek to attribute the cause of these phenomena to the chemical actions in his operations.

373. Ignorance of the law of contrast has, among drapers and manufacturers, been the subject of many disputes, which I have been happy to settle amicably, by demonstrating to the parties that they had no possible cause for litigation in the cases they submitted to me. I will relate some of these, to prevent similar disputes.

Certain drapers gave to a calico-printer some cloths of single colours, red, violet, and blue, upon which they wished black figures to be printed. They complained that upon the _red_ cloths he had put _green_ patterns; upon the _violet_, the figures appeared _greenish-yellow_; upon the _blue_, they were _orange-brown_ or _copper_-coloured—instead of the _black_ which had been ordered. To convince them that they had no ground for complaint, it sufficed to have recourse to the following proofs:—

1. I surrounded the patterns with white paper, so as to conceal the ground; the designs then appeared black.

2. I placed some cuttings of black cloth upon stuffs coloured red, violet, and blue; the cuttings appeared like the printed designs, _i. e._, of the colour complementary to the ground, although the same cuttings, when placed upon a white ground, were of a beautiful black.

374. The modifications which black designs undergo upon different coloured grounds are the following:—

Plate 13.

Upon _Red_ stuffs they appear Dark Green.

Upon _Orange_ stuffs they appear of a _Bluish-black_.

Upon _Yellow_ stuffs they appear _Black_, the violet tint of which is very feeble, on account of the great contrast of tone.

Upon _Green_ stuffs they appear of a _Reddish-grey_.

Upon _Blue_ stuffs they appear of an _Orange-grey_.

Upon _Violet_ stuffs they appear of a _Greenish-yellow Grey_.

[Illustration: PLATE XIII.]

These examples are sufficient to enable us to comprehend their advantage to the printer of patterns in colours complementary to the colours of the ground, whenever contiguous tints are to be mutually strengthened without going out of their respective scales.

DESIGNS FOR PAPER-HANGINGS.

375. The manufacture of paper-hangings has now arrived at such a point, that a knowledge of the law of contrast of colours is indispensably necessary to this branch of industry. We cannot estimate the true relations between the law of contrast and the art of paper-staining without dividing the papers into several categories to which the law is applicable.

1. Papers having figures and landscapes, or flowers of different sizes, and of varied colours, not intended for borders; these approach the nearest to painting.

2. Papers with patterns of one colour, or of colours but slightly varied.

3. Those employed as borders.

CHAPTER II.

On the Law of Simultaneous Contrast of Colours in relation to Paper-Hangings with Figures, Landscapes, or large Flowers of varied Colours.

376. The study which I recommend to artists occupied in fabricating paper-hangings, is in some measure that immediately applicable to every pictorial composition, or, in other words, the tapestry of figures and landscapes. But, whatever be the merit of paper-hangings of this category, they are not sought by persons of refined taste, and they do not appear to me destined to be any more so in future, for the twofold reason that the taste for arabesques, painted upon walls, or upon wood, and that for lithographs, engravings, and paintings, is spreading every day. These last three objects exclude, at least, all those papers with figures and coloured landscapes.

377. The applications of the law of contrast to this class of paper-hangings are easy, when we thoroughly understand the divisions of the book to which I referred above. In order to prove the advantage to be derived from the knowledge of this law, I need only refer to the bad effect presented by contiguous bands of two tones of the same scale of grey (serving as the ground to the figure of an infant), in consequence of the contrast of tone arising from their juxtaposition (321).

378. _On the Law of Simultaneous Contrast of Colours in relation to Paper-hangings with Designs in a Single Colour, or in Colours but slightly varied._

The remarks in 372 are applicable here also, as are those of 374. The best executed, and in the best taste, are those with black figures, or of figures much darker than the ground.

Paper-hangings, I do not say the most tasteful, but those most convenient for use, present very light grounds, with white or grey figures.

379. Grey patterns, upon papers tinted of a light colour, exhibit the phenomenon of maximum contrast; that is to say, the grey appears coloured with the complementary of the ground.

[Illustration: PLATE XIV.]

Thus, conformably to the law, (Plate 14)

Grey patterns upon a _Rose_ ground appear _Green_. ” ” ” an _Orange_ ” ” _Blue_. ” ” ” a _Yellow_ ” ” _Violet or Lilac_. ” ” ” a _Green_ ” ” _Rose_. ” ” ” a _Blue_ ” ” _Orange-grey_. ” ” ” a _Violet_ ” ” _Yellow_.

380. I mention these examples to instruct artists, for, in manufactories of paper-hangings, disputes arise between the proprietors and the preparers of the colours. For instance, a few years ago, the proprietors of one of the first manufactories in Paris, wishing to print grey patterns upon grounds of apple green and of rose, refused to believe that his colour preparer had given any _grey_ to the printer, because the designs printed on these grounds appeared coloured with the complementaries of the colour of the ground. It was only when the colour preparer, having attended a lecture I gave for M. Vauquelin, at the Museum of Natural History, and hearing me speak of the mistakes that these contrasts of colours might occasion, suspected the cause of the effects which he had unconsciously produced, and which had really caused him much annoyance.

OF THE LAW OF SIMULTANEOUS CONTRAST OF COLOURS RELATIVELY TO THE BORDERS OF PAPER-HANGINGS.

381. Every paper of one colour, or one belonging to the second category, should receive a border generally darker and more complex in design and colour than the paper which it frames.

The assortment of two papers exercises a very great influence on the effects they are capable of producing; for each of them may be of a fine colour, ornamented with designs in the best taste, yet their effect will be mediocre, or even bad, because the assortment will not be conformable to the law of contrast.

382. The ground of a border contributes greatly to the beauty of the pattern, whether this be of flowers, ornaments, or any other object. As we cannot treat of this influence in an absolute or methodical manner, I shall select a certain number of remarkable facts which I have had occasion to observe, and I shall principally dwell on those from which we can deduce conclusions, which, apparently not flowing from previous observation, might escape many readers, in spite of the great interest they have in knowing them. Besides, the exhibition of these facts will give me occasion to apply the law of contrast to designs presenting many tones of the same scale, and of different hues, and also often of different scales, more or less distant from each other. I shall not treat of simple borders, presenting black or grey designs upon a uniform ground, for I have already spoken of the modifications which in this case black designs undergo (374), and grey designs also (379).

383. The design of a border, either of ornaments, flowers, or any other object, being cut out and pasted upon a white card, designs identical with the preceding, which had been pasted upon cardboard, were then cut out, and placed upon grounds of black, red, orange, yellow, green, blue, and violet; then compared, not only by myself, but also by many persons whose eyes are much accustomed to seeing colours. When we had perfectly agreed upon their value, the results were noted as follows:—

1.—BORDER OF EIGHT INCHES IN HEIGHT, REPRESENTING GILT ORNAMENTS UPON DIFFERENT GROUNDS.

Plate 15.

[Illustration: PLATE XV.]

384. These ornaments, executed by the ordinary processes of paper-staining, contained no particle of metallic gold; yellow, lakes, and orange, of different tones and hues, had been exclusively employed in their production. After having stated the modifications which the painted gilt ornaments experience from the colour of the grounds, I shall indicate those which the metallic gilt ornaments receive comparatively from the same grounds; this comparison presenting results which appear to me interesting.

Black Ground.

385. Painted gilt ornaments placed upon black ground, compared with the same ornaments placed on a white ground, appear much more distinct than the latter; because the yellows and orange-yellows, colours eminently luminous, and the black ground, which reflects no light, give rise to contrast of tone, which the white ground, essentially luminous, cannot give with the colours which are themselves luminous. (See 53.)

We perceive thus, that the colours placed upon black are lowered in tone; but it must be noted that yellows and orange-yellows, far from being weakened (58), would only cause the black to gain in purity.

In considering more particularly the effects of two grounds, we see that a black imparts a red to the ornaments, and it is important to remark that the brightness of this red, instead of reddening the yellows, really gilds them. (See 394.)

We may thus understand how black, in taking away some grey, imparts brilliancy, and how this grey, which may be considered as a tarnished or subdued blue, may, with yellow, produce an olive colour. It is also necessary to remark, that the gilt ornaments in question present an olive-grey tint, which, far from being diminished by the white ground, is exalted by it.

Although the black ground lowers the tone of the colours, while white heightens them, it lowers yellow more in proportion than red, and consequently renders the ornaments redder than they appear upon a white ground; and, in taking away the grey, it purifies the colours, and acts also by giving them some red, or by taking away some green.

Metallic Gilt Ornaments.

386. Gilt ornaments stand out better from black than from white, but the orange colour is weakened and really impoverished. The black ground then does not purify the real gilt ornaments as it does the painted imitation of gold.

Deep Red Ground.

The yellows are more luminous, the whole effect with the painted ornament is clearer, more brilliant, less grey than upon a white ground.

Red much deeper than the ornament, lowers the tone of it; and this effect is also augmented by the addition of its complementary, green, a bright colour.

This example is of much importance, enabling us to see how the red, which appears as though it could be of but little advantage to ornaments, because it tends to weaken them by making them greener, is notwithstanding favourable, because the lightening or weakening of the colour is more than compensated for by the brilliancy of the complementary of the ground which is added to the yellow. We shall return to this effect in a moment. There is this analogy between the influence of the red ground and that of the black ground, that the tone of the colour is lowered; but there is this difference, that the ornaments become green on the first, while they become orange upon the second.

387. The red ground is not so advantageous for gilt ornaments as it is for the painted imitations of them, because the metal loses too much of its orange colour, and appears inferior to gold upon a black ground.

The red ground appears darker, and more violet than the ground upon which painted ornaments are placed.

Grounds of a light-red are still less favourable to the gold than red grounds of a dark tone.

Orange Ground deeper than the Ornaments.

388. The painted ornaments are bluer or rather greener than upon a white ground. The yellow and orange are singularly lower in tone.

This ground, then, is very disadvantageous to ornaments, as might have been expected.

389. Orange is not favourable to metallic gilt. The metal becomes too white, while the orange ground is redder and more vivid than that upon which the painted ornaments are placed.

Yellow Ground of Chromate of Lead more brilliant than the Yellow of the Ornaments.

390. The yellow of the painted ornaments is excessively enfeebled by the complementary of the ground which is added to it, the ornaments appear grey in comparison with those upon a white ground.

391. The yellow ground is not so unfavourable to gilt ornaments as it is to painted ones. The first assortment may, in certain cases, be recommended.

The yellow appears more intense, and perhaps greener.

Bright Green Ground.

392. Painted ornaments are darker upon a bright green ground than upon a red or white ground. They have acquired some red, but not the brilliant tint which is given to them by black—it is a brick-red tint.

393. It follows from the comparison of the effects of ornaments upon red and upon green grounds, that the first is much more advantageous than the second, because it adds an essentially brilliant tint to the colour of the ornaments, while the latter, adding red, or taking away green, produces a brick-red.

394. Upon a bright green ground, _metallic gilt ornaments_ acquire red, as the painted ornaments do, while the red, not sensibly diminishing the brilliancy of the metal, but, on the contrary, augmenting the intensity of its colour, produces an excellent effect.

The green ground is more intense and bluer than the same ground upon which the painted ornaments are placed.

395. The study of the effects of red and of green grounds upon painted ornaments, on the one hand, and upon gilt ornaments on the other, is extremely interesting to paperstainers and decorators; it demonstrates to them the necessity of taking into consideration, in the juxtaposition of bodies which it is proposed to associate, the brilliancy which these bodies naturally possess, and the brilliancy we wish to impart to them, if they have none. The preceding examples (386, 394) explain why the paperstainer

will choose dark red instead of green for his gilt ornaments, and why a decorator will prefer green to red for the colour of the hangings of a show-room of gilt bronzes, gilt clocks, &c.

Blue Ground.

396. Observation agrees perfectly with the law that it is really upon a blue ground, that painted ornaments, whose dominant colour is the complementary of blue, show themselves to the greatest advantage with respect to intensity of the gold-yellow colour. This effect more than compensates for the slight difference which may result from the red ground giving a little more brilliancy. The ornaments upon the latter ground, compared with those on the blue, are less coloured and appear whiter.

With _metallic gilt ornaments_ the blue ground is deeper and less violet than with painted ornaments.

Violet Ground.

397. Conformably to the law, the violet ground giving greenish-yellow to the painted ornaments, is favourable to them; they appear on this ground less olive-grey, more brilliant than upon the white ground, and less green than upon the red ground.

Metallic gilt ornaments stand out quite as well, the ground is raised in tone, and the violet appears bluer or less red.

398. It is remarkable that gilt ornaments, compared with their painted imitations, heighten all the grounds upon which they are placed. We cannot say that this metal causes the grounds to lose their brilliancy, for orange gaining some red, by the juxtaposition of the gold, appears, nevertheless, more brilliant than the orange in juxtaposition with the painted ornaments. The gold, by its orange colour, gives also some blue, its complementary, to bodies which surround it.

2.—BORDER OF FOUR INCHES IN BREADTH PRESENTING ORNAMENTS COMPOSED OF FESTOONS OF BLUE FLOWERS, OF WHICH THE EXTREMITIES ARE HELD BY GREY LEAVES OF ARABESQUES.

Plate 16.

399. These ornaments are opposed in some respects to the preceding by their dominant colour, which is blue.

Black Ground.

400. Grey lowered three tones in comparison with grey; upon white less reddened.

Blue flowers lowered two tones at least.

Red Ground.

401. The grey is greenish, while upon white it is reddish.

The blue flowers are lowered three tones, and the blue inclines to green.

Orange Ground.

402. Grey much lowered; less red than upon white. Flowers paler, and of a blue less red or less violet, than upon a white ground.

Yellow Ground.

403. Grey higher than upon white ground, more violet.

Flowers of a more violet-blue, less green than upon a white ground.

Green Ground.

404. The grey is reddish, while upon a white ground it appears greenish.

The blue gains red or violet, but it loses much of its vivacity; it resembles some blues of the silk-vat, which, giving yellow to the water, become slaty-blue-violet.

[Illustration: PLATE XVI.]

Blue Ground.

405. The blue ground being fresher than that of the ornament, it follows that it gives _orange_ to the blue of the flowers; that is to say, it _greys_ them in the most disagreeable manner.

The grey ornament is _oranged_, and lighter than upon the white ground.

Violet Ground.

406. Grey lowered, yellowed, impoverished. Blue tends to green, and is impoverished.

3.—BORDER OF FIVE INCHES AND A HALF IN BREADTH, REPRESENTING ROSES WITH THEIR LEAVES.

Plate 17.

407. This border is particularly useful as an example of the effect of two colours, red and green, which are very common in the vegetable world, and often represented upon paper-hangings.

Black Ground.

The green is less black, lighter, fresher, and purer, and its brown tones redder than upon a white ground. With respect to its lighter tones, I see them yellower, while, on the contrary, they appeared bluer to three persons accustomed to observe colours. This difference, as I at last found, arose from my comparing the general effect of leaves upon a black ground with that of leaves upon a white ground; while the other persons instituted their comparison more particularly upon the browns and the light tones of green, placed upon the same ground. This difference in the manner of seeing the same objects will be the subject of some remarks hereafter.

Rose lighter, yellower than upon a white ground.

Dark Red Ground.

408. Green more beautiful, less black, lighter than upon a white ground.

Rose more lilac, perhaps, than upon a white ground. The good effect of the border upon this ground is due chiefly to the greatest part of the rose not being contiguous to red, but to green; because the border and the ground exhibit flowers, the rose of which contrasts with the green of their leaves; while the same green contrasts with the red of the ground, which is deeper and warmer than the colour of the flowers.

Orange Ground.

409. The green lighter, a little bluer than upon a white ground.

Red much more violet than upon a white ground.

The general effect not agreeable.

Yellow Ground.

410. Green bluer than upon a white ground.

Rose more violet, purer than upon a white ground.

The whole exhibits a good effect of contrast.

Green ground, the tone of which is nearly equal to that of the lights of the leaves, and the hue of which is a little bluer.

Green of the leaves lighter, yellower than upon a white ground.

Rose fresher, purer, more velvety than upon a white ground.

[Illustration: PLATE XVII.]

Ground of an agreeable effect from harmony of analogy with the colour of the leaves, and from harmony of contrast with the rose of the flowers.

Blue Ground.

411. Green lighter, more golden than upon a white ground.

Rose yellower, less fresh than upon a white ground.

Although the green leaves do not exactly produce a bad effect upon the ground, yet the roses lose much of their freshness, and the appearance of the whole is not agreeable.

Violet Ground.

412. Green yellower, lighter than upon a white ground.

Rose faded.

If the ground does not injure the green of the leaves, yet it injures the rose so much that it is not agreeable.

4.—BORDER OF SIX INCHES IN BREADTH, REPRESENTING WHITE FLOWERS, AS CHINA ASTER, POPPY, LILY OF THE VALLEY, ROSES; SOME RED FLOWERS, AS THE ROSE-WALLFLOWER SOME SCARLET OR ORANGE, AS THE POPPY, POMEGRANATE, TULIP; BIGNONIA AND VIOLET FLOWERS, AS LILAC, VIOLETS, AND TULIPS WITH GREEN LEAVES.

413. This border was remarkable for the pleasing combinations of the flowers among themselves, and of the flowers with their leaves. In spite of the multiplicity of colours, and of the hues of red and violet, there was no disagreeable juxtaposition, except that of a pomegranate next to a rose; but the contact only took place at one point, and the two flowers were in very different positions.

Black Ground.

414. The whole lighter than upon a white ground.

Orange finer, brighter than upon a white ground.

White the same.

Green lighter, redder. The roses and the violets gain nothing from the black.

Red-Brown Ground.

415. The whole lighter than upon a white ground.

Whites and greens of fine effect. An orange-flower contiguous to the ground, for the reason explained above (407), acquires a brilliancy which it has not upon a white ground.

Orange Ground.

416. The whole more sombre, duller than upon a white ground. Orange-flowers and roses dull, lilacs bluer.

This assortment is not good.

Yellow Ground.

417. The orange-flower contiguous to the ground evidently loses vivacity in comparison with the white ground.

The whites are less beautiful than upon a red ground.

The greens are bluer than upon a white ground.

The roses become bluer, the violets acquire some brilliancy.

The whole effect is good, because there is but little yellow in the border, and but little orange contiguous to the ground.

Green Ground.

418. The ground being fresher than the green of the leaves, had not a good effect, relatively to them. On the other hand, the green in the border was in too small a quantity to produce a harmony of analogy, and it had not sufficient red for a harmony of contrast.

Blue Ground.

419. The oranges have a fine effect, the greens were reddened as well as the whites. The roses and the lilacs lost some of their freshness.

This arrangement did not produce a good effect, because there was not sufficient yellow or orange in the border.

Violet Ground.

420. Orange more beautiful than upon a white ground.

Roses, and violets especially, less beautiful than upon a white ground. A poor assortment.

Grey Ground.

421. As might be easily foreseen, this ground was extremely favourable to all the colours of the border.

422. The examination we have just made of four sorts of borders enables us to verify the exactness of the conclusions which are directly deducible from the law of simultaneous contrast of colours, and presents to us effects which we could scarcely have deduced from the same law without the aid of experiment. I now speak—

1. Of the influence which a complementary exercises by imparting _brilliancy_ to the colour to which it is added.

2. Of the very different manner in which not only different people, but even the same person, will judge of the colours of a more or less complex pattern, having a certain number of colours, according to the attention the spectator gives at a certain moment to different parts (407).

423. Our examination of the border of roses with their leaves (No. 3), and especially of that of the border of flowers varied in their forms and hues (No. 4), shows the necessity of a knowledge of the law of contrast to assort the colours of objects represented upon a border with the colour which serves as a ground to them. The examination of the border No. 4 has demonstrated experimentally that this assortment presents so much the more difficulty as we wish to have purer tints for the ground, and more varied colours in the objects we intend placing on it; besides, in demonstrating the good effect of grey as a ground for these latter objects, it has furnished an example of a fact which may be deduced from the law, and which is in perfect accordance with what practice taught us long ago.

PRINTED OR WRITTEN CHARACTERS ON PAPERS OF DIFFERENT COLOURS.

424. Having made it a rule in this work never to state any observations which I have not myself verified, I must mention that, not possessing every requisite for the examination of the subject of this section, I am obliged to develop certain points of it only.

We must regard—

1. The duration of the reading, and

2. The kind of light which illuminates the printed or written paper.

A.—INFLUENCE OF DURATION IN THE READING.

425. From the different conditions in which the eyei s found when it is apt to perceive the phenomena of simultaneous, successive, and mixed contrasts of colours (77 _et seq._), it may be conceived that in order to judge of the effect upon the sight of the assortments of the colour of the letters and that of the paper as to the degree of facility that they respectively present for reading, it may happen that one assortment will be more favourable during a brief reading, while the contrary will take place if the reading be prolonged during several hours. Besides, an assortment presenting the greatest contrast will be more favourable to a reading of short duration, while it will be less so to a prolonged reading; because, in consequence of the intensity of its contrast, it will fatigue the eye more.[2]

[2] Hence the pleasure of reading books printed on the modern _toned_ paper. De Morgan advises that tables of logarithms, and the like, should be printed on pale brown paper.

B.—INFLUENCE OF THE KIND OF LIGHT ON PRINTED OR WRITTEN PAPER.

426. The light we employ to supply the place of that of the sun, changing the relations of colour under which the same bodies appear to us illumined by daylight, it is evident that if we neglected this difference of relation it would give rise to error; because any assortment of colours favourable to read in diffused daylight, might be less so by the light of a lamp, &c.

427. I will now examine—

The influence of different assortments of the colours of writing and printing for reading by diffused daylight.

ON THE ASSORTMENT OF COLOURS FOR READING BY DIFFUSED DAYLIGHT.

Reading of a Few Minutes' Duration.

428. Letters upon paper can be read without fatigue only when there is a marked contrast between the letters and the ground. This contrast may be of tone, or of colours, or both.

429. _Contrast of tone_ is the most favourable condition for distinct vision, if we consider white and black as the two extremes of a scale, comprehending the gradations from normal grey; in fact, black letters upon a white ground present the maximum of contrast of tone, and may be read in a perfectly distinct manner without fatigue by diffused daylight. Indeed, all whose sight is enfeebled by age require the utmost contrast of tone.

FOURTH DIVISION.

Employment of Colours in Architecture.

I. ON THE EMPLOYMENT OF COLOURS IN EGYPTIAN ARCHITECTURE.

430. The Egyptians employed various colours, as red, yellow, blue, green, and white, to decorate their monuments.

Lancret remarks, "All who have seen Egyptian paintings, can attest that when seen, even for the first time, they were not disagreeable; and, that if at first the colours appear distributed arbitrarily, it is because observers have not combined a sufficient number of observations, and that it will one day be found that this part of the arts of the Egyptians was, like all the rest, submitted to invariable rules."

431. Champollion the Younger expresses himself in these terms on the application of colours to Egyptian architecture: "I should like to introduce into the great temple of Ipsamboul, all who refuse to believe in the elegant richness that painted sculpture adds to architecture; in less than a quarter of an hour, I engage that they would perspire away all their prejudices, and that their _à priori_ opinions would quit them through every pore."

432. The fact of colouring hieroglyphics being once admitted, the colouring of the other figured objects which accompany them appears to have been a necessary consequence, either to bring out certain symbols, or allegories more distinctly and more agreeably, by the effect of their various colours, or because, if the hieroglyphics only were differently coloured, there would be no harmony between them and the other figured objects. No one can mistake the harmony between the hieroglyphics and other painted objects, and we therefore should not see any impropriety in them if we mistook them for figures traced by the capricious imagination of the artist. This harmony clearly justifies Lancret and Champollion the Younger, in the passages quoted above.

II. ON THE EMPLOYMENT OF COLOURS IN GREEK ARCHITECTURE.

433. The discovery of Greek temples coloured on the exterior is doubtless a very remarkable fact in archæology; for if any monuments seemed to reject the application of colours to their external decoration, it was assuredly those of the Greeks. At this day, it is impossible not to admit that it was among these people that the alliance of colours with architecture was made, not in the declining epoch but at a period when monuments were erected in the best style; in fact, the ruins of coloured temples discovered by the excavations made in Greece, Italy, and Sicily, in places where many Greek colonies prospered, have this characteristic in a remarkable degree.

434. If we seek the cause which determined the Greek architect to seize upon one of the most powerful means that the painter has of addressing the eye, we shall find it especially, I think, in a taste for colours, rather than in the intention of rendering the various parts of an edifice more distinct from each other; and of substituting painted ornaments for ornaments in relief, whether sculptured

or moulded, or of augmenting the relief these ornaments already possessed; indeed, the communication of the Greeks with the Egyptians, may have induced them to imitate the latter in this application of colours to ornaments.

435. In the coloured drawings of Greek monuments which I have been able to procure, I have remarked not only the number of colours employed in these monuments,—_white_, _black_, _red_, _yellow_, _green_, and _blue_,—but also the use which has been made of them under the relation of _variety_ and _purity of tint_, of _distinct view of the parts_, and of the _harmony of the whole_. For instance, the principal lines, as the fillets of the architrave and of the cornice, are _red_; the mutules _blue_, and their guttæ _white_; the triglyphs _blue_, their channels _black_, and their guttæ _white_; and the more extended parts of the frieze and the cornice, as well as the architrave, are of light _yellow_.

We see that _red_, a brilliant colour, indicated the greater part of the principal lines; that _blue_, associated with _black_ in the triglyphs and their channels, formed an harmonious and distinct union of the neighbouring parts: also that the dominant colour, light _yellow_, produced a much better effect than it would if the most intense or the most sombre colours had predominated. Finally, the colours were distributed in the most intelligent manner possible without being motley, presenting a variety and lightness in the tints, with easy separation of parts.

III. ON THE EMPLOYMENT OF COLOURS IN GOTHIC ARCHITECTURE.

436. In the great Gothic churches, colour has rarely been employed on the exterior, except in a few cases, and always in a restrained manner, and without injury to the general harmony; for the colour on porches and in niches is altogether insignificant in this point of view; and, besides, there is nothing to show that it was not added long after the erection of the structure on which it is found. One of the things I most admire in these vast edifices is the art, or, if you will, the luck, with which they have succeeded without colour, by having recourse only to architecture and sculpture, in giving to the exterior of the edifice a variety which in no respect injures the imposing effect of the whole.

437. If we now regard the interior of these churches, the magic of the colours of the stained windows will complete the enjoyments the sight can receive from colour allied to architecture—enjoyments which can only strengthen the power of the religious sentiment in all who enter these edifices to address their prayers to God. M. Boiserée, author of a work full of research, as original as profound, on the cathedral of Cologne, thinks that the ceilings of Gothic churches ought, according to a general custom, to represent the celestial vault, and be painted blue, studded with gilt stars.

438. If painting has from the beginning really concurred with architecture, and even with painted sculpture, in the interior decoration of Gothic churches, it can only have been in a secondary degree and on the system of flat tints, from the time when it had been decided to put in windows of stained glass; for no painting applied upon an opaque body, such as stone, wood, &c., could sustain itself beside the brilliant coloured light transmitted by the glass; and if this painting had been graduated according to the rules of chiaro-'scuro, all its merit would have disappeared, for want of pure and white light, the only kind suitable for illuminating it.

439. Is it true that the vicinity of stained glass necessarily requires as an effect of harmony, painting on the contiguous walls? Without deciding absolutely in favour of the contrary opinion, I confess that, after reflecting long upon the deep impressions I have received in great Gothic churches where the walls present only the simple effects of light and shade upon a uniform surface of stone, where there are no colours except those transmitted by the stained glass, I say that the sight of more varied effects would have appeared to me an error against the principle of suitability of the place to its destination; and this opinion was especially fortified by seeing, after the coronation of Charles X., the fine vault of the ancient cathedral at Rheims, which had been painted for the occasion blue, sprinkled with _fleurs-de-lis_. I am reminded of the impression it produced upon me some years before, when it presented to my sight only the uniform colour of the stone.

APPLICATION TO THE INTERIORS OF EDIFICES.

440. I shall treat in succession—

1. On the assortment of stuffs with the wood of seats, &c. 2. On the assortment of frames with the pictures, engravings, and lithographs which they surround. 3. On the general decoration of interiors of churches. 4. On the decoration of museums, galleries, &c. 5. On the decoration of houses, palaces, &c.

On the Assortment of Stuffs with the Wood of Seats.

441. There should be between the two parts of the seat—the wood and the stuff—harmony of contrast and harmony of analogy. The beauty of the wood and of the stuff which accompanies it, may mutually enhance each other. From what has been said, it is evident that we must assort violet or blue stuffs with yellow woods, as the root of ash, the yew, satinwood, maple, &c. Green stuffs with rose or red-coloured woods, as mahogany, cherry-tree, rosewood, &c.

Violet, or blue-greys, are equally good with yellow woods, as green-greys are with the red woods.

But to obtain the best possible effect it is necessary to take into consideration the contrast resulting from depth of tone; for a dark blue or violet stuff will not accord so well with a yellow wood as a light tone of the same colours; and it is for this reason that yellow does not assort so well with mahogany, as with a wood of the same, but not so deep a colour.

442. Among the harmonies of contrast of tone that can be made with wood, may be mentioned ebony, the brown colour of which permits its employment with light stuffs to produce contrasts of tone, rather than contrasts of colour. We can use it with very brilliant, intense colours; such as poppy, scarlet, aurora, flame-colour, &c.

443. When we employ painted woods instead of those which retain their natural colour, it is better for a stuff to give the wood such a colour as will best assort with the stuff. For assortments of this kind, I believe we cannot do better than refer to the examples of the assortments of the principal colours with white, black, and grey. (P. 49 _et seq._)

444. Ebony wood, on account of its dark colour, be employed with dark stuffs to produce the assortments of analogy. In this case it can be allied with brown tones, and with red, blue, green, and violet. It is scarcely necessary to remark that these assortments prevent our using with ebony, white and yellow inlaying woods, which can be used with more or less advantage in those assortments which enter into the case of harmonies of contrast.

445. Frequent use is made of crimson woollen, velvet, and mahogany. This assortment, which is related to the harmony of analogy, is preferable to many others, only in consideration of the great stability of the colour of the stuff, and therefore independently of every idea of harmony. This induces me to examine it under several relations, that we may make the best possible use of it, according to the particular purpose.

When, in assorting crimson with mahogany, we wish to produce the harmony of analogy, by marking out the lines where the wood and the stuff touch, we can employ a cord or narrow galloon of yellow, or of golden yellow with gilt nails; or, better still, a narrow galloon of green or black, according to our wish to render the border more or less prominent.

When, in assorting these colours, we are guided by the twofold motive of the stability of the crimson colour and of the beauty of the mahogany, we must necessarily increase the distance which separates the stuff from the wood, by making the black or green border wider.

446. As the red woods always lose more or less of their beauty by the juxtaposition of red stuffs, we can never ally mahogany to colours which belong to the vivid reds, such as poppy or cherry; and more particularly to orange-reds, such as scarlet aurora; for these colours are so bright, that, taking away from this wood its peculiar tint, it becomes no better than oak or black walnut.

ON THE SELECTION OF FRAMES FOR PICTURES AND ENGRAVINGS.

447. If a frame is necessary to a picture, engraving, or drawing, to isolate it from the objects around it, it is always more or less injurious to the illusion the painter or designer has desired to produce, when it occupies its destined place. I only purpose here to examine the relation of colour between the frame and the object it surrounds.

448. Gilt frames accord well with large pictures painted in oil, when the latter do not represent gildings, at least so near the frame as to render it easy for the eye to compare the painted gold with the metal itself.

I will instance a bad effect from such proximity. A Gobelins tapestry, after Laurent, represents a genius armed with a torch, near which is a gilt altar, executed in yellow silk and wool, all of which are entirely eclipsed by the metallic brilliancy of the gilt bronzes profusely spread over the mahogany frame of the tapestry. This may convince us that the richness of a frame may not only be a fault against art, but also against common sense.

449. Bronze frames which have but little yellow brilliancy do not injure the effect of an oil picture which represents a scene lighted by artificial light, such as that of candles, torches, a conflagration, &c.

450. When black frames, such as ebony, detach themselves sufficiently from an oil painting, they are favourable to large subjects; but whenever they are used, it is necessary to see whether the browns of the painting or drawing which are contiguous, do not lose too much of their vigour.

451. A grey frame is favourable to many landscape scenes painted in oil, particularly when the picture having a dominant colour, we take a grey lightly tinted with the complementary of that colour.

452. Gilt frames accord perfectly with black engravings and lithographs, when we take the precaution of leaving a certain extent of white paper round the subject.

453. To conclude. The rule to be followed in assorting a frame to a picture is, that its colour, brightness, and ornaments also, injure neither the colours, nor the shadows, nor the lights of the picture, nor the ornaments which it represents.

When we propose to put a border between the frame and an engraving, plain or coloured, we must take into consideration,—

1. The effect of the height of tone of this border upon the different tones of the design.

2. The effect of the complementary of the colour of the border upon the colour of the design.

3. The intensity of the diffused light which is considered most suitable to light the design. Because for a given border the mutual relations between the browns, the half-tints, the lights and the whites, change with the intensity of the daylight, and change more for a given composition with certain borders than with others.

A composition of small or medium size may be painted so that the artist himself will do well to choose the frame best adapted to it, and to paint up those parts of his picture which are contiguous to it. (See also 483.)

ON THE GENERAL DECORATION OF THE INTERIORS OF CHURCHES.

I now resume this subject, no longer to treat of it relatively to a given architectonic form, but to consider it under the most general point of view.

Conformably to the principle enunciated above (346), of judging the productions of art by the rules drawn from the nature of the materials employed, I establish two distinct classes of churches, not according to their form, but to a fundamental consideration which subordinates the interior decoration to the quality of the light, coloured or colourless, diffused through plain or coloured glass.

Stained Glass Windows.

1. From the bad effect of the mutual proximity of white and stained glass (365), it results that where one is employed in a church the other must be excluded, at least from the nave, choir, in a word, from all that the spectator can embrace at one point of view. The colourless glass in some of the chapels of the aisles is of no consequence in the general effect.

2. If pictures be near stained windows, they must be flat, or present subjects as simple as possible, since their effects are entirely sacrificed to those of the stained glass (438).

3. We can place pictures in a large church where the light is transmitted through coloured glass; but, for the view to be satisfactory, they must necessarily encounter such a union of conditions, that they will almost always be found out of place. In fact, if the pictures are not at a certain distance from the glass,—if the coloured lights which emanate from them are not, by their mutual admixture, in the requisite proportions for producing white light, or, at least, a very faintly coloured light—or if this feebly coloured light is insufficient to lighten the interior of the church properly, the pictures will lose their colour, unless they have been executed with reference to the nature of the light from the stained windows; but this is not, to my knowledge, ever realized.

White Glass Windows.

454. Churches with white glass windows harmonize with every ornament we can imagine in the employment of wood, marbles, porphyry, granite, and the metals. Mosaics may ornament the floors and adorn the walls with true pictures, as we see in St. Peter's at Rome. Painting in fresco, in oil, plain and coloured sculptures, also combine to ornament the interior.

1. In churches of this class, the profusion of riches at the disposal of the decorator, far from being always of advantage to him, may be the cause of difficulties; for, the more varied the objects he has to arrange, the greater the difficulty of presenting only such

objects as are in keeping with the place he has to embellish. It is not enough to have precious woods, marbles, metals, pictures; he must also make these objects harmonize. Thus, he must avoid putting coloured marbles contiguous to the white stone of which the walls are constructed; he must also proscribe surrounding bas-reliefs in white stone with slabs or borders of red or green marble.

2. The cathedral of Cologne, for churches with _coloured_ glass, and St. Peter's at Rome, for those with _white_ glass, are two types which it will be sufficient to mention when we wish to demonstrate that beauty is compatible with different systems.

3. Much as I admire the marvels which the arts have accumulated in churches where white light freely enters, and although I acknowledge the effects which certain pictures of the first order are capable of producing in the Christian mind, yet the churches in which we see these decorations, resemble museums of art more than temples consecrated to prayer; and under this aspect they do not appear to me to fulfil the conditions imposed by the principle of fitness of edifices to their purpose in the same degree as Gothic churches with stained glass windows.

ON THE DECORATION OF MUSEUMS AND GALLERIES.

455. The essential condition which these edifices must fulfil, is, that the light be as white and as vivid as possible; but always diffused and distributed equally and in the most suitable manner upon all the objects exhibited to the spectator, so that they may be seen without fatigue, and distinctly in every part.

Picture Galleries.

456. There is generally a disposition to be prodigal of ornaments and gilding in such buildings. Without pretending that all decoration should be proscribed, yet I believe that there is less disadvantage in erring by deficiency than by excess; in fact, the pictures, &c., are the precious objects, and it is to them that we must attract attention. Let me add, that one of the most injurious things to the effect of pictures is their accumulation—their being crammed all together; the position they then occupy, so different from that for which the painters destined them, diminishes the illusion which each would produce if it were in its proper place. Few, except the intelligent connoisseur and amateur, on seeing a picture exhibited in a gallery, experience all the effect which the artist wished to produce. Even the contiguity of the frame to the picture is destructive of the illusion of perspective: hence the difference between the effect of a framed picture and the effect of the same picture when seen through an opening, which permits us to see neither frame nor limits: it then recalls all the illusion of the diorama.

Sculpture Galleries.

457. Statues of white marble or stone, as well as plaster casts, stand out well in a gallery, the walls of which are of a pearly-grey colour; and if we would augment the whiteness of the statues by neutralizing the red hue which the marble, stone, or plaster might have, we could colour the walls with a chamois or orange-grey tint. If, on the contrary, we preferred giving to the statues a warm colour, which many sculptors esteem so highly, the walls must be of blue-grey. Green walls will give to the statues a rosy tint, which is not disagreeable.

The tone of their colour must be lower, the brighter we wish the sculptures to be.

458. When there are bronzes, the colour of the walls of the gallery must be determined by that which we wish to predominate in the statues; because, as is very well known, the metallic alloy of which they are formed yields two very different tints; one _green_, acquired by exposure to atmosphere; the other the peculiar _golden_ tint which it possesses where it is not oxidized. If we wish to exalt this green tint, the colour of the walls of the gallery must be _red_; while they must be _blue_ to bring out the brilliancy of the metallic bronze, which has not experienced the action of the atmosphere.

459. The walls of the gallery are considered as giving rise to effects of contrast, and not of reflection.

Museums of Natural History.

460. In these edifices it would be wrong to give the walls any positive colour, for the objects exhibited should appear to the eyes of the naturalist of the colour peculiar to each; consequently the interior of cabinets, glass-cases, and drawers must necessarily be white, or normal grey, very light in tone.

Wainscoting.

461. From the fact that wainscotings are generally concealed by the furniture placed before them, we may conclude that they must be of a dark, rather than of a light colour, and that, if they have ornaments, these must be simple, and not prominent. The wainscoting may be considered as serving as a ground to the furniture, whenever it is not entirely concealed by the latter. We shall see hereafter what colour is necessary to be given them that they may suit their purpose.

DECORATIONS OF THE INTERIOR OF HOUSES.

Hangings.

462. In consequence of an apartment never being too light—for we can always diminish superfluous light—hangings should be of a light colour, that they may reflect, not absorb, light.

463. We proscribe all dark hangings, whatever be their colour, because they absorb too much light; we proscribe also red and violet hangings, because they are exceedingly unfavourable to the colour of the skin. For this latter reason we reject the light tones of the red and violet scales. Orange is a colour that can never be much employed, because it fatigues the eye too much by its great intensity.

1. Among the simple colours, there are scarcely any which are advantageous, except yellow and the light tones of green and of blue. Yellow is lively; it combines well with mahogany, furniture, but not _generally_ with gilding (see 469).

2. Light green is favourable to pale complexions as well as to rosy ones; to mahogany furniture, and to gilding.

3. Light blue is much less favourable than green to rosy complexions, especially in daylight; it is particularly favourable to gilding, it does not injure mahogany, and associates better than green with yellow or orange woods.

4. White or whitish hangings of a light grey (either normal green, blue, or yellow), uniform or with velvet patterns of the colour of the ground, are also very useful.

5. When we would choose hangings upon which to place a picture, their colour must be uniform, and make the greatest contrast possible with that which predominates in the picture, if the hangings are not of a normal grey. I shall return to this assortment (483).

464. Hangings in the best taste are those—

1. Which present designs of a light tone, either normal or coloured grey, upon a white ground, or the reverse, and in which the pattern is at least equal in extent of surface to the ground; for a small pattern has a very poor effect, at least in a large room.

2. Patterns of two or more tones of the same or very near scales assorted conformably to the law of contrast.

465. Hangings of brilliant and varied colours representing real objects, forming patterns more or less complex, do not admit of pictures; and as such hangings should exhibit themselves distinctly, they must not be concealed by the furniture in any of their parts.

466. When we have to adapt a border to a monochromous hanging, or to one presenting a dominant colour, we must first determine whether we can have recourse to a harmony of analogy or to a harmony of contrast; in all cases the border ought to detach itself more or less from the hangings, which it is intended to surround and separate from contiguous objects.

Harmony of contrast is the most suitable to papers of a uniform pure colour, such as yellows, greens, and blues; consequently we recommend for the dominant colour of the border, the complementary of that of the hangings, whether this border represents ornaments, arabesques, flowers, or imitations of fringes or tissues. But, as a contrast of colour ought not generally to offer also a contrast of tone, then the general tone of the border must only surpass that of the hangings so far as to avoid a deadening effect. If a double border be required, the exterior border must be of a much deeper tone than the other, and always narrower.

467. Among the colours suitable for borders we recommend the following as harmonies of contrast:—

1. For yellow hangings, violet and blue mixed with white; if a fringe, of flowers garnished with their leaves, or ornaments.

2. For green hangings, red in all its hues; the painted gilt-yellows upon a dark-red ground; the borders of brass.

3. For white hangings, orange and yellow; the borders of brass or gilt moulding: these are much better on blue than on green.

468. Among the harmonies of analogy, I recommend the following:—

For yellow hangings, a border of brass or gilt moulding.

White or Whitish Hangings of Normal Grey, Pearl Grey, or very pale coloured Grey, of a uniform colour, or with a Velvet Pattern of the Colour of the Ground.

469. Although papers of this kind admit of borders of all colours, yet we must avoid too great a contrast of tone in a border containing pure colours; for the intense tones of blue, violet, red, green, are too crude to combine with these light grounds. Gilt brass borders accord well with these grounds, especially with the pure or grey whites. If a grey present a tint of green, of blue, or of yellow, we may use borders of the complementary of these tints, taken many tones above, or of a grey, deeply tinged with this complementary.

470. Among the harmonies of analogy, we may take for grey hangings, borders of some tones higher, and of a grey contrasting with their tint, but very lightly.

For Borders of Hangings that present a pure Colour with White, or many Tones belonging either to the same Scale or to contiguous Scales (see 466).

For _chintzes_, we must have analogous borders.

For larger patterns than chintzes, repeated like the latter, a binding of galloon suffices.

Hangings with human figures, landscapes, or other pictures, require a frame either of painted, gilt, or bronzed wood, or, better still, a border imitated by painting.

Colour of the Wainscoting relatively to the Hangings.

When the Hangings and the Border make a Contrast of Colour.

471. The dominant colour of the wainscoting must generally be more or less approximating, and may be—

1. The same as that of the border, but a little darker, and especially more or less broken with black.

2. Grey lightly tinted with the colour of the border, and of the same tone, or very near it.

3. The complementary of the colour of the hangings, when the dominant colour of the border is not its complementary. If we employ a complementary lightly broken with black, the moulding must be picked out in brown on the border and on the wainscoting.

4. A grey complementary to the colour of the hangings, when the border is not the complementary of the hangings.

In these cases we bring out upon the colour of the hangings, properly so called, that of the wainscoting, which we always render more or less dull. Thus the colour of the hangings and the wainscoting are agreeably harmonized, and the border suitably separates them.

5. A normal grey of many tones, with which we may combine white.

472. When the colour of the wainscoting is the same as that of the hangings, but duller or deeper, in general it has a poor effect, arising particularly from the fact that the colour of the border, which contrasts with that of the hangings and of the wainscoting, is in too small superficial proportion to the other.

When the Assortment of the Hangings and the Border make either the Harmonies of Contrast of Scale or of Contrast of Hue, or the Harmonies of Analogy.

The dominant colour of the wainscoting may be—

1. The complementary of the colour of the hangings, but more or less broken, and a little deeper.

2. Grey complementary to the colour of the hangings.

3. A colour which, without being complementary, contrasts with that of the hangings.

4. Grey, tinted by a colour which, without being complementary to that of the hangings, contrasts with them.

473. When the hangings are white, or of an extremely feeble tone of colour, and the border does not stand out very strongly by its colour, we may make a harmony of tone or of hue with the tint of the wainscoting. For example, white, or nearly white hangings, with a gilt or brass border, harmonize well with a wainscoting which differs only by some tones more from the colour of the hangings.

Cornice of the Ceiling.

474. The cornice of a white ceiling must be of light colours, and but little varied; not according with those of the hangings, but of the wainscoting. White parts, which may be confounded with the ceiling, must be carefully avoided, as must also whatever will cause too much difference between the parts of the whole. When the hangings are white, or of a very pale grey, with a gilt or brass border, the cornice may present ornaments of the same material, and in this case they may stand upon a white or upon a grey, a little deeper than that of the hangings.

Chairs, Sofas, &c., placed in front of the Wainscoting or Hangings.

475. The colour of the covering of chairs should be complementary to that of the hangings, properly so called, or, more generally, the same as that of the border, because this may be different from its complementary, and contrast, nevertheless, with the tint of the hangings. We see, then, that the chairs should contrast with the hangings, as may also the wainscoting; but the colour of the chairs being pure, it will also be purified by that of the wainscoting, which, for this reason, we have advised to be deadened.

1. The case of clearest contrast—_i.e._, when the colours of the hangings and the chairs are complementary—is the most favourable to distinct vision, as well as to successive contrast, whenever we observe first the hangings separately, and afterwards the chairs separately, and _vice versâ_.

2. When the colour of the hangings and of the chairs contrast without being complementary, we must take into consideration the degree of _light_ in the colour of the hangings. For example, if they are blue, and the border is yellow, the covering of the furniture being a yellow, more golden than citron, this stuff must be of a much higher tone than the blue tone of the hangings; and the tone of the wood of the chairs, &c., must be still higher than the yellow, to avoid a dull appearance.

3. We may border the stuff at the parts contiguous to the wood, either with well-assorted dark colours, or with the same colour as the hangings, but of a higher tone; there is also a means of harmonizing the hangings and the furniture, in uniting the same colours, but in inverse proportion.

4. When, instead of sofas, arm and other chairs, there is a _divan_ which entirely conceals the wainscoting, we must use the complementary colour of the hangings, when it is more advantageous for the colour of the border to form a contrast of scale or of hue with the hangings. In this case, yellow hangings bordered with brass in relief with a violet-coloured divan, will produce an excellent effect, at least by daylight; for we must not forget that yellow and violet lose in artificial light.

5. We regard as a harmony of contrast of colour light hangings of a pure colour with furniture of a grey, tinted with the complementary to that of the hangings.

476. Rooms differing in dimensions, according as they belong to the lively or grave harmonies, will be adapted to very different purposes.

1. In small rooms—such, for example, as boudoirs, where the hangings are bright—a harmony of contrast of hue, of scale, or a harmony of analogy, is generally preferable to a harmony of contrast of colour, if the hangings are uniform, or have a dominant colour. If they have a decided colour allied to white, or if they present patterns of various colours, such as _chintzes_, the furniture most suitable will be a divan of the same material as the hangings; and it is conformable with the object of boudoirs, or of similar places, to diminish their apparent extent to the eye, by employing only one material for the hangings and the chairs, instead of seeking to fix the eye upon distinct objects.

2. In large rooms there is an arrangement of good effect—viz., white, or very light grey hangings, with furniture of a pure colour, such as red, yellow, green, blue, and violet. When we employ these pure colours, we must heighten the tone only so much as to avoid a faded appearance. Sky-blue is the most suitable for this arrangement; crimson, which is also employed, is too harsh, especially if the room is neither very large nor well lighted.

477. _Grave Assortments_ are adapted to places devoted to quiet meetings, such as libraries, museums, studies, &c. In general, the smaller the place, or the less space there is to receive the hangings, the more the assortment must be that of a harmony of analogy.

The hangings or the pictures must present only normal grey, or a grey of a colour more or less broken; the chairs must be black or of a dark grey, either normal or coloured; and in this case we can take a grey tinted with the complementary of the colour of the grey of the hangings. If more contrast is desired, we can have recourse to the brown tones of this complementary of the colour, which tints the grey of the hangings.

478. _Window and Bed-curtains_ should be similar to each other.

When the Chairs have a decided Colour—such as Red, Yellow, Green, Blue, or Violet—the hangings should be of a pure colour, contrasting favourably with that of the chairs.

The curtains should generally be of the colour of the chairs, and their borders of the colour of the hangings, or of the colour of the hangings bordered with the colour of the chairs.

The Chairs being Grey, or of a very subdued Colour, and the hangings of a decided colour, the curtains should be either,—1. Of the colour of the chairs, with a border of the colour of the hangings: or, 2. Of the complementary of the hangings, or contrasting favourably with them; the colour of the border should be that of the hangings.

The Hangings being of a Grey Colour, or White, the curtains should be,—1. Of the colour of the chairs: or, 2. Of a pure colour, complementary to the grey of the hangings, if the latter do not belong to the scale of normal grey.

479. _Doors._—Doors being, by their use, size, and position, relatively to the plane of the wall, absolutely distinct from the wainscoting, should be distinguished from it by their colour, notwithstanding the contrary practice of painters, who make them the same. Their different parts might be painted in many low tones of the same, or of approximating scales, and always according to the harmony of analogy, as the parts of one object are concerned. The colour of the doors should be of normal grey, or of a grey tinged with the colour of the hangings or of its complementary, which will thus always unite with the hangings, either by harmony of analogy, or by harmony of contrast. The door frames should be darker than the door itself.

480. _Window Frames_ should be like the doors, according to a rule which has long been generally observed. The fastenings must be black, bronzed, or of brass.

Carpets.

481. Whatever may be the dominant colours of the subjects represented in their central part, with regard to brilliancy and contrast, they should always be separated from the chairs by a sufficient interval to prevent discord with the colour of the latter.

1. The more numerous and vivid the colours are, the more we must control their brilliancy; and the carpet most suitable will be one of simple colours and pattern. In many cases, an assortment of green and black will have a good effect.

2. If the furniture is of a single colour, or of many tones, either of the same colour or of approximating scales, we can, without disadvantage, employ a carpet of brilliant colours, and thus establish a harmony of contrast between them and the dominant tint of the furniture.

482. But if the furniture is of mahogany, and we wish to bring out its colour, then we must not have either red, scarlet, or orange as a dominant colour in the carpet.

In short, to get the best effect of the colours of the furniture, in the first case, the colours of the carpet, more or less sombre, must enter into the harmonies of analogy; while in the second, where harmony of contrast of colour does not exist in the furniture, we can, if we choose, have recourse to this harmony in the carpet without ill effect.

Pictures (See 453).

483. Whenever pictures are placed on hangings, the latter must be of a single colour, or of two very similar colours or tones of the same scale. The pattern of these hangings must be as simple as possible. Whenever a picture is placed on coloured hangings, we must always take care that the dominant colour of the hangings be complementary to the dominant colour of the picture.

Engravings and plain lithographs must never be placed beside oil paintings, or even coloured drawings.

Pearl grey, or rather deep normal grey, is a good tint to receive engravings and plain lithographs in gilt or yellow wood frames.

484. Yellow hangings can receive with advantage landscapes, in which green grass, and leaves, and a blue sky predominate. The most suitable frames in this case are those of violet ebony, or wood painted grey or black. Gilt frames have not a bad effect on the picture; but the gold of the frame and the yellow of the hangings do not contrast sufficiently to most eyes.

485. Oil-paintings in gilt frames have a good effect on hangings of olive-grey more or less deep, according to the tone of the picture. Carnations and the gold assort well on a similar ground. Papers of a deep green, and even of a deep blue, may also be advantageously employed in many cases.

ON THE ASSORTMENT OF COLOURS IN INTERIORS, THE WALLS OF WHICH ARE PANELLED OR COVERED WITH MARBLE, STUCCO, OR PAINTED WOOD.

Panelled Interiors.

486. Notwithstanding the present taste for decorations, which it is so easy to satisfy by means of paper-hangings, woven fabrics, and other accessories, I think there are in large suites of apartments two rooms for which a paneling more or less finished is very suitable; these are the dining and the billiard rooms; the scene being, as it were, concentrated on the dining or billiard tables, there is no reason to distract the attention by clothing the walls with ornaments. Where an interior is paneled, the floor should be in parquetry; a pavement of tiles, stones, or marbles would be out of keeping.

487. The colour of the curtains, for paneled interiors, must be chosen conformably to the preceding principles. For example—

White curtains will heighten the tone of the woodwork;

Blue curtains will bring out the golden tint of many woods, especially of polished oak.

Interiors covered with Marbles.

488. We can arrange marbles together on the principle of harmony of contrast or of harmony of analogy. Bronze adapts itself to them very well. If granite and porphyry are to be added, the lower courses must be composed of the latter.

Blinds are preferable to curtains, which are not suited to marbles.

Interiors covered with Wood painted of several Colours.

489. The painting on a wainscot which is not beautiful enough to be seen uncovered has for its object the imitation—1. Of hangings; 2. Of wood more or less costly; 3. Of marble.

490. When we decorate walls of a pale grey ground, which require to be warmed with arabesques, we must endeavour to imitate pictures rather than mosaics.

491. The more carefully arabesques are executed, the more variety they will present in their forms and colours, and the less they should resemble the draperies, with which they are associated. Thus, white curtains with a simple and ample border, or curtains of a slightly-elevated tone of colour, or of an extremely simple design, should have the preference to curtains which are related to arabesques by their vivid colours, their varied patterns, or striking colour; in short, the colour of the curtain, if it has any, must be sacrificed to that of the arabesques.

FIFTH DIVISION.

CLOTHING.

492. In explaining the applications of the law of contrast to the colours of Male Clothing, my intention is to discuss principally the question of the combination of colours in military uniforms as a matter of State economy; and, in the case of Female Clothing, the combinations which are most suitable for a portrait. The first question is entirely one of administrative economy; the second belongs solely to the domain of art.

I shall attain my end if, in the views set forth, the portrait-painter find the means of selecting associations of colours which, by imparting to his works more brilliancy and harmony, render them thereby less likely to appear antiquated when the prevailing fashion of his time is forgotten.

I. _Men's Clothing._

493. A dress composed of cloths of different colours may be worn much longer, and will appear better, although nearly worn out, than a suit of a single colour, even when the latter is of a piece of cloth identical with one of the first. The law of contrast fully gives the reason of this fact.

OF THE ADVANTAGES OF CONTRAST, CONSIDERED WITH REGARD TO THE APPARENT CLEANLINESS OF CLOTHS FOR CLOTHING.

494. Contrast in the colours of cloths composing a dress is not only advantageous to the brightness and _apparent preservation_ of the colours of these cloths, but also to render less visible the inequalities which a cloth presents on account of the colouring material not having equally penetrated to the centre of the stuff; the surface wearing unequally, according as it is exposed to different degrees of friction, the colour of the cloth becomes lighter, or, as it is commonly called, _whitens_, in the parts most exposed to friction. Many blue, scarlet, and madder-red cloths present this result, especially on the salient parts of the vestment, such as the seams.

495. This defect which certain cloths have of _whitening in the seams_ is much less apparent in a coat of two or more colours than it is in a monochromous coat; because _the vivid contrast of different colours, fixing immediately the attention of the spectator, prevents the eye from perceiving the inequalities, which would be visible in a monochromic coat_.

For this reason stains, on the same ground, will always be less apparent in a polychromous than in a monochromous garment or dress.

496. For the same reason also a coat, waistcoat, and trousers of the same colour cannot be worn together with advantage, except when new; for when one of them has lost its freshness, by having been more worn than the others, the difference will be increased by contrast. Thus new black trousers worn with a coat and waistcoat of the same colour, but old and slightly _rusty_, will bring out this latter tint, while at the same time the black of the trousers will appear brighter. White trousers or reddish-grey will correct the defect. We see, then, the advantage of having a soldier's trousers of another colour than his coat, especially if, wearing this coat all the year, he only wears trousers of the same cloth during winter. We see also why white trousers are favourable to coats of every colour.

II.—_Female Clothing._

497. Although there are many varieties of the human race with respect to the colour of the skin, yet we may arrange them in the three following divisions:—The Caucasian, or white race; the American Indians, whose skin is red or copper-coloured; the negro race, the Malays, &c., who have black or olive skins.

Colours for the Dress of Women with White Skins.

498. To give precision to this subject, we must begin by establishing certain distinctions.

1. That of the two types, with skins more or less white and rosy:—

The one with light hair and blue eyes. The other with black hair and black eyes.

2. That of the juxtaposition of the articles of the toilet, whether pertaining to the hair or to the complexion; for a colour may contrast favourably to the hair, yet produce a disagreeable effect with the skin.

3. That of the modifications of the complexion, by coloured rays emanating from the head-dress, and which, being reflected on the skin, tinge it with their peculiar colour.

499. The colour of light hair being essentially the result of a mixture of red, yellow, and brown, we must consider it as _a very pale subdued orange-brown_; the colour of the skin, although a lower tone, is analogous to it, except in the red parts. Blue eyes are really the only parts of the fair type which form a contrast of colour with the whole; for the red parts produce, with the rest of the

skin, only a harmony of analogy of hue, or at most a contrast of hue, and not of colour; and the parts of the skin contiguous to the hair, the eyebrows, and eyelashes, give rise only to a harmony of analogy, either of scale or of hue. The harmonies of analogy, then, evidently predominate in the fair type over the harmonies of contrast.

500. The type with black hair shows the harmonies of contrast predominating over the harmonies of analogy. The hair, eyebrows, eyelashes, and eyes, contrast in tone and colour, not only with the white of the skin, but also with the red parts, which in this type are really redder, or less roseate, than in the blonde type; and we must not forget that a decided red, associated with black, gives to the latter the character of an _excessively deep_ colour, either blue or green.

Of the Colours of the Hair and Head-dress.

501. The colours which are usually considered as assorting best with light or black hair, are precisely those which produce great contrasts; thus, sky-blue, known to accord well with blondes, is the colour that approaches the nearest to the complementary of orange, which is the basis of the tint of their hair and complexions. Two colours, long esteemed to accord favourably with black hair—yellow, and red more or less orange—contrast in the same manner with them. Yellow and orange-red, contrasting by colour and brilliancy with black, and their complementaries, violet and blue-green, in mixing with the tint of the hair, are far from producing a bad result.

Of the Colours of the Complexion and the contiguous Drapery.

502. The juxtaposition of drapery with the different flesh tints of women offers to portrait-painters a host of remarks, which are all the results of the principles already laid down. We shall state the most general: thus—

503. ROSE-RED cannot be put in contrast with even the rosiest complexions without causing them to lose some of their freshness. _Rose-red_, _maroon_, and _light crimson_ have the serious disadvantage of rendering the complexion more or less green. This is shown in the following experiment:—

Place two sheets of paper of either of the above colours beside two sheets of flesh-coloured paper, when it will be seen how much they are mutually injured, the lighter becoming greenish, and the darker rather of a violet hue. By substituting light green for the red, we shall find them mutually heightened and improved. The height of tone of the green influences the result: a very deep green, acting by contrast of tone, so enfeebles the complexion, that the slight contrasts of its colours will be inappreciable; a deep red, by contrast of analogy, blanches the complexion. It is necessary, then, to separate the rose from the skin, in some manner; and the simplest manner of doing this, is to edge the draperies with a border of _tulle_, which produces the effect of grey by the mixture of white threads, which reflect light, and the interstices, which absorb it; there is also a mixture of light and shade, which recalls the effect of grey, like the effect of a casement-window viewed at a great distance. Dark red is less objectionable for certain complexions than rose-red, because, being higher than the latter, it tends to impart whiteness to them in consequence of contrast of tone.

504. DELICATE GREEN is, on the contrary, favourable to all fair complexions which are deficient in rose, and which may have more imparted to them without disadvantage. But it is not as favourable to complexions that are more red than rosy; nor to those that have a tint of orange mixed with brown, because the red they add to this tint will be of a brick-red hue. In the latter case a dark green will be less objectionable than a delicate green.

505. YELLOW imparts violet to a fair skin, and in this view it is less favourable than the delicate green.

To those skins which are more yellow than orange it imparts white; but this combination is very dull and heavy for a fair complexion.

When the skin is tinted more with orange than yellow, we can make it rosy by neutralizing the yellow. It produces this effect upon the black-haired type, and it is thus _that it suits brunettes_.

506. VIOLET, the complementary of yellow, produces contrary effects; thus it imparts some greenish-yellow to fair complexions. It augments the yellow tint of yellow and orange skins. The little blue there may be in a complexion it makes green-violet. This, then, is one of the least favourable colours to the skin, at least when it is not sufficiently deep to whiten the skin by contrast of tone.

507. BLUE imparts orange, which combines favourably with white, and the light flesh tints of fair complexions, which have already a more or less determined tint of this colour. Blue is thus suitable to most blondes, and in this case justifies its reputation.

It will not suit brunettes, since they have already too much of orange.

508. ORANGE is too brilliant to be elegant; it makes fair complexions blue, whitens those which have an orange tint, and gives a green hue to those of a yellow tint.

509. LUSTRELESS WHITE, such as cambric muslin, assorts well with a fresh complexion, of which it relieves the rose colour; but it is unsuitable to complexions which have a disagreeable tint, because white always exalts all colours by raising their tone; consequently it is unsuitable to those skins which, without having this disagreeable tint, very nearly approach it.

510. VERY LIGHT WHITE draperies, such as muslin or lace, appear more grey than white. (See 503.) We must thus regard every white drapery which allows the light to pass through its interstices, and which is only apparent to the eyes by the surface opposed to that which receives incident light.

511. BLACK draperies, by lowering the tone of the colours with which they are in juxtaposition, whiten the skin; but if the vermilion, or rosy parts, are somewhat distant from the drapery, it will follow that, although lowered in tone, they appear relatively to the white parts of the skin contiguous to the same drapery, redder than if not contiguous to the black. This effect is analogous to that mentioned (385).

The Head-dress in relation to the Coloured Rays which it may reflect upon the Skin.

512. The effect of coloured bonnets on the complexion can now be readily understood; and whether it is true, as is generally believed, that a rose-coloured bonnet gives a rose tint to the skin, while a green bonnet gives a green tint to it, in consequence of the coloured rays which each of them reflects upon it, it is no longer a question about those head-dresses which, being too small or too much thrown back to give rise to these reflections, can only produce the effects of contrast, as I have said above, when treating of the juxtaposition of coloured objects with the hair and skin (501, _et seq._)

513. If an object in relief is illuminated exclusively by a coloured light, it will appear tinted with the colour of this light. A white plaster figure, for example, placed in an enclosure where the red rays illuminate it, will appear red, at least to most eyes, and under most circumstances; for certain eyes, in some cases, may perceive the sensation of the complementary of the coloured rays in looking at some parts of the figure.

514. But if the figure is placed so as to receive, at the same time, coloured rays and diffused daylight, there will be produced on the eyes of a spectator, suitably placed, a complex effect; resulting—

1. From some parts of the figure being white, reflecting to the eyes of the spectator the coloured rays falling from above.

2. From some parts of the figure reflecting diffused daylight in sufficient quantity to appear white, or almost white.

3. From there being between the parts which reflect coloured light to the eye, and those which send diffused daylight, some parts in a condition which appears to be complementary to the reflected coloured light.

515. One very remarkable consequence of this is, that the rays of mutually complementary colours, successively lighting the same object, concurrently with the diffused daylight, give rise to _the same coloration_.

516. This may be proved thus:—Between two windows directly opposite to each other, admitting diffused daylight, place a white plaster figure in such a position that each half shall be lighted directly by only one of the windows. On completely intercepting the light of one of the windows, and hanging a coloured curtain before the other, the figure appears only of the colour of the curtain; but if we open the other window, so that the figure is lighted by diffused daylight, while it is at the same time lighted by the coloured light, we then perceive some parts white, and some parts tinted with the complementary of the coloured light transmitted by the curtain.

517. This experiment, then, teaches us, that if a bonnet, rose-coloured, for example, give rise to a reflection of this colour on a complexion, the parts thus made rosy by the effect of contrast, themselves give rise to green tints, since the figure, while it receives rosy reflections, receives also diffused daylight.

518. To consider the real influence of the bonnet, we place three white plaster casts of the same model in a position equally illuminated by daylight; then observe them comparatively, after having clothed the middle cast with a white bonnet, and the two others with bonnets of which the colour of one is complementary to that of the other. _In this way we may satisfy ourselves that the

influence of reflection in colouring a figure is very feeble, even when the bonnet is placed in the most favourable manner for observing the phenomenon._

519. _Rose-coloured Bonnet._—Rose colour reflected upon the skin is very feeble, except on the temples; wherever the rosy parts are contiguous to parts feebly lighted by daylight, the latter will appear very lightly tinged with green.

520. _Green Bonnet._—Green colour reflected upon the skin is very feeble, except on the temples; wherever the green parts are contiguous to parts feebly lighted by daylight, the latter will appear slightly rosy; the effect of green in colouring it rose, is greater than the effect of reflected rose in colouring it green.

521. _Yellow Bonnet._—Yellow colour reflected upon the skin is very feeble, except on the temples; wherever the yellow parts are contiguous to parts feebly illuminated by daylight, the latter will appear very sensibly violet.

522. _Violet Bonnet._—Violet colour reflected on the skin is very feeble, even on the temples; wherever the violet parts are contiguous to parts feebly illuminated by daylight, the latter will appear slightly yellow; but this coloration is very feeble, because the reflections of violet have it themselves.

523. _Sky-blue Bonnet._—Blue colour reflected on the skin is very feeble, except on the temples; wherever the blue parts are contiguous to parts feebly illuminated by daylight, the latter will appear slightly orange.

524. _Orange Bonnet._—Orange colour reflected on the skin is very feeble, except on the temples; wherever the parts are contiguous to parts feebly illuminated by daylight, the latter will appear slightly blue.

525. It is evident, then, from these experiments, that a coloured bonnet produces much more effect by virtue of contrast, arising from juxtaposition with the flesh tints, than by the coloured reflections which it imparts to them.

526. Let us now see what advantage the painter can derive from the preceding observations, when he prescribes a bonnet to a model, belonging either to the light-haired or to the black-haired type.

FAIR-HAIRED TYPE.

527. A black bonnet with white feathers, with white rose or red, suits a fair complexion.

528. A _lustreless white bonnet_ does not suit well with fair and rosy complexions. It is otherwise with bonnets of gauze, crape, or lace; they are suitable to all complexions. The white bonnet may have flowers, either white, rose, or particularly blue.

529. A _light blue bonnet_ is particularly suitable to the light-haired type; it may be ornamented with white flowers, and in many cases with yellow and orange flowers, but not with rose or violet flowers.

530. A _green bonnet_ is advantageous to fair or rosy complexions; it may be trimmed with white flowers, but preferably with rose.

531. A _rose-coloured bonnet_ must not be too close to the skin; and if it is found that the hair does not produce sufficient separation, the distance from the rose colour may be increased by means of white, or green, which is preferable. A wreath of white flowers in the midst of their leaves has a good effect.

532. I shall not advise the use of a light or deep red bonnet, except when the painter desires to diminish too warm a tint in the complexion.

533. Finally, the painter should never prescribe either yellow or orange-coloured bonnets, and be very reserved in the use of violet.

TYPE WITH BLACK HAIR.

534. A _black bonnet_ does not contrast so well with the general appearance of the type with black hair as with the other type, yet it may produce a good effect, and receive advantageously accessories of white, red, rose, orange, and yellow.

535. A _white bonnet_ demands the same notice as that, concerning its use, in connexion with the blonde type (528), except that for brunettes it is better to give preference to accessories of red, rose, orange, and yellow, rather than of blue.

536. Bonnets _of rose-red or cherry-colour_ are suitable for brunettes, when the hair separates, as much as possible, the bonnet from the complexion. White feathers accord well with red; and white flowers, with abundance of leaves, have a good effect with

rose.

537. A _yellow bonnet_ suits a brunette very well, and receives with advantage violet or blue accessories. The hair must always interpose between the complexion and the head-dress.

538. It is the same with bonnets of an _orange_ colour, more or less broken, such as chamois, with which blue trimmings are eminently suitable.

539. A _green bonnet_ is suitable to fair and light rosy complexions, rose-red or white flowers are preferable to all others.

540. A _blue bonnet_ is only suitable to a fair or light-red complexion; nor can it be allied to such as have a tint of orange-brown. When it suits a brunette, it may take with advantage yellow or orange trimmings.

541. A _violet bonnet_ is always unsuitable to every complexion, since there are none to which the addition of yellow will be favourable. Yet, if we interpose between the violet and the skin, not only the hair, but also yellow accessories, a bonnet of this colour may become favourable.

542. Whenever the colour of a bonnet does not realize the intended effect, even when the complexion is separated from the head-dress by large masses of hair, it is advantageous to place between the latter and the bonnet certain accessories, such as ribbons, wreaths, and detached flowers, &c., of a colour complementary to that of the bonnet, as I have prescribed for the violet bonnet. The same colour must also be placed on the outside.

ON THE ASSORTMENT OF COLOURS IN THE DRESS OF WOMEN WITH COPPER-COLOURED SKINS.

543. The tint of the complexions of the women of the North American Indian races is too positive to induce them to endeavour to dissimulate, either by lowering its tone, or by neutralizing it. There is, then, no alternative but heightening it, for which purpose we must use draperies either of white or of blue strongly inclining to green, when the tint will become of a redder orange.

ON THE ASSORTMENT OF COLOURS IN THE DRESS OF WOMEN WITH BLACK OR OLIVE SKINS.

544. If I have prescribed the harmony of contrast of tone where the colour of the complexion is copper-red, there is a stronger reason for it when we have to drape olive or black skins; we can then use either white or the most brilliant colours, as red, orange, and yellow. The consideration of contrast determines which one we ought to choose in a particular case. If the complexion is intense black, dark olive, or greenish-black, red is preferable to every other colour; if the black is bluish, then orange is particularly suitable. Yellow will best accord with a violet-black.

545. _Results applicable to Portrait painting._

The tint may be heightened without leaving its scale:—

1. By a white drapery which heightens by contrast of tone. 2. By a drapery the colour of which is exactly the complementary of the tint, and of which the tone is not too high; such as perhaps a green drapery for a rosy complexion; or perhaps a blue drapery for the orange complexion of a blonde. The tint may be heightened by making it leave its scale:— 1. By a green drapery of a light tone upon an orange complexion. 2. By a blue drapery of a light tone upon a rosy complexion. 3. By a yellow, canary, or straw-coloured drapery, upon an orange complexion, of which the complementary violet neutralizes some of the yellow of the complexion, and heightens its rose.

546. _Note._—The modifications resulting from the juxtaposition of parts diversely coloured are much more positive than those arising from reflection by one part upon another.

If the Painter wishes to dissimulate a Tint of the Complexion—

547. As above, he must distinguish two cases:—

1st, WHEN HE SEES THE COLOURS MODIFIED BY JUXTAPOSITION ONLY, _when the tint may be lowered without leaving its scale_:—

1. By a black drapery, which lowers it by contrast of tone. 2. By a drapery of the same scale as that of the tint, but of a much higher tone.

Such, perhaps, as a red drapery upon a rosy complexion; or, an orange drapery upon an orange-tinted complexion; or, the effect of a dark green drapery on a complexion of a green tint.

2nd, _The tint may be lowered by making it leave its scale_.

1. By a green drapery of very dark tone, upon an orange complexion. 2. By a blue drapery of a dark tone, upon a rosy complexion. 3. By a very dark yellow drapery, upon a very pale orange complexion.

APPLICATIONS TO HORTICULTURE.

SECTION I.

548. The applications I propose to make are of two kinds: the one relating particularly to the arrangement of plants in gardens, according to the colour of the flowers; the other, to the method of distributing and planting ligneous plants in masses, which I suppose to have been previously planned. Doubtless, I need not have discussed the latter subject, but I have been led to it so naturally, and the rules which guided me are so positive and simple, that I have no doubt of their proving profitable to those of my readers who follow them in laying out plantations, &c.

The artist who conducts these operations is called a Gardener, or Landscape Gardener.

ON THE ART OF ARRANGING ORNAMENTAL PLANTS IN GARDENS SO AS TO DERIVE THE GREATEST POSSIBLE ADVANTAGE FROM THE COLOURS OF THEIR FLOWERS.

549. Among the pleasures afforded us by the cultivation of choice plants, there are few so intense as the sight of a collection of flowers, varied in colour, form, size, and position. It is probably because we admire the plants individually, and become attached to them on account of the pains they cost us, that we have hitherto so generally neglected to dispose them in such a manner as to produce the best possible effect when their flowers are seen collectively.

Thus, no defect is more common than that of the _proportion_ in which flowers of similar colours are distributed in a garden. Sometimes the eye is struck by blue or white, sometimes it is dazzled by yellow. Add to this defect of proportion, the ill effect produced by placing together many species of flowers, which, although of the same colour, are not of the same tint: for instance, in spring we see the leopard's bane (_doronica_), of a brilliant golden yellow, side by side with the narcissus, which is of a pale greenish yellow; in autumn, the Indian pink beside the African marigold, dahlias of various reds grouped together, &c.

Such arrangements as these cause the eye, accustomed to appreciate the effects of contrast of colours, to feel sensations quite as disagreeable as those experienced by the musician whose ear is struck with discords.

550. Previously to my observations on simultaneous contrast, and the demonstration of the law which governs it, it was impossible to prescribe rules which, by instructing horticulturists to place, with certainty of success, flowers in proximity whose colours reciprocally enhance each other, enabled them to avoid either the monotony resulting from the grouping of flowers of the same colour, or the disagreeable effect of a collection of flowers whose hues are mutually injurious.

ASSORTMENTS OF FLOWERS,

Where the Plants are apart.

551. The associations of flowers which relate to the harmonies of contrast of colour, are first, those with colours mutually complementary to each other; such as blue with orange, or yellow with violet. Rose or red flowers contrast with their own leaves.

552. White flowers accord more or less favourably with blue and orange flowers, already allied together; and perfectly with rose or red flowers, but not so well with yellow or violet flowers, already allied. White associates much less favourably when the latter is brighter or greener.

White flowers are the only ones that possess the advantage of heightening light tones of any colour, and of separating those whose colours are mutually injurious.

553. Yellow flowers, especially those which incline to orange, accord very well with blue ones.

Flowers of a yellow, more green than orange, have a very good effect with flowers of a red inclining to blue, rather than to orange.

Deep red flowers accord well with deep-blue flowers.

Orange flowers are not misplaced near violet flowers.

ASSORTMENTS RELATING TO THE HARMONIES OF CONTRAST OF HUES.

554. It is so difficult to make associations of hues which will have a satisfactory effect, that I prescribe _in general_ the mutual association of flowers whose colours belong to neighbouring scales.

We must then separate

Pink flowers from those that are either Scarlet or Crimson. Orange " " Orange-yellow, Yellow " " Greenish-yellow,

I shall even go further in advising the separation of— Red flowers from Orange, Blue or Pink from Violet.

Where the Plants are indiscriminately mixed.

555. Flowers which only present contrasts of hues and which spring from seeds sown thickly in borders, or in beds, will not have the same objection as when the roots are planted at a distance from each other.

556. Flowers, presenting a disagreeable contrast of hues, may still produce a good effect, when their assortment makes part of an arrangement of contrasts of colours, strongly opposed; in this case being no longer seen isolated, they become in a manner the element of a picture.

SECTION II.

ASSORTMENTS AS TO HARMONY OF ANALOGY.

557. I only reckon shrubs susceptible of this harmony; because only perennial plants afford to the horticulturist a guarantee that the flowers of one year will be identical with those of the preceding; consequently, if we plant woody shrubs in such manner as to secure a regular gradation of tones, the successive annual flowerings will be constantly according to that order. We may apply this kind of arrangement to standard roses.

558. But I do not advise any one to attempt submitting annuals to this arrangement, because of the uncertainty that exists in the tones of their colour.

Harmonies of Analogy of Hues.

559. If I have spoken against the associations of _contrast_ of hues (554), I am more inclined to speak against the associations of _analogy_ of hues, always remembering the restrictions I have stated above (Section 1). We must not forget that my intention is to describe assortments, whose good effects are certain. Now the more the colours contrast, conformably to our law, the more latitude there will be, although the colours of individual flowers associated vary in tone and in hue.

560. An objection might be addressed to me _that the green of the leaves, which serves as a ground to the flowers, destroys the effect of their contrast_. But it is not so; and to be convinced of it, it is sufficient to fix upon a screen of green silk, two kinds of flowers in conformity with the arrangement of the coloured bands (_pl. 1. fig. 7_), and to look at them from a distance of about ten paces; for when the eye is fixed on two well-defined objects simultaneously, surrounding objects, especially distant ones, produce but feeble impressions.

ON THE ART OF ASSORTING LIGNEOUS PLANTS IN GARDENS, SO AS TO DERIVE THE BEST POSSIBLE ADVANTAGE FROM THE COLOUR OF THEIR FOLIAGE.

561. If we consider trees and shrubs no longer under the relation of the colour of their flowers, but with regard to the manner in which we may employ their foliage in the decoration of gardens, we shall perceive that there is only a very small number of contrasts of scale and hue which we can realize while vegetation is active; yet in autumn, when plants, losing their leaves before falling, assume various colours, as red, rose, scarlet, orange, and yellow, these, by their brilliancy, recall the season of flowers.

Most trees and shrubs present, in the summer season, only the green of their foliage; and, although this green varies in tone and hue, the differences are always trifling.

562. _Harmonies of Contrast._—The most decided contrast of colour that we can establish between the leaves of ligneous plants, is that of green, with foliage nearest to red. But even the _purple beech_ is more of a red-brown than a dark _red_, properly so called, for the colour of leaves results from a mixture of red and green, which, according to the principle of mixing colours must produce black, if they are in suitable proportion, or a brown tone of the green or red scale, according as one or the other colour predominates. The contrast of hue is established by the assortment of a bluish-green and a yellowish green of tones unequally high, by the contrast of a bluish-green brown with a yellowish light green, &c.

563. _Harmonies of Analogy._—Nearly all the masses of various trees in our landscape gardens present certain harmonies of hues mostly resulting from associations established according to considerations foreign to those of the assortment of foliage—an evident result, remembering (561) that the colours of the leaves of the greater part of plants are of green belonging to scales more or less allied, and of tones but little distant from each other.

(_a_) Harmonies of analogy of hues formed of allied tones belonging to neighbouring scales, are those which it is least difficult to obtain.

(_b_) Arrangements of foliage presenting a series of equidistant tones of the same scale of green.

ON THE DISTRIBUTION AND PLANTING OF TREES, ETC., IN MASSES.

564. The principal object of the two following chapters is to supply a deficiency in works on gardening as to the manner of distributing and planting trees in masses, &c., the outlines of which have been previously sketched conformably with precise rules. For authors say nothing on this subject, and the embarrassment of a landowner who wishes to plant an estate already planned out, is further increased by this circumstance, that, in the majority of cases, the author of the plan of the projected garden, after having defined the lines of the plantations, indicated the places where isolated trees must be placed, designated the kinds of trees which should constitute groups, and others which must enter into the formation of masses with trees and shrubs (which he does not generally indicate), leaves the care of planting and other details to ordinary gardeners.

Yet the distribution of trees and shrubs, however easy it may appear, in a piece of ground otherwise perfectly planned, contributes more than is generally supposed to the pleasure of a landscape garden, and presents also more difficulties than to allow of its being effected in a satisfactory manner, when it is abandoned, as generally happens, to chance. In fact, if, at the end of a few years, we observe the greater part of masses planted as they frequently are, we shall be struck with defects which were not at first perceptible, because we were then under the influence of the pleasure we always experience at witnessing the development of plants which have been confided to a carefully prepared soil; and besides, there are some defects which are only perceptible after a certain time, such, for example, as that resulting—

1. _From the plants being placed too near together._

2. _From placing, in the front row, clumps which rise too high, or which lose their lower branches._ Such are the elder tree, and sumach.

565. It was after many years of lost enjoyments, through having planted without fixed rule, masses otherwise well designed in their contours, that I was led by my own experience to seek the means of avoiding similar errors in future. The rules I now give are not the result of reflection merely; they have been practised many years, and I am much deceived if those who observe them will not derive great facilities in their application, and experience from them a lively satisfaction.

566. I will now define several expressions employed to designate the different associations of plants which may form part of a landscape garden.

An assemblage of trees and shrubs, occupying a large space, is termed a _forest_. But in a landscape garden a similar assemblage, or that which has been arranged to present the appearance of a vast space, is called a _wood_, if it is composed of trees and underwood; and a _park_, if it consists of trees only.

[Illustration: ARRANGEMENT OF PLANTS IN LANDSCAPE GARDENING.

PLATE XVIII.]

A collection of trees, shrubs, bushes, and underwood, is called a _grove_; when it consists only of trees, it is termed _a group of trees_.

There are _thickets_ of shrubs, bushes, underwood, and of flowering herbaceous plants.

There are _thickets_ formed of a single species of plants, and thickets formed of several species. The first are called _homogeneous_, and the second _heterogeneous_, or _varied_.

There are _isolated masses_, and _masses subordinated together_.

A small mass of flowers or shrubs, isolated, and of a circular or elliptical form, is called a _bed_.

CHAPTER I.

Of Lines of Plants.

567. I call a _line of plants_, plants placed at equal distances from each other, in straight or curved lines: these plants may be trees, shrubs, bushes, underwood, or flowering herbaceous plants.

568. A _line of plants_ of sufficient extent, and of which the plants are close enough to conceal from view objects placed behind them, is called a _screen_.

All masses planted according to my method are composed of lines of plants parallel to each other; in other words, there is between two similar lines an equal distance throughout. But the distance between the first and the second may differ from the distance between the second and the third, and so of the others. The result would be the same if the lines were closed curves, as, for instance, circles or ovals. The lines of plants are the elements of the masses.

ARTICLE I.

Of the Lines of Plants called Screens.

569. When we desire to conceal any object of considerable extent, we have recourse to a _screen of plants_. Whenever the extent of the land will not permit of the planting of several lines, constituting a mass, evergreens, such as thujas, almond-laurels, &c., are those to be preferred, succeeded by the hornbeam, lilac, privet, &c.

The most homogeneous screens, that is to say, those which are formed of a single species of plant, are preferable to all others for the object they are intended to fulfil; and to avoid the monotony of a single species, we must have recourse to one which offers varieties. For example, a screen composed of violet and white lilacs, will possess at the same time the advantage of homogeneity for concealing what is behind it, and the advantage of variety of foliage; the leaves of the violet-lilac being of a less yellow-green than those of the white lilac. We may alternate one or more plants of violet-lilac with one plant of white lilac.

Of Lines of Plants considered as Elements of Masses.

570. 1st. If the plants in the same line are not of the same species, it is essential that they do not differ too much from each other in respect to height.

2nd. Where a line happens to be entirely seen, the same species must be placed alternately.

3rd. We must avoid placing the same species in two neighbouring lines, when we would employ varied masses which are composed of several lines only.

RULE.—_When two lines of vegetation are planted to constitute a mass, in planting the first or exterior line, we must follow the rule indicated above_ (570), _then go on planting the second line, in the same manner as the first, except that the stakes indicating the centre of vegetation must be placed chequer-wise relatively to the centre of vegetation of the first line._

I will cite an example of a plantation of two lines intended to conceal a wall.

1st _Line_. 1. Almond-laurel. 2. Violet-lilac. 3. Laburnum. 4. Violet-lilac. 1_a_. Almond-laurel, &c.

2nd _Line_. 1. Clump of _prunus mahaleb_. 2. _Idem_, &c.

The distance between the clumps of the first line is four or five feet.

We may plant the first line in _screen_, and the second with trees larger than in the first; we may also plant the second line with roots of _prunus mahaleb_, comprehending between two roots three or five clumps of the same species.

Of Homogeneous Masses.

571. The _homogeneous mass_ includes only a single species of plant, because the intention of the gardener in forming it, is to produce an effect of _individuality_.

In the large French garden, designed by Le Notre, where the trees combine so effectually with the elements established by the architect, to prolong, so to speak, a similar work, the symmetrical plantations are identical, and generally composed of trees of a single species.

572. Although homogeneous masses of trees have a good effect in a large composition, it is not so with those which are composed of a single species, or of a single variety of flower. They almost always present a monotonous aspect, especially if the latter have a definite extent; and if the species of plant of which they are composed is in flower only a part of the year, the defect of monotony will be greatly increased. Homogeneous masses of shrubs or of flowers are only suitable when they are in leaf or in flower during a great portion of the year; as their extent is small, and they serve simply as a bond of union between different parts more or less distant from each other.

Of Heterogeneous or Varied Masses.

573. I shall distinguish two cases—one where it is a _heterogeneous_ or _varied_ mass, isolated, intended to serve as an individual composed of distinct parts; and the other where it consists of many varied masses, allied together, and separated by paths, at least in some parts.

Isolated Masses.

If each line consists of only a single species, we must arrange the lines according to their size. For example—1. Lilacs. 2. Laburnum. 3. Judas trees.

574. _Heterogeneous or varied masses_ placed together so as to form a whole, are generally separated from each other by glades, or unplanted intervals, but cultivated or sown in grass, or by paths. To make what follows thoroughly understood, I must point out the essential difference that exists between landscape gardening and French (geometrical) gardening.

575. French gardening is regular and symmetrical, the paths are straight, and the eye is only impressed by objects slightly varied; for when there are squares or straight borders, symmetry necessarily requires that the objects on one side be repeated on the other. The result is, that when the spectator has visited the principal points of this composition, which are never very numerous, he has seen everything it has to offer to his curiosity.

576. I will not say, with some writers, that landscape gardening is conceived with an entirely different aim. The spectator who surveys a landscape garden, should be excited, so to speak, at every step, by the sight of various objects. The different points of view must be as numerous as possible, the paths must always, therefore, be traced, so that from no point can their whole extent be discovered. The plantations must be disposed so as to conceal the walls, fences, or other disagreeable ill-placed objects. They must allow the eye the greatest possible scope, at all the points the gardener wishes to be displayed; and the views must vary with the different points successively observed.

577. To achieve this, it is evident that there must be no straight paths, but only curved ones. When paths pass between masses, the intervals between these masses must also permit to be seen groups of objects, which must form planes, skilfully prolonging the perspective, as far as possible. The masses, though varied, must nevertheless be allied together, so that neighbouring masses may harmonize as dependent parts of the same whole.

ARTICLE II.

578. _Harmony between masses distant from each other_, in which harmonies may be established by the same general means as they are between neighbouring masses. The foliage in the masses being much more abundant than the flowers, the shades of their greens will not differ so much from each other as the colours of their flowers; consequently, the distant masses, however varied in their foliage, are always in harmony of form and colour, if they have been planted according to our rules; and if they are composed solely of ligneous plants, which lose their leaves in winter, or solely of evergreens, which do not lose them; but in the opposite case, that is to say, when the masses are formed, the one of deciduous trees, and the other of evergreens, some remarks must be made relative to the conditions of harmony, which are the more necessary, as even the most studied landscape gardens generally err in this respect; for a clump or a mass of evergreens is almost always out of keeping in a large space where masses of deciduous trees are found. To remedy this defect we must multiply the groups or masses of evergreens, so as to establish between all of them this same correlation which is required by deciduous trees; but it is not necessary that the trees should occupy a space equal to that occupied by ordinary trees; it is sufficient if their forms recur at suitable intervals. In a word, for evergreens to produce a good effect, they must compose a whole, which unites or intercalates with the general effect of the masses of deciduous trees.

We may oppose allspice trees to pines, cedars to larches; different groups, composed of three or four trees only, suffice to harmonize a large space of ground occupied with two or three groups composed of half a hundred similar trees.

579. _There are certain cases in which the want of either perspective or harmony requires, in a large mass, a line of trees which is neither concentric with its circumference, nor identical with the central line, if there be one; such, for example, as the line P. R., which is found in the masses 1 and 2_ (Pl. 18); _for if the planting of this line be correct, and according to the preceding principles, the trunks, which define it, beyond the concentric plantings, must be in the points of intersection of the line P. R., with the concentric lines, and the central line, if there be one; and the trunks must be as much as possible at equal distances from each other._

Such a plan, always easy to make, will enable a landowner, when once his masses are planned, their concentric lines traced, and the species to be planted determined upon, to order from the nurseryman the exact number of each species he requires.

580. _After tracing the lines of plantations, and putting in the stakes to mark out the centre of the holes to be dug, we must draw upon grey paper lines representing those of the masses we intend to plant, taking as many equidistant points as there are stakes in the corresponding lines of plantation; we then fasten on these points wafers, or little circles of paper, of the colour of the flowers or the foliage of the plants, according to the desired effect._

By this means we can judge of the harmony of the colours of flowers with the different hues of green composing the mass, and thus rectify any defect in the plan before we begin to plant.

The principles on which the preceding rules are founded are those of height, form, variety, facility of development, and distinctness of view. Harmonious arrangement, with reference to these points, not being so exclusively the object of this work as the subject of colour, must be passed with this indication.

Contrast of Colours.

581. This principle, regarded generally, is included in the preceding, since a difference in colour will render plants distinct which have numerous analogies; but viewed specially, it produces among perfectly dissimilar plants, effects which can only be obtained from colour; and it is then that the principle of contrast is to be taken into consideration.

In the application of the law of contrast to the arrangement of flowers, we must never forget the difference between an assemblage forming a line of plants, and an assemblage of flowers belonging to plants of various heights, standing on different planes, so as to produce the effect of a picture. I have alluded to this before (551); for in a linear arrangement, for example, there is nothing more unpleasant than the blue flowers of the German iris, associated with the light violet of the lilac. But if we add to this association large tufts of _alyssum saxatile_, Persian iris, and red tulips, so that the golden yellow, white, and deep red, appear on one plane, and the deep blue and the light violets on a more distant plane, we shall obtain general effects of a most agreeable kind.

Repetition.

582. When a line of plants exhibits the repetition of the same species, and presents them regularly at the same intervals, an effect is produced which, although very agreeable, is but little appreciated—for it is very rarely met with in gardens. It is especially the repetition of a similar arrangement of colours that is agreeable, and which recommends the observance of this principle.

Repetition of the same arrangement of plants of various kinds, and of course distinct to view, contributes greatly to prolong the extent either of an alley or of a mass; a similar general effect repeated a certain number of times becomes a standard, by means of which the eye judges the space to be greater than if it were bordered with individuals of the same species or variety equal in number to the former. This effect is carried to the utmost extent when the arrangement is composed of a certain number of tufts—five, for instance—placed between two trees, which rise above them, but not too high.

Repetition and distinctness of view concur in producing an agreeable effect.

583. _Variety_, like every other principle, should never be carried too far, and it is a great mistake to suppose that plantations made without design, and which thus it might seem must be extremely diversified, produce in this respect more effect than those which have been arranged according to the principles of distinct view, contrast, and repetition.

Whenever objects must have a certain superficial extent, we gain nothing by multiplying varieties of them. Thus, the repetition of an arrangement of three colours, including white or black, will generally be more agreeable than that of an arrangement of five colours.

Diversity of colours, pushed to the extreme, can only be permitted in a continuous border, or a bed of different varieties of the same species of flowers, as a border of larkspur, china aster, or anemones; but, for flowering shrubs, we shall gain everything by not indefinitely multiplying their colour, in a view which the eye can embrace at once. And as with colours so with forms, which must not be too diversified in the same arrangement.

Symmetry.

584. We should deceive ourselves very much if we supposed the principle of symmetry to be excluded from landscape gardening. But, in order to perceive it or to put in practice, it is necessary to distinguish the _symmetry of similar parts_, and _the symmetry of parts merely corresponding_.

The former is that of two equal parts of one whole, as the two halves of a circle, of a square, of an equilateral or isosoceles triangle, &c.; while

Symmetry of parts merely corresponding, is that of two parts of the same whole, which, without being equal, have the same form, or nearly so; such are the two triangular parts of the Mass 3, Plate 18.

Or, that of two separate parts, more or less analogous in form, extent, or nature, which have a correspondence of position relatively to an intermediate object.

Or, that of two masses or groups of trees, or of a mass and a group of trees which are presented, the one to the left, the other to the right.

General Harmony.

585. In the general composition of a large landscape garden, it is not enough to have satisfied all these principles, if the different masses subordinated together, which we shall now regard as individuals, as well as the various constructions of wood or of stone, are not combined by some harmonious relation suitable for satisfying the principles of _general_ harmony. The isolated or subordinated masses near or distant from each other must be allied together by the same vegetable form or by analogous forms, or by the same arrangements of several species; or, lastly, by the same colours of flowers or of foliage. By the aid of similar means, we ally the house and other buildings to the different parts of the garden. When the neighbouring masses, especially those formed near buildings, are not sufficiently allied together, or the perspective of their concentric or median lines is not satisfactory, we have recourse to a different line of vegetation, which cuts the first and thus adds to the general harmony. Thus, as I have so strongly insisted, when we decide to plant evergreens in a landscape garden, they must be distributed throughout the composition.

SIXTH DIVISION.

INTERVENTION OF THE PRECEDING PRINCIPLES IN THE JUDGMENT OF COLOURED OBJECTS, RELATIVELY TO THEIR COLOURS, CONSIDERED INDIVIDUALLY, AND TO THE MANNER IN WHICH THEY ARE ASSOCIATED.

586. In this division my object is purely critical. The positive conclusions at which I have arrived upon certain assortments of colours, so as to derive the best result from them under given circumstances, become rules, adapted to guide those who would

judge a work of art in which such assortments occur. The generalizations established in the preceding chapters, with the object of aiding the numerous artists who use colours, now critically considered, will serve as the basis of a conscientious and sound judgment upon the merit of any work in which these generalizations are concerned. They will, I trust, possess the double advantage of all the rules involved in the nature of such things; they guide the workman who does not disdain them, and they direct the critic who judges the work of which these rules govern some element. We cannot then refuse to recognise the utility of such an examination, both for artists and for the public, to whom they are more particularly addressed, in the hope that a clear demonstration of what is laudable or censurable will form such a public taste as, by preventing a reliance on first impressions, will lead to a sound judgment; and that we may not henceforth strive to enlist public suffrages by falling into unsuitable singularity, or by wandering from the truth.

587. If there exists a subject worthy of being studied critically on account of the frequency and variety of the cases it presents, it is unquestionably this; for whether we contemplate the works of nature or of art, their varied colours form one of the finest spectacles man is permitted to enjoy. Hence the desire of reproducing the coloured images of objects which excite our admiration or interest, has produced the art of painting. The imitation of the painter's works has given birth to tapestry, and carpets, and mosaics; while the necessity for economically multiplying designs has led to ornamental printing. The love of colour has also induced man to paint his dwelling and to dye his garments and household decorations.

588. The sight of colours, so simple a thing for the greater part of mankind, is, according to some philosophers, a phenomenon entirely out of the domain of positive knowledge, inasmuch as they consider that it varies with the organization, and even the imagination, of individuals; consequently, they think that it cannot be inferred that, because one man sees an object in a certain way, another will see it in like manner under the same external circumstances. They believe that no generalization, deduced from observation, can direct the artist with certainty, either in the art of seeing his model or in faithfully reproducing a coloured image of it: they also think that no useful physiological generalization can arise from a profound study of the modifications his organs experience from the sight of the colours that bodies present to him.

I cannot admit that we ought to abstain from the study of a subject because it presents variable phenomena.

All those who are engaged in the study of the positive sciences, should inquire for some fact capable of illustrating the study of these phenomena.

589. I entered upon this study, not having spontaneously chosen it, but because it appeared to me indispensable before pretending to establish a sound judgment on the beauty of the dyer's colours. As soon as I felt the necessity for this study, in my capacity of Director of the Dyeing Department of the Royal Manufactories, my first care was to discover whether I saw colours as the generality of persons see them. I was soon perfectly convinced that I did, and not till then did I venture to make my researches the subjects of public lectures. These have been repeated before the students of the Polytechnic School. Certain questions addressed to my auditors to satisfy me that they saw the things I put before their eyes as I saw them myself, have, in the majority of cases, always proved them to be so, and yet my demonstrations were given in the reception-hall at the Gobelins,—a place ill adapted for the exhibition of the phenomena of contrast to a large audience. Certain observations by myself, tested by a great number of persons in my laboratory, and afterwards publicly exhibited, form the subject of this book; all who repeat my experiments will discover whether my opinion is well-founded, or whether an opinion is correct which pretends that the sight of colours is not capable of giving a general positive result. Because some individuals have organs of sight so imperfect that they cannot distinguish green from red, or blue from grey, &c., must we write our treatises on optics without mentioning either red, green, or blue, and cast away these colours from the palette? Assuredly human nature is too limited to allow of our making such a sacrifice of our common organization to the infirmity of an individual.

590. In order to comprehend clearly how experiment and observation, after having disentangled the causes which exercise a determinate influence upon the sight of colours, led me to adopt the opinion that these phenomena are perfectly defined by the law of contrast and the conclusions therefrom, doubtless it will suffice to consider how

1. Our former ignorance respecting the different states of the eye, which, in seeing colours, give rise to the phenomena of simultaneous, successive, and mixed contrasts.

And our former ignorance respecting the definite influence that the direct or diffused light of the sun exercises, according to its intensity, upon the colours of bodies, have led to the establishment of an opinion contrary to my own;—that is to say, the opinion that _the same colour appears so diversely to different persons, and even to the same person, that nothing general or precise can

be deduced from the sight of coloured objects, with regard to their respective colours_.

2. To consider how the following have passively contributed to belief in this opinion.

The limited number of ideas we have generally about the modifications of coloured bodies, by their mutual mixtures; or in other terms, upon the colours resulting from these mixtures.

The want of a precise language to convey the impressions we receive from colours.

591. It is indisputable that if we are ignorant of the regularity with which the eye passes successively through stages, the extremes and the mean of which are very different, in viewing the colours which put the organ into the condition of perceiving the phenomenon of one of the three contrasts (77) we shall be led to consider the sight of colours as a very variable phenomenon, _while the successive stages through which the organ passes being once distinguished, the variations of the phenomenon become perfectly definite_.

592. If we are ignorant of the law of simultaneous contrast, we shall suppose that the same colour varies in tint according to the colour with which it may be associated; and if we are ignorant that contrast affects the tone as well as the colour, we cannot explain how two similar colours (for instance, blue and yellow at the same depth of tone) will appear redder by juxtaposition; while, if the blue is very deep relatively to the yellow, it will appear black, rather than violet, and the yellow will appear more green than orange. Finally, if we are ignorant of the effect of the brightness which a complementary can give to a dull colour, we cannot explain the great difference there is between the effect that a red ground has upon imitative gilt ornaments, and the effect of the same ground upon metallic gilt ornaments (384).

593. Doubtless, also, if it be not known that in a complex object, the eye can only see clearly at the same moment a small number of parts and that the same part may appear to different eyes with different modifications, according as it is seen juxtaposed with one or another colour, as in the instance given (407).

594. We might know the regularity of the successive states of the eye during the sight of coloured objects, and the law of simultaneous contrast of colours, and yet, if we were ignorant of the influence of various degrees of intensity of light in varying the colour of bodies and in rendering the modifications of contrast more or less evident, we should be led to believe in an indefinite variation in the aspect of colours; but this variation is perfectly defined by the following remarks:—

If the direct light of the sun or diffused daylight illuminates a monochromous body unequally, the part most vividly lighted is modified as it would be if it received orange, and the modification appears the stronger the greater the difference of light on the parts (280): thus the more intense the light, the more it gilds the body it illumines; it is thus always easy to foresee the effects of it when we know the result of the mixture of orange with various colours.

595. The phenomena of simultaneous contrast being less evident in a very vivid light than in a weaker light (63), it follows that if we disregarded the difference in the effects, we should greatly deceive ourselves in our appreciation of the phenomena of contrast of similar colours. Simultaneous contrast, which tends to make the differently coloured parts appear as distinct as possible, is carried to a maximum, precisely when the light being feeble, the eye requires the greatest contrast of colour to perceive distinctly the various parts upon which it is fixed.

596. We may perceive the modifications presented by bodies when lighted, and yet we may experience much difficulty in accounting for them, for want of knowing how to represent exactly the modifications which the coloured materials experience, in their colour, according as they receive light or white, shade or black; or according as they are mixed together. It is partly to make these modifications clearly known that I have designed the _chromatic hemisphere_ (134, _et seq._). In describing it, I have attached less importance to its material realization than to the rational principle upon which it depends. On looking at the lines of this diagram independently of all colouring, we understand how any colour is reduced by white, deepened by black, and broken by black and white, and how, by mixture with a pure colour, it produces hues. I shall add subsequently some new considerations on the gradations of colour made with coloured materials.

My object would not have been attained had not the chromatic hemisphere given me the means of representing, by a simple nomenclature, the modifications which a colour undergoes by the addition of white and black, modifications which produce the _tones of its scale_; those which it receives from black yielding _broken scales_, and those resulting from the addition of a pure colour, produce scales which are _hues_ of the first colour.

597. Finally, to the definitions which I have given of the words _tone, scale, hue, broken colours_, I must add the distinction of the associations of colours into _harmonies of analogy_, and _harmonies of contrast_ (172).

I am convinced that all those who accept the small number of definitions I have given, will find much advantage from them in accounting for the effects of colours, and in expressing their views to others. By their aid it will be easy to notice relations which might have escaped observation, or which, in the absence of precise language, could not have been clearly communicated.

598. It would be ignoring a fact to attribute the opinion I have combated, exclusively to ignorance of what I have just recapitulated, or to believe, that in order to establish the contrary opinion, which I maintain, it is sufficient to dissipate this ignorance.

But I am satisfied with pointing out the error, without making the least pretension to overthrow it, otherwise than by stating what I believe to be the truth.

599. The study of the positive facts just reviewed, leads to a certainty in the view of colours which all may acquire who devote themselves to it. They will see how fruitful it is in applications, and that it is independent of every hypothesis, and that it would be impossible to obtain this result, if there did not commonly exist among men an average organization of the eye, which permits them to perceive in similar circumstances the same modifications, but with varied intensity of perception.

600. Having noticed the series of principles upon which my book is founded, I next consider these facts under the three following relations:—

1. The certainty they give in judging of the colour of an object.

2. The certainty they give to our judgment in the various arts which address the eye by coloured materials.

3. The union they establish between the principles common to many arts, which speak to the eye as it were various languages, in employing different materials.

4. The influence that the disposition of the spectator's mind may have upon his judgment of a work of art.

SECTION I.

ON THE CONNEXION OF THE LAW OF SIMULTANEOUS CONTRAST OF COLOURS WITH THE JUDGMENT WE FORM UPON ALL COLOURED BODIES, UNDER THE RELATIONS OF THE RESPECTIVE BEAUTY OF PURITY OF THEIR COLOURS, AND OF THE EQUALITY OF THE DISTANCE OF THEIR TONES IF THESE BODIES BELONG TO THE SAME SCALE.

601. The most simple and general conclusion deduced from the law of contrast is certainly that which concerns the judgment we exercise, either by taste or profession, on a colour, whether presented by a coloured paper, a textile fabric, a glass, an enamel, a picture, &c. All those who have some experience in the matter consider one condition as essential to be fulfilled to avoid error, namely, that the colour concerning which we have to determine be compared with another colour analogous to it. _If we are ignorant of the law of contrast, the result of this comparison is not exact, whenever the objects compared are not identical._ I now proceed to demonstrate this by examples adapted to the application of the principle spoken of. Further, a more remote consequence of the law affords the means of knowing whether the tones of a scale of wool or silk are equidistant.

ON THE COMPARISON OF TWO SAMPLES OF THE SAME COLOUR.

602. When we have to do with two patterns of any kind, which are related to the same colour, if there is no identity between the tints, we must take into account the contrast which exaggerates the difference; thus if the one be greenish-blue, it will make the other appear less green, or more indigo, or even more violet, than it really is; and, reciprocally, the first will appear greener than when viewed alone; the same with the reds, if one is more orange than the other, the latter will appear more purple, and the former more orange, than they really are.

INFLUENCE OF A SURROUNDING COLOUR UPON ONE COLOUR WHEN COMPARED WITH ANOTHER.

603. Since the contrast of colours which are not analogous, tends to improve and purify them, it is evident that whenever we would exercise a correct judgment upon the beauty of colours, after comparing them with the colours of objects analogous to the first, we must take into account the kind of work, and the manner in which they are juxtaposed, if the objects compared are not the exact

representation of the same subject. For, other things being equal, the same colours not blended, and which are not sufficiently analogous to injure each other, will certainly appear more beautiful disposed in contiguous bands than if each were seen on a ground which consisted of it exclusively, and which consequently produced only a single impression of colour upon the eye. Colours forming palms like those of Oriental shawls or patterns, as of Turkey carpets, produce a much greater effect than if they were shaded or blended, as they generally are in paintings. Consequently, for example, in comparing a stripe of crimson in a Cashmere shawl of various stripes with the crimson of a French shawl, we must destroy the contrast of colours by placing around it a piece of grey or white paper, cut out so as to allow this stripe only to be seen, when the parts compared will be submitted to the same influence from the surrounding objects.

604. So, when we compare the colours of old tapestries, pictures, &c., with colours recently dyed or painted. Time acts very unequally, not only on the different kinds of colours of dyed stuffs, but also upon the tones of the same scale. Thus, the deep tones of certain scales,—those of violet, for example,—fade, while the deep blues of the indigo-blue scale, the deep tones of madder, kermes, cochineal, are permanent. Also, the light tones of the same scale fade during a time which has no sensible effect in altering its deep tones. Whence the colours which have most resisted the destructive action of time, being more isolated from each other, as well as deeper and less blended, appear to have more brilliancy. There are many pigments, as most of the lakes, which are in the same condition as compared with ultramarine, the oxides of iron, the blacks, &c.

On the Effect of Contrast upon the Browns and the Lights of most of the Scales of Wool and Silk employed in Tapestry and Carpets.

605. When we look at the whole effect of tones of most of the scales made use of in these manufactures, the phenomenon of contrast exaggerates the difference of colour observed between the extreme and the middle tones of the same scale. For instance, in the scale of indigo-blue, applied to silk, the lights are greenish, the browns are tinged violet, while the intermediate tones are blue; but the difference of green and violet at the two extremes is augmented by the effect of contrast. So in the scale of yellow, the light tones appear greener, and the browns redder, than they really are.

606. In speaking of a difference existing between the deep and the light tones of most of the scales of wool and silk, which is exaggerated by contrast, I will add some remarks relative to the gradations the dyer produces. This gradation is very seldom perfect, as the light tones are exactly represented to the eye by the colour taken at its normal tone, reduced by white. Thus, a compound which at the normal tone is pure yellow, or slightly tinged with orange, will, by reduction, produce light tones of a greenish-yellow. An orange-red compound upon silk or wool will yield light tones tinged violet-red. To obtain a correct gradation, we must in most cases add to the weak tones a new coloured material, adapted to neutralize or weaken the defect spoken of.

607. Many of the colouring matters used in painting produce the same result when reduced with white. I do not speak here of changes which may be the effect of chemical action; I allude only to those which result from an attenuation of the coloured material. For example, the normal tone of carmine is a much purer red than its light tones, which are evidently tinged with lilac. Ultramarine, so beautiful in itself, yields light tones which, with respect to the blue rays, appear to reflect more violet rays than the normal tone. In consequence of these facts, it is difficult to colour the chromatic diagram, because many trials must be made to obtain the modification of colour which yields the normal tone of a scale, by the addition of such coloured materials as will render the gradation correct.

MEANS AFFORDED BY CONTRAST FOR ASCERTAINING WHETHER THE TONES OF A SCALE OF COLOUR ARE EQUIDISTANT.

608. Contrast, which augments the difference existing between two tones of the same colour, affords the means of judging with greater certainty than could otherwise be done, whether the numerous tones of a scale are at the same distance from each other. Thus, if the tone 2, placed between 3 and 4, appears equal to the tone 1, it follows, if the tones are equidistant, that 3 placed between 4 and 5 will appear equal to 2; that 4 put between 5 and 6 will appear equal to 3, and so with the others. If the tones are too near together to yield this result, we must move them successively, not one degree, but two or three. This means of judging of the equality of distance that separates the tones of the same scale, is based upon the fact, that _it is easier to establish an equality than to estimate a difference between patterns of the same colour._

OF THE BINARY ASSOCIATIONS OF COLOURS, CRITICALLY CONSIDERED.

609. In order to sum up in few words the generalities which must serve as the bases of our judgment, not on one colour compared with another of the same sort, but on the associations of two colours, which any object whatever presents to our eyes, we must consider combinations both of complementary and non-complementary colours.

1st. _Combination of Complementary Colours._

This is the only association where the colours mutually improve, strengthen, and purify each other without leaving their respective scales.

This case is so advantageous to the associated colours, that the combination is also satisfactory when the colours are not absolutely complementary; also when they are made dull with grey. I therefore prescribe the complementary association when we have recourse to the harmonies of contrast in painting, in tapestry, in the arrangement of coloured glass windows, in the assortment of hangings with their borders, in that of stuffs for furniture and clothing; and, lastly, in the arrangement of flowers in our gardens.

2nd. _Combination of Non-complementary Colours._

The product of this combination is distinguished from the preceding in this,—the complementary of the juxtaposed colours, differing from the other colour to which it is added, there must necessarily be a modification of hue in the two colours, as well as a modification of tone, if they are not taken at the same height.

610. Juxtaposed non-complementary colours can _certainly_ give rise to three different results:—

1. They may improve each other. 2. The one may be improved, the other may lose some of its beauty. 3. They may injure each other.

The greater the difference between the colours, the more favourable will the juxtaposition be to their mutual contrast; consequently, the more analogy they will have, and the more chances there are that the juxtaposition may injure their beauty.

1. _Two non-complementary colours improve each other by juxtaposition._

611. Yellow and blue are so dissimilar, that their contrast is always sufficiently great for their juxtaposition to be favourable, although the juxtaposed colours belong to different scales of yellow and blue.

2. _One colour juxtaposed with another which is not its complementary, may be improved, while the latter may be injured._

A blue, which is improved by a yellow, being placed beside a violet (blue rather than red) may lose some of its beauty, by becoming greenish; while the orange it adds to the violet, neutralising its excess of blue, rather improves than injures it.

3. _Two non-complementary colours may injure each other._

A violet and a blue are reciprocally injurious, when the first greens the second, and the latter neutralizes sufficient of the blue in the violet to make it appear _faded_.

It might also happen that although the colours juxtaposed be modified, neither gaining nor losing in beauty, that the one may gain without the other losing; lastly, that the one may neither gain nor lose, while the other loses.

612. _In the association of two colours of equal tone, the depth of the tone may have some influence on the beauty of the association._

For example, a deep indigo-blue and an equally deep red, gain by juxtaposition; the first, by losing some violet, will become a pure blue, the second, in acquiring orange, will become brighter. If we take light tones of the same scales, it may happen that the blue will become too green to be good as a blue, and that the red, acquiring orange, will be too yellow to be a pure red.

613. _In the association of two coloured objects of tones very distant from each other, belonging to the same scale, or to scales more or less allied, the contrast of tone may have a favourable influence upon the beauty of the light tone_; because, in fact, if the latter is not a pure colour, its juxtaposition with the deep tone, upon the whole brightening it, will purify the colour from whatever grey it may have.

614. It is very necessary for the correction of our judgment of these principles on the binary associations of colours, not to lose sight of all that precedes, concerning colours that are “dead,” or without gloss, and that their combination be considered independently of

the form of the objects presenting them, for the twofold reason, that _the glossiness of the coloured surfaces, and the form of the bodies which these surfaces bound_, may modify the effect of two associated colours; consequently, the analysis I have made of the optical effects of colours would be incomplete without speaking of the possible influence of these causes.

Influence of Gloss taken into consideration in the Effect of Contrast of two Colours.

615. The optical product of the juxtaposition of contrasted flat colours is composed of two effects:—1. The effect which arises from each of the juxtaposed colours, by receiving the complementary of the colour contiguous to it, is thus strengthened or tinged agreeably, independently of any augmentation of gloss. 2. The effect arising from gloss in the two juxtaposed colours. Here it may be remarked that associations which I have not prescribed, such as red with violet, or blue with violet, have a fine effect in the plumage of certain birds and butterflies; for, in these natural associations, the effect arising from the addition of the complementaries to each, which would injure the _flat_ colours, is entirely insensible in surfaces which acquire _metallic brilliancy_ from their organic structure. Finally, I shall add, that it would be necessary, before raising the objection, to demonstrate that the same red, associated with green, the same violet associated with yellow, and the same blue associated with orange, equally glossy, would be less effective than in natural assortments.

Influence of Form taken into consideration in the Effect of Contrast of two Colours.

616. Elegance of form, the arrangement of the parts, their symmetry, the effects of light and shade, and the association of ideas which may connect this form with an agreeable recollection, will prevent the perception of the ill effect of two associated colours, even when not glossy. Thus, for example, in flowers, combinations, which would not produce a good effect upon two plain surfaces, are very beautiful. For example, the flower of the sweet pea, which has the combination of red and violet.

617. The critic must be directed by the considerations here summed up:—

1. The kind of association: the greater the difference between the colours, the more they beautify each other; and, the less difference there is, the more they will tend to injure one another. 2. The equality in depth of tone. 3. The difference of tone, the one being deep, the other light. 4. The glossiness of the surfaces which reflect the colours to the eye. 5. The form of the coloured body.

OF THE COMPLEX ASSOCIATIONS OF COLOURS, REVIEWED CRITICALLY.

618. It is evident that the rules prescribed for judging of a colour, and the associations of two colours, in an absolute manner, must serve for judging as to the colours of an association, however complex it may be. We shall consider the masses of colours which are upon the same plane, the extent which each occupies, and the harmony which unites them. On submitting to a similar examination the colours on the other planes, we can then look at the colours of the latter. The critic who is well satisfied with seeing clearly at the same time, only a very small number of the objects that a picture presents to him and who is also accustomed to examine a coloured composition in this manner, is in the position of a person who reads in succession writing on the same side of a sheet of paper; one series of lines crossing the first at right angles, and the third composed of lines running diagonally across the paper. The critic must review the _ensemble_ of the picture as to its colours, and then, being attentive to their particular and general associations, he will be in a condition to enter into the thought of the painter, and to see whether he has employed the most suitable harmonies to express it. Although it is easier to form with opposed colours than with neighbouring colours binary assortments favourable to the associated colours, yet, when a great number of pure and brilliant colours are employed, it is more difficult to harmonize them than if we produced the effect with a small number of colours, which would involve only the harmony of analogy, or that of scale, or of hue.

619. Although harmony of contrast most favourably causes two colours to impart value to each other, yet, when we desire to derive the greatest advantage from a union of numerous brilliant colours in any work—a picture, for instance,—this diversity presents some difficulties in the general harmony, which a smaller number of colours, and especially of brilliant colours, would not present. It is, therefore, evident that, if we compare two effective pictures, well adapted to be judged under the relation of colour (other things being equal), the one which presents more harmony of contrast of colour will have the greater merit, on account of the difficulty overcome in the employment of the colours; but it must not be inferred that the painter of the other picture is not a colourist; for the art of colouring is composed of several elements, and the talent of opposing pure colours to each other, is only one of these elements.

620. Let us now consider the relations existing between the subjects of painting and the harmonies they admit of. We know that the more pictures address the eye by numerous contrasts, the more difficulty the spectator experiences in fixing his attention; especially if the colours are pure, varied, and skilfully distributed upon canvas. It results, therefore, from this, that these colours, being much more vivid than the flesh tints, the painter who wishes that his idea should be found in the expression of his figures, and who, deeming this part of his art superior to the rest, is convinced that the eyes of most people ignorant of the art of seeing, being carried away by their first impressions, are incapable of returning from these to receive others;—the painter, I say, who knows all this, and is conscious of his power, will be restrained in the use of harmonies of contrast, and prodigal of the harmonies of analogy. But he will not derive advantage from these harmonies, especially in a subject covering a vast space filled with human figures, as the "Last Judgment" of M. Angelo, unless he avoids confusion by correct drawing, by a distribution of the figures in groups, skilfully distributed over the canvas, so that they may cover it almost equally, yet without cold symmetry. The eye of the spectator must embrace all these groups easily, and seize the respective positions; while in looking into one of them he must discover a variety which will invite his attention to other groups.

621. The painter who fails to gain the effects of the physiognomies, &c., in having recourse to the harmonies of analogy, will not have the same advantage in fixing general attention, as the painter who employs the harmonies of contrast.

The harmonies of contrast of colour are especially applicable to scenes (illumined by a too vivid light), representing fêtes, ceremonies, &c., which may be sober without being mournful; they are also applicable to large subjects, comprising groups of men animated with various passions.

Hence, the critic must never compare the colouring of two large compositions without taking into account the difference which may exist in the suitableness of each subject with one kind of harmony rather than with the other.

Painting in Flat Tints.

622. To apply painting in flat tints to historical, portrait, and landscape painting—in a word, to the imitation of any object of which we can produce a faithful representation, would be going back to the infancy of art; but to abandon it to practise exclusively the system of painting where all the modifications of light are reproduced according to the rules of chiaro-'scuro, would be an error which can be demonstrated beyond question.

1. That, in every instance in which a picture must be placed at such a distance from the spectator that the details of chiaro-'scuro will not be visible, we must have recourse to flat tints,—not neglecting, however, to use masses of light and shade adapted to give relief, if it is considered suitable.

2. That, in every case where the picture is necessary to the decoration of an object, flat tints are preferable to chiaro-'scuro, because the use of the object almost always prevents the picture which ornaments it from being clearly seen under all circumstances. Thus painting in flat tints is preferable to the other—

For ornamenting boxes, tables, screens, which, from the various positions their use requires, only allow to be seen a part of the pictures which decorate them; or, if the paintings are entirely visible, as those of a screen, they will be presented relatively to the daylight in a manner quite different from each other, on account of these various positions of their parts;

For decorating curved surfaces, as those of vases, the surfaces of which are never plain.

3. That the qualities peculiar to painting in flat tints are:—

Purity of outline; Regularity and elegance of forms; Beautiful colours properly assorted.

Whenever suitable, the most vivid and the most contrasting colours may be advantageously employed.

Simplicity in the whole, so as to render clear and distinct view easy.

OF THE ARTS WHICH ADDRESS THE EYE BY EMPLOYING COLOURED MATERIALS OF A DEFINITE SIZE, CONSIDERED RELATIVELY TO THE PHYSICAL CONDITION OF THESE MATERIALS, AND TO THE PECULIARITY OF THE ART IN WHICH THEY ARE EMPLOYED.

623. If we examine paintings with sufficiently powerful magnifiers, we shall see that the coloured material, far from being continuous in all its parts, is in separate particles, and consequently, if the naked eye does not perceive them separately, it is because they are

too small. In fact, the coloured threads (elements of tapestries and carpets), and rigid coloured prisms (elements of mosaics), which are visible to the naked eye, may be reduced to such a state of division, and so mixed and combined, that at the distance from which we view them united they appear as a uniform coloured surface—as if painted; whence the possibility of making, with these elements, works which correspond to those painted in chiaro-'scuro; but it will be easier to execute such as correspond with flat tints.

TAPESTRIES, CARPETS, MOSAICS, AND COLOURED GLASS WINDOWS, CORRESPONDING TO PAINTINGS IN CHIARO-'SCURO.

Tapestries with Human Figures.

624. Tapestries with human figures derive their origin from the taste of mankind for painting. They had adorned churches, palaces, and castles, before they appeared in simple dwellings.

From the filamentous condition of the elements constituting them, their size, the direction the weaver gives them in twisting the weft upon each thread of the warp, results a coloured image presenting two systems of lines cutting each other at right angles. From this structure it results, that a tapestry will not produce the effect of a painting (the surface of which is entirely uniform), if the spectator does not view it from a point sufficiently distant; so that, these lines ceasing to be visible, the delineation which separates each part of the design from the contiguous parts, will appear like the delineations of a painting, as much so as the indentations of the outlines which are oblique to the weft will permit. Hence _the objects represented by it must be large, of various colours, forming harmonies of contrast rather than harmonies of analogy_.

625. Every model which does not fulfil the previous conditions is bad, and as, in pictures which have not been painted with the intention of being reproduced in tapestry, it is difficult to meet with the union of pure outline with harmonies of colours sufficiently numerous and contrasted, it follows that what would be very advantageous to the art, is the execution of pictures intended to serve exclusively as models, painted broadly, so as to resemble, in some degree, painting in flat tints.

The weaver not having, at least at present, models painted on this system, has to make, not only, as we say, _a translation_, but also _a free and not a literal translation_, of the model; and it is this, in my opinion, which distinguishes the artist-weaver from the mere _workman_. Far from contending, then, with painting, the weaver, on the contrary, must study the circumstances in which he should yield in the struggle, so that he may avoid the difficulties with the means at his disposal; and when, especially, he must deviate from his model.

Tapestries for Furniture.

626. The preceding consideration respecting the size of objects that figured tapestries should reproduce, is not applicable to tapestry for furniture, seeing that the threads of the warp produce lines which, far from being disagreeable, are often imitated by the paperstainer.

627. These fabrics being intended for chairs, couches, curtains, screens, &c., the painter charged with composing designs for this class of works, must never forget that tapestries may occupy dark places, where they are imperfectly and often indistinctly seen; consequently he must select simple and elegant forms, in harmony of colour with the tapestry, &c., in the apartment. These models, even more than those for tapestries with human figures, must assimilate with painting in flat tints.

From among the facts I could quote to support this opinion, I shall select the following. There was a deep rose-red curtain, the centre representing a large bouquet of flowers of various colours, framed, as it were, in a garland of white roses. The artist had painted the model under the idea of executing this garland with silver thread; but this metal being objectionable, on account of its tarnishing by various exhalations, preference was given to white and grey silk, imitating the tones yielded by a silver object in relief. An experiment showed that it could not be attained by these means, because the contrast of the ground made all the half-tints appear _green-grey_, and these in their turn made the lights appear rusty-pink, in consequence of the greenish colour of their contrast. This annoyance being communicated to me, I advised M. Deyrolle, in reproducing the model, to make use of only three light tones of the rose scale in silk, and a white linen thread. By this means I expected that the complementary of the ground, neutralizing the rose, would produce a greyish half-tint, well adapted to set off the white. The result was such as I had foreseen. A second copy, made with a mixture of the light tones of the pure rose scale, slightly broken, gave an image less white, less _silvery_ than the preceding; or, in other terms, appearing a little greenish when compared with the first, and more harmonious. It resembled

the effect obtained with rose-red under lace or tulle, which permits little of the ground to be seen. This example indicates the means of executing white designs upon any kind of ground.

Savonnerie Carpets.

628. Carpets are larger than the tapestries for hangings; on the other hand, being liable from their position to be soiled by the feet, and to receive furniture on some part, they are in a less favourable condition than tapestries for being distinctly seen. This, then, is one reason why we should choose models, of design and colour adapted to the circumstances necessitated by custom, and in harmony with what is around.

Mosaics.

629. Mosaics being composed of minute prisms, and of materials susceptible of polish, we can rigorously copy very small objects, and, consequently, approach much nearer to painting in chiaro-'scuro than by employing threads. But to arrive at this result, without being unfaithful to the peculiarity of the art, the materials must be sufficiently solid, and joined together so intimately as to resist the agencies which would destroy a painting; for if this end be not attained, we cannot see the use of copying a picture in mosaic. So that to justify the production of such works, we must make sure that, in the situations in which they are placed, they will resist the agents which would destroy the works of the painter.

Windows of Coloured Glass.

630. A work executed in small prisms of transparent coloured glass, in imitation of painting in chiaro-'scuro, would be a true transparent mosaic. I do not know that such an imitation has ever been executed.

All the coloured glass windows which I have spoken of as decorations of Gothic churches, are composed exclusively of small pieces of glass of uniform colour, united by strips of lead or of iron; or altogether of these small pieces of glass, and of glass upon which we have applied with a pencil materials which afterwards have been vitrified: we can only entertain the question of the latter in this article.

We may propose two different objects in the production of these windows: either the coloured pieces are altogether secondary in the work, that is to say, occupying a much smaller extent of surface than the others, they do not attain to the perfection of painting,—such is the case with the greater part of the windows of large Gothic churches,—or else these pieces are the principal parts, which, predominating over the others, we attach great importance to the design and to the gradation of tints; such are several windows executed at the Royal Manufactory at Sèvres. The more such works resemble the preceding windows by the effect of their variety, brilliancy, and apposition of colours, the more they attain the object they must essentially fulfil.

Tapestries, Carpets, Mosaics, and Coloured Glass Windows, corresponding to Painting in Flat Tints.—Tapestries with Human Figures.

631. Although I have advised for tapestry models executed on the system of painting in chiaro-'scuro to resemble painting in flat tints, yet I shall not recommend taking the models entirely according to this latter system.

Tapestry for Furniture.

It is quite otherwise with patterns of tapestry for furniture. I believe that we can make some very beautiful works by copying patterns in flat tints; and that, in the decoration of large apartments, we may obtain an excellent effect from this kind of tapestry. I believe, also, that it would be more suitable for forming part of a general system of decoration, than the kind of tapestry of which I have spoken in the preceding article. Moreover, it is more favourable than the latter to the splendour of the colours.

The preceding observations are entirely applicable to the production of carpets.

Mosaics.

632. Mosaics being composed of more rigid and coherent coloured materials than are employed in the arts which combine coloured materials, I believe that it will be requisite, in judging works of this sort, to consider the power of the materials to resist the effects of friction, water, and atmospheric agents as essential qualities; the colour will follow.

Windows of Coloured Glass.

633. Considering coloured glass windows under the threefold relation of transmitting light into large Gothic churches, of their accordance with the decoration of objects consecrated to the rites of the Church, of transmitting a coloured light entirely in unison with the religious sentiments, I prescribe a uniform colour for rose windows and straight windows with circular or pointed tops, the smallest number of colours in the glass, glass of uniform colour predominating over the other to produce the best possible effects of colour.

OF THE DISPOSITION OF THE MIND OF THE SPECTATOR IN RESPECT TO THE JUDGMENT HE FORMS OF AN OBJECT OF ART WHICH ATTRACTS HIS EYE.

634. It is not enough to have indicated the rules to be followed and the principles to be observed in the production of effects, and the judgment of them in relation to art; we must also speak of the disposition of the spectator for receiving, more or less intensely, the impression of those effects. To take no notice of this disposition would be to display ignorance of human nature, and of the utility of the examination, which should be impartially pursued also by the critic, who may exaggerate blame as well as praise.

Without examining the influence that the passions exercise in opinions formed on works of art, I will say a few words upon a predisposition which may be remarked in a portion of the public, at least at certain epochs, and which has its source in man's vanity; then I will point out the part which the association of ideas performs in our adoption of opinions.

635. When a body of painters, called a _school_, has produced some _chefs-d'œuvre_, it frequently happens that a great number of mediocre works, executed under the pretence of continuing them, far from being favourable, are, with a portion of the public, injurious to them, on account of the monotony resulting from an imitation, more or less servile, of their form, colour, and even of their subjects. The public, under these circumstances, are ready to applaud any innovation that will excite emotions which it has not for some time found in contemporary painting, and it is then that amongst the public, voices are raised against great works, which have nothing in common with the tame imitations of them produced by mediocrity. Indeed, there comes an epoch when innovation, losing the only advantage it possessed of presenting to the eye images differing from those which it had been a long time accustomed to see, the public returns to the _chefs-d'œuvre_, and forgets all the feeble works composed in imitation of them by feeble pupils; and we will add that, if works _professing to be of the new school_, and endowed with undeniable merit, should exist, they would, in the estimation of connoisseurs, take the places they ought to occupy; whilst those which had arrested attention by innovation only, would disappear for ever.

636. Finally, to notice the effect which associations of ideas have on our opinions. For example, he who arrives at Versailles, full of admiration for the age of Louis XIV., repeoples the gardens with all the great men that have frequented them, and his thoughts recurring to the _fêtes_ given by an elegant and polished court, the admiration of Europe, he will judge the work of Lenôtre more favourably than he who, without being hostile to the _grand siècle_, will see nothing but a garden subordinate to a palace. And the Christian who associates in his mind the architectural form, the brilliancy of the coloured glass, and the religious ceremonies of the Gothic Church, all which he has venerated from his childhood, will be in a disposition to prefer the cathedral of Cologne to that of St. Peter's at Rome; while the latter would be associated with the profoundest veneration in the mind of a Christian of Rome.

ON THE COLOURS OF MILITARY UNIFORMS.

The following section, in which are described the advantages of contrast with regard to the heightening and purifying of the colour of cloths for dress, properly belongs to the chapters on clothing, pp. 165, &c. But, as in the present day, the colours of men's ordinary dress are not usually very various or strongly contrasted, this portion of the work has a more special application to military uniforms; the choice of colours being regulated by the principles laid down and exemplified throughout the work.

And, independently of economical considerations, the selection and arrangement of colours for military uniforms demand investigation as to the prominence or obscurity resulting from their combination, as well as to their æsthetical effect.

Of Uniforms composed of Complementary Colours.

By the law of contrast, red and green of similar tone in the same uniform, will heighten each other. Let us suppose the augmentation of colour by juxtaposition to equal one-tenth, its optical effect may be stated as 1¹/■■. If a single coloured uniform, by one year's wear lose one-tenth of its colour, it is clear that the uniform of the above two colours after being worn the same time will

be as effective as the single colour was originally.

Similar reasoning may be applied to all colours that are complementary, as orange and blue, violet and greenish yellow, &c.; it is necessary however to take into consideration their difference of tone.

Among colours which are not complementary, but which produce an agreeable contrast, may be mentioned particularly blue and yellow, blue and scarlet, green and yellow.

Blue and Yellow.—These two colours harmonize well, the blue imparting to the yellow an orange tint so much the deeper as the tone of the blue is raised, while the yellow communicates to the blue a beautiful tint of violet, or if the blue have any unpleasant greenish tint the yellow will neutralize it. If, however, there be a great difference in the tone of the two colours, contrast arising from this difference might destroy the effect of the contrast of colours; so that a deep blue might appear black or less violet, while the yellow, being enfeebled, might seem greenish.

Blue and Scarlet.—Deep blue and scarlet make a beautiful assortment, the blue giving fire to the scarlet; the latter rendering the blue more pure. There is no doubt that for effect a clearer blue and a fresh orange would be preferable, if there be no white in the uniform.

Green and Yellow.—This combination pleases by its gaiety, which suits cavalry of the line. But the green should be yellower and clearer than that which associates well with red; for the twofold reason that the yellow, by neutralizing a portion of the yellow in the green, raises the colour of the blue, and consequently lessens the brilliancy of the green. Besides, this effect tends constantly to increase, as the yellow of the green fades sooner than its blue. On the other hand, the yellow cloth receiving red from the green, must not be taken too deep. This case furnishes a good example of the economical advantage of contrasts of colour generally; and it will be seen that good arrangements are so much more difficult to make, as we depart from the contrast of complementary colour.

Of a single Colour and White.

We must refer to our preceding observations with respect to the juxtaposition of white with colours (178) to reason upon these combinations in uniforms. Colours are heightened, their complementaries are added to the white, and effects are produced which are so much the more perceptible as the colours are less raised in tone. If the white is rusty the juxtaposition of blue will heighten its tint; violet placed beside it will clear it, rendering it yellow; green will increase its redness; yellow, and especially orange yellow, will enfeeble it.

A white uniform has a good effect, not only when white pantaloons are worn with a white coat, or with facings, collar, &c. of white to a light coloured coat; but it has a good effect also with light trousers; for instance, light blue and white coat, or collar and facings. White trousers also do well with a uni-coloured coat.

Bi-coloured Uniforms with White.

White produces a really good effect only with blue and orange, or blue and red, being much inferior with green and yellow, or blue and yellow. It is, however, very suitable for trousers, with any combination of two agreeable colours in the coat. Nothing more clearly demonstrates the advantage of blue or red with white, than the difference between a uniform of deep red and blue without white, and the same with white facings and buff-skin belt, &c.

Bi-coloured Uniforms with Black.

Black enters advantageously into the composition of many uniforms of two luminous colours, such as scarlet, orange, yellow, or bright green. A scarlet coat with facings of greenish, rather than orange, yellow, is perfectly adapted to black trousers. And black trousers may be associated with sombre colours in the other parts of the dress for a uniform which is not to be conspicuous or seen far off.

Uniform of more than two Colours, not comprising Black and White.

Although three colours may be combined without producing a bad effect, yet I give the preference to a bi-coloured dress with a mixture of black and white. And I may remark here that if the sight of several colours be more agreeable than of one only, there are disadvantages in the union of many colours, especially if the colours are scattered on different objects, or several parts of the same object.

Uniform of several Shades of the same Colour.

Strictly speaking, it is possible to make an agreeable arrangement of colours belonging to the same or neighbouring scales; yet the difficulty of doing this, and the chances of success where there is a contrast of colour, determine me to reject the former, at least whenever brilliant colours are employed; but for sombre-coloured arrangements they may be employed. In proof of this, I will mention the bad effect of those French uniforms, in which there is a juxtaposition of madder and of cochineal reds.

Uniforms of two Tones of the same Scale.

This arrangement is not successful, for the lighter loses its colour, and if the deep tone acquire it, it is scarcely ever advantageous.[3] We will not therefore dwell upon it.

[3] It must be remembered that Chevreul speaks here of colours exclusively as to their optical effect, and that the very objection which he states to such an arrangement of colours, would be one of its best recommendations to the advocates of an obscure, in preference to a conspicuous uniform, as for Rifle Corps.

Of a Mono-coloured Uniform.

If uniforms of contrasted colours are advantageous in an economical point of view, if light coloured uniforms present advantages when it is desirable to exhibit to the enemy the numbers who oppose him, there are many cases in which the object is rather to conceal and dissimulate their presence, than to display them. Well, for such purposes, or if there is to be established a sort of hierarchy among the various corps, by means of dress, we may have recourse to a single and sombre-coloured uniform.

The Influence of Superficial Extent upon Combinations of Colours in Polychromous Uniforms.

I have already several times had occasion to speak of the influence of extent in the proportions of colours even when well associated, I must now add that it is not enough merely to make a satisfactory combination, but that _to produce the best results from colours, they must be employed in suitable respective proportions_.

When a colour is in feeble proportion to another, it must be spread as equally as possible throughout the garment; as, for example, in the uniform of the artillery, blue and scarlet; the latter, although far less in superficial proportion, produces a very good effect, because it is distributed throughout the uniform.

In a polychromous uniform, where one colour is found in several garments, we must avoid confounding the colour with the superposed or contiguous parts, so as to make one portion seem to belong to another. For example, the French regiments wear red trousers, with a blue coat turned up with the same red as the trousers. What happens? At a certain distance the one seems a part of the other, and the blue coat-tails seem far too narrow. It would be easy to remedy this defect by putting blue with red braid for the portions of the coat turned up.

From the above, I admit the two following principles:—1. Whenever the coat and trousers are of the same colour, and there is a second colour put upon the coat in feeble proportion, it must be repeated on the trousers, in a broad band, if the soldier wear boots, or in a braid, if he wear shoes. 2. Whenever the trousers are not of the colour which forms the basis of the coat, but of facings or distinctive parts, a band or simple braid of the main colour of the coat will restore to the trousers their distinctness.

* * * * *

These remarks show how desirable it is that the choice of colours, and especially of those which are distinctive of regiments or corps, should be the result of rules, established by their adaptation to the duties to be rendered by the regiments wearing them.

INDEX.

A. Aërial perspective, 83. Analogy, harmonies of, 48. Arabesques, varieties of, 164. Architecture, Egyptian, employment of colours in, 138; Greek, 139; Gothic, 141; application of colours to the interior of edifices, 143. Art, judgment which a spectator forms as to an object of, 225; associations of ideas connected therewith, 226. Arts, which address the eye by employing coloured materials, considered relatively, 218; as coloured tapestries, carpets, mosaics, &c. 219 _et seq._; coloured materials in flat tints, 224. Association of ideas in judging of a work of art, 226. Assortments of different colours, red, orange, yellow, green, blue, and violet,

with white, black, and grey, 49 _et seq._; binary and tertiary, 50. Author's inquiries, history of the, 201.

B. Beauvais, tapestries of, 102; difference of from the Gobelins, 113. Binary assortments of colours, 50, 59. Binary combinations of primary colours with black, 54, 55. Binary mixture of primary colours, 104. Black, juxtaposition of coloured bodies with, 19; assortments of different colours with, 54, 63 _et seq._; binary combinations of colours complementary with, 55; not complementary with, 56; its association with luminous colours, 64; inferior to white in certain assortments, 65. Black and white, effects of their juxtaposition, 19. Black draperies, 171. Blue, complementary to orange, 16, 17, 18, 20; placed beside greenish-blue, 25; subtracted from green and from violet, 44; its arrangement with a binary colour, 63. Blue and black, effects of juxtaposition of, 20; combinations of, 55. Blue and grey, effects of juxtaposition of, 22. Blue and orange, assortments of, with white, 51; with black, 55; with grey, 60. Blue and violet, assortments of with white, 53; with black, 58; with grey, 62. Blue and white, effects of their juxtaposition, 18. Blue draperies, 170. Blue light, modifications produced by, 71. Bonnets, coloured, effect of upon the complexion, 171-4; rose-coloured, 173; green, yellow, violet, sky-blue, and orange, 174; colours of, suited for fair-haired women, 175; for black hair, 176. Borders, coloured, of paper-hanging, 123; flowered, 130, 131, 133. Broken colours, 35. Browns of wool and silk employed in tapestry and carpets, effect of contrast on the, 208.

C. Calico-printing, colours of, 118; false judgment of the value of recipes for colouring compositions, 119; laws of contrast demonstrated in, 119, 120; modifications which colours undergo on different coloured grounds, 120. Carmelite mixture, 108. Carpets, of Savonnerie, 102, 222; assortment of colours for, 161; corresponding to paintings in chiaro-'scuro, 219, 222; in flat tints, 224; effect of contrast on the browns and lights of, 208. Chairs, colour of, for harmonizing with the interior of a house, 157. Chemical nature of coloured bodies, 23. Chiaro-'scuro, art of painting on the system of, 69; various modifications of coloured light, 69, 70; of white light, 75 _et seq._; difficulties of, 85, 86; paintings in, 219 _et seq._ Chromatic diagrams, 37; their construction, 39; their uses, 41 _et seq._ Chromatic hemisphere, principles of the, 203. Churches, coloured glass windows in, 113 _et seq._, 147, 223; general decoration of the interior of, 147; white glass windows, 148. Clothing, harmony and contrast of colours in, 165; of men, _ib._; of women, 167. Coloured light, modifications of, 69 _et seq._ Colouring in painting, 82 _et seq._ (See PAINTING.) COLOURS, HARMONY and CONTRAST of, 1 _et seq._; simultaneous contrast of, 4, 8, 9, 10; effects of juxtaposition of, 11, 18, 21, 24; primary and secondary, 25; various kinds of contrast, 29; definitions of terms, 34; different distinctions of, 35; chromatic diagrams, 37 _et seq._; general harmony of, 46; assortments of, 49 _et seq._; modifications and effects of coloured light, 69 _et seq._; in painting, 82; in aërial perspective, 83; harmony of local colours, 85; the laws of contrast, 89, 95; distribution of, 101; of textile fabrics, 102, 105; of glass windows, 113, 147; colour printing of calicos, papers, &c., 118 _et seq._; of clothing, 165; application of to horticulture, plants, flowers, &c., 179 _et seq._; employment of in architecture, 138-143; general principles of, 197; sight of, 198, 200; study of, 199; contiguous, 205; influence of one colour upon another, 206, 207; binary associations of, critically considered, 210; combination of, _ib._; complex associations of, 214; of tapestries, carpets, mosaics, &c. 219 _et seq._ Combinations of colours, 55. Complementaries of colours, 18-23, 43, 45. Complementary colours, mixture of, for threads, 105; combination of, 210. Complexions of women, colours of, in association with the drapery, 169-171; effect of head-dresses upon the, 171-4, 175, 176; results of dress as applicable to portrait painting, 178; dissimulating a tint of the, _ib._ Composition, predominance of a certain colour in, 100; distribution of colours in, 101. Compound colours, 26, 27, 28. CONTRAST of COLOURS, 1, 4, 8; law and formulæ of, 8, 9, 10, 29 _et seq._; simultaneous and successive, 29, 87; mixed, 29-33, 88; law of, 34; harmonies of, 48, 217; lectures on, at the Gobelins, 80; uses of the law of, 89 _et seq._; principles of, 91; results of, 93; applications of the law of, 95 _et seq._; principles of in connexion with the production of tapestry, 109; law of demonstrated in calico-printing, 119-121; advantages of with regard to clothing, 165; harmonies of in gardening, 182, 183, 184; in the arrangement of plants and flowers, 194; effect of upon the browns and lights of wool and silk employed in tapestry and carpets, 208. Cornices for the interior of a house, 157.

D. Daylight, modifications produced by the, 73. Definitions of terms of art, 34. Diagrams, chromatic, 36-46. Distribution of colours in a composition, 100, 101. Draperies of women as associated with complexion, 169-171; rose-red, _ib._; delicate green, yellow, violet, and blue, 170; orange, white, and black, 171; results applicable to portrait painting, 178. Dress of women, assortment of colours in the, 177.

E. Egyptians, various colours used by the, 138. Eye, different states of the, in seeing colours, 200, 201, 202.

F. Females, colours of their clothing, 167; the dress assorting with fair skins, _ib._; colours of the hair and head-dress of, 168; of the complexion and the contiguous drapery, 169. Figures, coloured, in paper-hangings, 121-3. Flat tints, painting on the system of, 69, 81, 82, 217; for ornamenting boxes, tables, screens, &c., 218. Flowers, Coloured, in paper-hangings, 121; arrangement of according to their colours, 180; assortments of, when the plants are apart, 181; when they are indiscriminately mixed, 182; assortments of, as to harmonies of contrast and analogy, 182, 183; small masses of designated a bed, 187; law of contrasts in the

arrangement of, 194. Foliage of ligneous plants, assortment of according to their colour, 184. Forest, definition of a, 186. Form, its influence in the effect of contrast of two colours, 213. Formulæ which represent the law of simultaneous contrast of colours, 8. French gardening, 191. Furniture, tapestries for, 220.

G. Galleries of the Fine Arts, on the interior decoration of, 150. Gardening, applications of colour to, 179 _et seq._ (See HORTICULTURE.) Glass, Coloured, in Gothic church windows, 113 _et seq._, 147; beautiful effects of, 116; employment of, 117; corresponding to paintings in chiaro-'scuro, 219, 223; in flat tints, 224, 225. Gloss of wool and silk, its influence in the effect of contrast of two colours, 213. Gobelins, lectures at the, 80; tapestries of the, 102, 104; qualities which they must possess, 111; difference of, from the Beauvais, 113. Gothic architecture, employment of colours in, 141. Greek architecture, employment of colouring in, 139. Greek painters, 94. Green, complementary to red, 15, 17, 18, 20; to violet, 44. Green and black, effects of juxtaposition of, 20. Green and blue, change by juxtaposition, 27; assortments of with white, 53; with black, 58; with grey, 62. Green and grey, effects of juxtaposition of, 22. Green and violet, change by juxtaposition, 26; assortments of with white, 53; with black, 58. Green and white, effects of their juxtaposition, 18. Green and yellow, change by juxtaposition, 27. Green draperies, 170. Green light, modifications produced by, 71. Greenish yellow, complementary to violet, 3, 16, 17, 21. Greenish yellow and black, effects of juxtaposition of, 20. Greenish yellow and white, effects of their juxtaposition, 18. Grey, juxtaposition of coloured bodies with, 21; assortments of different colours with, 58, 63 _et seq._; its association with luminous and sombre colours, 65, 66. Grounds, black, of paper-hangings, 125; various coloured ones, 126-135. Grove, definition of a, 187.

H. Hair, black, colours of bonnets suited for, 176. Hair, fair, colours of bonnets suited for, 175. Hair and head-dresses of women, colours of the, 168. Hangings, coloured, for the interior of a house, 152-7; colour of the wainscoting, relation to the, 155. Harmonies of contrast, 48, 217; analogy of in gardening, 182, 183, 184. Harmony of colours, 46; distinct kinds of, 48; law of, 95; between masses of trees in gardening and plantations, 192. Harmony and contrast of colours, 1 _et seq._ (See COLOURS.) Head-dresses of women, colours of the, 171; effect of upon the complexion, 171-4. Hieroglyphics, Egyptian, colouring of, 139. HORTICULTURE, applications of colour to, 179; how to derive the greatest advantage from the various colours of flowers, 180; assortments of flowers, so far as they relate to the harmonies of contrast of colours, 181; contrast of hues, 182; harmonies of analogy, 182, 183; assortments of plants, 184; distribution of trees, 185; lines of plants, 187, 188; homogeneous masses of plants, 189; varied and isolated masses, 190; harmony between masses distant from each other, 192; arrangement of plantations, 193; symmetry and general harmony, 196; general principles of, 197 _et seq._ Houses, decorations for the interior of, 152; hangings, 152-7; cornices, 157; chairs, sofas, &c., _ib._; on decorating the different rooms of the, 159; and their appropriate assortments, 160; carpets, 161; pictures, 162. Hues, definition of, 34, 35; harmony of, 48; harmony of contrast, _ib._; harmonies of contrast in flowers, 182; analogy of, 183. Human figures, tapestries for, 219.

I. Imitation of colouring, 101. Indigo, complementary to orange-yellow, 3, 16, 17. Indigo and black, effects of juxtaposition of, 21. Indigo and grey, effects of juxtaposition of, 22. Indigo and red, changed by juxtaposition, 27. Indigo and violet, changed by juxtaposition, 27. Indigo and white, effects of their juxtaposition, 19. Interiors of buildings, painters of, 101; various assortments of colours in, 143; stuffs with the wood of seats, _ib._; frames for pictures and engravings, _ib._; of churches, 147; of museums and galleries, 149; of houses, 152 _et seq._; when the walls are panelled, or covered with marble or stucco, 163.

J. Juxtaposition of colours, 11, 211, 212; of coloured surfaces with white, 18; with black, 19; with grey, 21; of coloured bodies belonging to the same group of coloured rays, 24.

L. Landscape, colours used in, 95; in paper-hangings, 121-3. Landscape gardening, 179. (See HORTICULTURE.) Light, different rays of, 1; its combinations of colour, 55. Light, modifications of, 69 _et seq._ Light, influence of on printed or written paper, 137; contrast of tone in, 138. Lights of wool and silk employed in tapestry and carpets, effects of contrast on the, 208. Lines of plants, their arrangement, 187, 188. Luminous colours, 50; their association with black, 64; with grey, 65, 66.

M. Marbles, in the interior of a building, assortment of colours for, 164. Men's clothing, colours of, 165, 166. Mixed contrast of colours, 29-33, 88. Mixtures, of the three primary colours, 108. Modifications of coloured light, 69, 70 _et seq._; of white light, 75 _et seq._ Mosaics, corresponding to paintings in chiaro-'scuro, 219, 222; in flat tints, 224. Museums, on the interior decoration of, 149, 151.

N. Natural History, museums of, on the interior decoration of, 151. Non-complementary colours, combination of, 210, 211.

O. Opposition of colours, 67. Orange complementary to blue, 3, 16, 17, 18, 20; placed in juxtaposition with scarlet-red, 24; complementary to green, 43; to violet, 44; effects of its predominance in a picture, 100. Orange and black, effects of juxtaposition

of, 20. Orange and blue, mixture of for coloured threads, 106. Orange and green, change by juxtaposition, 26. Orange and green, assortments of with white, 52; with black, 57; with grey, 61. Orange and grey, effects of juxtaposition of, 22. Orange and indigo, change by juxtaposition, 26. Orange and red, change by juxtaposition, 26. Orange and violet, assortments of with white, 52; with black, 57; with grey, 61. Orange and white, effects of their juxtaposition, 18. Orange and yellow, change by juxtaposition, 27; assortments of with white, 52; with black, 57; with grey, 61. Orange draperies, 171. Orange light, modifications produced by, 70. Orange-yellow, complementary to indigo, 16, 17, 21.

P. Painters, Ancient, of Italy, their excellences, 87. Painting, Art of, 69; two systems of—chiaro-'scuro and flat tints, _ib._; on colouring in, 82; of aërial perspective, 83; harmony of the colours, 85, 95; simultaneous contrast of colours in, 87; modification of light, 89; application of the law of contrast, 97-99; distribution of colours, 101; painters of interiors, _ib._; imitation of coloured objects, 102 (see GOBELINS TAPESTRY); difference of from tapestry, 111; relations existing between the subjects of, and the harmonies they admit of, 216; in the flat tints, 217; in chiaro-'scuro tapestries, carpets, mosaics, and coloured glass windows, corresponding to, 219 _et seq._ Panelling in the interior of a building, assortment of colour for, 163. Paper, printed or written, influence of light on, 137; contrast of tone, 138. Paper-hangings, colours for printing, 118, 121; designs for, 121; simultaneous contrast of colours in relation to, 121, 123, 124; borders, 123, 130-3; black ground, 125; various coloured grounds, 126 _et seq._; metallic gilt ornaments, 126, 129; printed or written characters, 136. Park, definition of a, 187. Picture Galleries, on the interior decoration of, 150. Pictures in the interior of buildings, assortment of colours for, 145; assortment of, for the interior of a house, 162. Plantations, arrangements of, 193; lines of, _ib._ PLANTS, Ornamental, art of arranging according to the colours of their flowers, 180, 181; assortments of, according to the harmonies of contrast and analogy, 182, 183; according to their foliage, 184; distribution of, 185; lines of, 187, 188; screens of, 188, 189; masses of, 189, 190; different names of, when employed to form a landscape, forest, wood, park, grove, group, thicket, &c., 186, 187; isolated ones, 190; arrangement of into plantations, 193 _et seq._; repetition of the same species, 194, 195; variety of arrangement, 195; symmetry of parts, and their general harmony, 196. Portrait Painting, predominating colour in, 97; hints respecting the colour of the drapery, 169-171; results of dress and complexion applicable to, 178; dissimulating a tint of the complexion, _ib._ Position, varied, effects of, 75. Prepossessions, influence of, 225. Primary Colours, 25, 36; arrangements of, 63; binary mixture of, 104; mixture of, in such proportions that they do not become neutralized, 108. Printing in colours, 118; of calico patterns and paper-hangings, 118, 121, 123; of carpets, 161. Pure colours, modifications of, 42, 45.

R. Rays of solar light, 1. Rays, Coloured, juxtaposition of coloured bodies with, 24. Reading, on the assortment of colours for, by diffused daylight, 138. Red, complementary to green, 3, 15, 16, 18, 20; placed in contact with orange-red, 24; its arrangement with a binary colour, 63. Red and black, effects of juxtaposition of, 20. Red and blue, change of by juxtaposition, 27; assortments of with white, 52; with black, 56; with grey, 60; mixture of, for coloured threads, 105. Red and green, assortments of with white, 51; with black, 55; with grey, 59; mixture of, for coloured threads, 106. Red and grey, effects of the juxtaposition of, 21. Red and violet, assortments of with white, 52; with black, 56; with grey, 61. Red and white, effects of their juxtaposition, 18. Red and yellow, change by juxtaposition, 27; assortments of with white, 52; with black, 56; with grey, 60; mixture of for coloured threads, 104. Reflection, laws of, 75. Rose-red draperies, 169.

S. Savonnerie carpets, 102, 222. Scales of colours, definition of, 34; chromatic, 36 _et seq._; their different tones, 47; harmony of, 48; harmony of contrast of, _ib._; of wool and silk employed in tapestry and carpet, 208. School of painters, 226. Screen of plants, 187, 188. Sculpture Galleries, on the interior decoration of, 150. Seats in the interior of buildings, assortment of colours for, 143. Secondary colours, 25, 26. Shrubs, small masses of, designated a bed, 187. Sight of colours, 198, 200. Silk employed in tapestry and carpets, effect of contrast upon the browns and lights of, 208. Simple colours, pass by juxtaposition into compound colours, 25. Simultaneous contrast of colours, 4, 8, 9, 10, 29; application of the law of, 34; in painting, 87; in calico-printing, 119, 121; principles of, 205. Skin, the coloured rays which may reflect upon the, 171. Skins, copper-coloured, black, or olive, assortment of dress suited for each, 177. Sofas, colour of, for harmonizing with the interior of a house, 157. Solar light, rays of, 1. Sombre colours, 50; proportion of to luminous ones, 66. Spotty, use of the term, 101. Stained glass windows, 113 _et seq._, 147. (See GLASS.) Stripes, Coloured, juxtaposition of, 24. Stuffs, Coloured, modifications of, 78, 79; in the interior of buildings, assortment of colours for, 143. Successive contrast of colours, 29. Sun, modifications produced by the light of the, 73.

T. Tapestries, 102; of the Gobelins and of Beauvais, 102, 104; qualities which they must possess, 111; difference of from the Beauvais, 113; principle of contrast in the production of, 109; difference of, from painting, 111; requisites for assimilating it to painting, 112; patterns for, _ib._; effect of contrast on the browns and lights of, 208; principles involved in the colours of, 219; with human figures, 219, 224; for furniture, 220, 224; critical remarks on, 221; corresponding to paintings in chiaro-'scuro, 219; in flat

tints, 224. Ternary assortments of colours, 50, 51, 59. Ternary combinations of colours complementary with black, 55; not complementary, 56. Textile fabrics, colour printing on, 118. Thickets of trees, different kinds of, 187. Threads, coloured to make mixtures of, 102, 104 _et seq._; red and yellow, _ib._; red and blue, 105; yellow and blue, _ib._; mixture of complementary colours, 105. Tint of the complexion, how to dissimulate it in portrait painting, 178, 179. Tone, contrast of, 4; experimental demonstrations, 7; the height of to be considered, 66; contrast of on written or printed paper, 138. Tones, definition of, 34; of the same scale of colour, 47; of the scales of wool and silk, judging their equidistance, 209. Trees, assortment of in gardens according to the colour of their foliage, 184; distribution and planting of, in masses, 185; different terms applied to groups of, when employed to form a landscape, 186, 187; harmony between masses of, 192.

V. Vandyke, masterpieces of, 99. Violet, complementary to greenish-yellow, 16, 17, 18, 20; placed in juxtaposition with scarlet-red, 24. Violet and black, effects of juxtaposition of, 21; combinations of, 55. Violet and blue, change by juxtaposition, 27. Violet and grey, effects of juxtaposition of, 22. Violet and red, change by juxtaposition, 26. Violet and white, effects of their juxtaposition, 19. Violet draperies, 170. Violet light, modifications produced by, 72.

W. Wainscoting for the interior of buildings, 151; colour of, 155, 156. White, juxtaposition of coloured surfaces with, 18; modifications of, 19; assortments of different colours with, 50, 63; ternary assortments of colours not complementary with white, 51. White draperies, 171. White light, various modifications of, 75 _et seq._ Windows, of coloured glass, 113 _et seq._, 219, 223; in churches, 147, 149; of white glass, 148, 149. Women's clothing, colours of, 167; assortment of colours in, according to complexion, 177. Wood, in the interior of a building, assortments of colours for, 164. Wood, definition of a, 186. Wool, employed in tapestry and carpets, effect of contrast upon the browns and lights of, 208.

Y. Yellow, placed beside orange-yellow, 24; its arrangement with a binary colour, 63. Yellow and blue, changed by juxtaposition, 27; assortments of with white, 53; with black, 57; with grey, 62; mixture for coloured threads, 105. Yellow and green, assortments of with white, 53; with black, 57; with grey, 61. Yellow and grey, effects of juxtaposition of, 22. Yellow and violet, assortments of with white, 51; with black, 56; mixture of, for coloured threads, 107. Yellow draperies, 170. Yellow light, modifications produced by, 71. Yellowish-green, complementary to violet, 19. Yellowish-orange, complementary to indigo, 19.

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Aeolus; or, the future of the flying machine

Major Oliver Stewart

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AEOLUS

TO-DAY AND TO-MORROW

For the Contents of this Series see the end of the Book

AEOLUS

OR

THE FUTURE OF THE FLYING MACHINE

BY

OLIVER STEWART

Author of 'The Strategy and Tactics of Air Fighting,' etc.

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AEOLUS

THE FUTURE OF THE FLYING-MACHINE

INTRODUCTION

The aeroplane is an aerial sailing-ship, its wings are the sails, its source of power the wind. It can claim to be a direct descendant of the family of sailing ships whose father was AEOLUS, god of the winds and the inventor of sails.

Aeroplane, helicopter, ornithopter, rotorplane, and autogiro are sailing-ships because they all derive lift from sails or aerofoils. An aerofoil is a structure so shaped as to obtain a reaction from the wind—a sail is nothing more and nothing less. Whether the wind is natural or is artificially raised by an engine does not affect the function of aerofoil or sail.

The heavier-than-air flying-machine, either engineless glider or power-driven craft, is the true aerial sailing-ship. The prolate gasbag which is called an airship resembles only one kind of ship, a sinking ship, because it is totally immersed in the fluid which supports it. If a sea parallel to the airship is required, that parallel may justly be said to be the submarine, which is suspended in the water as the airship is suspended in the air.

Before I deal with the future of the aerial sailing-ship I must define three aeronautical terms. No excuse is needed for introducing these apparently elementary definitions since aeronautical terms are almost as well misunderstood by aviators as by laymen. The three terms are:

Wing Airscrew Propeller

The definitions I advance are supported by the Royal Aeronautical Society's _Glossary of Aeronautical Terms_ and by the British Engineering Standards Association's _Glossary of Aeronautical Terms_ although they are often departed from in official forms and in speech.

Wing. A few days ago I read in a newspaper of a "single-winged airplane". Accustomed as I am to the aircraft which appear between the drapers' advertisements in the daily newspapers, I was startled at the notion of a "single-winged airplane". A bird has wings. A single-winged bird would be a queer creature and would be incapable of flying. A "single-winged airplane" would be equally queer and equally earth-bound.

The reporter, in trying to hack out an explanatory synonym for monoplane, docked the aeroplane of one of its wings.

Airscrew and Propeller. An aeroplane can have an airscrew yet no propeller. Most aeroplanes, in fact, are without propellers. In the interests of differentiation it is worth endeavouring to confine the word propeller to the thing that propels or pushes the machine, to use airscrew as a general term, and tractor airscrew when a precise definition is required for the thing that pulls the machine. The colloquialism "prop'" may perhaps be allowed to stand for both tractor airscrew and propeller.

In the following pages I make no attempt to hit upon any sudden invention which may revolutionize flight. I confine myself to developing lines of progress which have already given some proof of practicability. For determining the general trend of progress I rely upon a utilitarian review of the aeronautical situation. I have avoided leaping into the distant future. Readers will be disappointed to learn that things like inter-planetary voyaging are not dealt with in this booklet.

I am aware that scientists have demonstrated that some of the things I do mention are impossible. But scientists have demonstrated that the world is flat, that it is round, and that it is oblong. In the future they will demonstrate that it is rectangular. It was Mr W. N. Sullivan, I think, who said that "To judge from the history of science, the scientific method is excellent as a means of obtaining plausible conclusions which are always wrong, but hardly as a means of reaching the truth." While a few generations can still witness wide variations of opinion among those who know, I incline to the Pyrrhonic doctrine. It is impossible to know with certainty what is impossible, and in attempting a forecast the best that can be done is to take the trend of contemporary thought and, with that, to build a future upon the principles of the present.

I deal with the future of three kinds of flying-machine, the civil, the service, and the lighter-than-air or airship. The type of machine I say will become popular for short distance air-transport may seem at first to be too unconventional. But I think the whole trend of advanced thought (slotted wings, wingflaps, anti-stall gears and differential ailerons are manifestations of it) is towards the result I suggest.

I

The future of the aerial sailing-ship or heavier-than-air flying-machine will be affected more by the attitude which the world adopts towards it than by technical achievement. In England the national attitude towards machinery is moulded by statesmen and financiers. Under the guise of preserving the liberty of the individual that attitude strangles the life out of the machine; it may be described in the words of the schoolboy who said that _Habeas Corpus_ was a phrase used during the great plague of London meaning 'Bring out your dead'.

The statesman has helped to mould the national attitude towards the motor-car through the medium of laws and the manner of their enforcement by his servants the police, and the Courts. The history of the cause and effect of the national attitude towards the motor-car is being repeated with the flying-machine, and the parallel is close.

Having the safety of the public for its ostensible object, the Motor-Car Act limits the speed of motor-vehicles to twenty miles per hour, proclaims it an offence to drive to the common danger and to be drunk while in charge of a motor-car.

Of the last-mentioned provision I will say nothing beyond mentioning that there are motorists who are incapable of driving safely except when they are drunk. Of the other two, the 20 m.p.h. speed-limit for many years has been generally recognized as having

no bearing on safety or danger, whereas for many years motorists have been condemning certain manoeuvres on the road as constituting, legally as well as in truth, driving to the common danger.

The English police, with the connivance of magistrates and Home Secretaries, have concentrated on enforcing the speed-limit and have ignored the dangerous manoeuvres.

This pass has been brought about by the statesman, who has no direct interest in motor-cars or other new-fangled machines (except when there is a general strike). As a consequence, the car built as a car for speed and control is becoming an object of general dislike. The continued insistence that speed of itself is dangerous and the pompous tyranny of the police (who find motorists tamer and more plastic than thieves) are gradually engendering in the public fear of and dislike for the machine-entity. Instead the wheeled furniture-shop is gaining in popularity. The doctrine of Safety First is threatening initiative and killing the spirit of adventure, while there is ignorance of how to attain safety. Road-racing, the only sure means of increasing car-safety, is prohibited because it is not safe. The result is the dismal, abysmal mess described as the modern British motor-car, which is chiefly remarkable for not containing a single original idea.

Now the result of statesmen moulding a similar attitude towards the flying-machine will be equally dismal. Yet they are already exerting their influence in that direction.

Instead of employing policemen and Courts to harry and hunt the herd of aeronauts, designers, and constructors, however, the statesman employs an army of air-officials. In the world of aeronautics these officials are all-mighty. The private person has no control over them and no reply to them. If he goes to Court against them he will lose. If he appeals against the decision of the Court he will lose again. If he appeals to public opinion he will lose for the third time. The official tells the airman what he may not do, warns the designer of the manner in which he may not design, and informs the constructor how he is forbidden to construct.

The result of this official attitude towards the flying-machine is already faintly visible.

At the time I write Britain holds no world's air-records. For seven years she has made no great flight. She has three or four commercial air-lines against Germany's forty-three. Her fastest aircraft is about 50 m.p.h., slower than the fastest foreign aircraft. Her highest climbing aircraft cannot attain within thousands of feet of the altitude attained by foreign aircraft. Her longest range aircraft can accomplish little more than half the distance covered by foreign aircraft. Her Air Force can put fewer effective war-machines in the air than any one of three other countries.

One of our pilots has succeeded in proving that, in an English aeroplane, you can go from London to anywhere else more slowly, and in more acute discomfort, than by boat and train.

In one thing only does England excel. She spends more on aviation than any other country in the world.

I am familiar with the excuses for England's aeronautical failings. I know that the House of Commons has been told that there is no object in England attempting to obtain world's air-records. I have heard the claim that the Royal Air Force flies more than any other air force, and I have heard the Air Ministry refuse to supply any figures in support of the claim. I know that the French are said to obtain their high speeds and great distances by cutting down the load-factor of their machines. I have been told about the theory that we _could_ gain world's records, run air-lines, win air-races, and have an effective Air Force but that we do not want to do so. I am familiar with these excuses, and, having mentioned some of them, I think I can proceed to indicate a cure for the failings in British aviation. For some cure is the essential preliminary to any future for the flying-machine in England.

The cause of England's aerial impotence is chiefly official interference leading to a wrong national attitude towards the aeroplane.

The cure is to give English aviation the freedom of the air.

If the official is given powers to make vehicular transport safe, he will, as we have seen in the motor-car analogy, infallibly not make vehicular transport safe and he will stop any mechanical development in the vehicle itself. Freedom, then, is the essential condition of aeronautical development.

I said at the beginning of this essay that the financier, as well as the statesman, helped to mould the public's attitude towards the machine. I speak only of the pure financier or business-man who uses aeroplanes, motor-cars or tin cans with equal indifference as money-making tools; who has no direct interest in any material creation; who repeats that honesty is the best policy and hopes the other man will believe it.

All such business-men in England are humble imitators of American business men. In their advertisements, offices, talk, and indigestion they endeavour as closely as possible to copy the Americans. They therefore believe that, if English people are to produce cars or aeroplanes, they must produce them in the American way—that is cheaply and in mass. Standardization has, in their view, taken the place of craftsmanship and mass-production of hard work.

Already events have shown that the English are incapable of imitating the Americans well. The reason is that the American mechanic regards his work as an unpleasant necessity, to be got through as quickly as possible and to be paid for at as high a rate as possible in order that he may have time and money for the real purpose of life—doing nothing. The English mechanic, although the statesman is trying to knock such foolishness out of him, still expects to find something satisfying in his work. He still seeks a measure of contentment in the exercise of skill.

Mass-production fits in well with the American workman's ideas: it does not fit in with the English workman's ideas. The English do not and will not produce cheap motor-cars or cheap aeroplanes as quickly and as well as the Americans.

If English flying-machines are to be made capable of competing with American and others, the English, after being freed from official interference, must leave standardization and mass-production to people who are temperamentally suited to them, and instil into these flying-machines some of the idiosyncrasy of their race. Their flying-machines must be creations expressive of the characters of those who design and construct them.

The only English cars having any success in America (and elsewhere) are those few in which perfection of craftsmanship and idealism in design are notable. They are the kind of cars English designers and mechanics are temperamentally able to produce. The mass-produced cheap English car or flying-machine will remain a feeble imitation of the American. But the idealistic creation, the machine-entity of the English artist-scientist in car or flying-machine has a place to itself in the scheme of things. In its best form it is unique.

The financier's influence in aviation is not yet so noticeable as in motoring, but it is becoming stronger. Should the aeroplane pass entirely into his hands, it will cease to progress as a flying-machine and will start progressing as a bank-note churn. With the future of such an instrument I am unable to deal, since I have no personal experience of either churns or bank-notes.

If it is to make headway as an individual creation the flying-machine must receive the freedom of the air. It must develop its own individuality as a machine-entity. Freedom of the air and the complementary institution of mechanical craftsmanship are the essential conditions for development of the flying-machine. Without those conditions I have nothing to write of its future. With those conditions the flying-machine presents possibilities of development in high-speed transport that will warrant future generations describing the present age as the static age.

But I must insist that, for the forecast I am now to make, I postulate the gagging and binding or otherwise bottling-up of the statesman and financier.

Only then will this machine-entity, the creation of the artist-scientist, grow. And that the machine-entity, the car or aeroplane as a real and living thing exists will be accepted by all who have spent much time in controlling and looking after high-performance aeroplanes or racing-cars. These machines, built with a single purpose, are sensitive to the treatment they receive as the stone is sensitive to the sculptor's chisel or the violin-strings to the musician's bow.

Turn for one moment from the standard cars, the wheeled furniture-shops "replete with every comfort including cigarette lighter and flower vase" which make hideous our streets to the other extreme and regard the finely-wrought, aesthetically satisfying racing-car which is to be seen in the American and Continental road-races and occasionally at Brooklands. I do not suggest that racing-cars should be used for transport even in these "most brisk and giddy paced times"; I merely refer to the racing-car as indicative of a certain attitude towards the machine. The makers of flying-machines should be free, if such is their desire, to aim at the fineness, craftsmanship, and originality in design exemplified in the racing-car.

II

The civil flying-machine, when it is examined in the light of contemporary aeronautical research-work, seems rich in possibilities.

Apart from electrical repulsion, there are five different ways of flying, of which only two are at present in general use, lighter-than-air flight and fixed-wing heavier-than-air flight. I think that a third method is about to be widely adopted, and that this third method will,

in time, profoundly influence the whole future of aeronautics.

A comparison between the present system of artificial flight and natural flight will suggest what that third method is.

Let us go to Croydon, the airport of London, and examine a typical three-engined passenger-carrying aeroplane.

The three engines are running, for the machine is about to take off. The coffin-shaped thing whose sides flap in the wind from the airscrews is the fuselage. The machine shows signs of malnutrition, for its bones are prominent in the form of wires and struts. As the engines are run up, the tail shakes and sneezes and coughs until it seems that the fuselage will be ruptured. Now the machine taxis over the aerodrome, its engines open up with a roar, it labours over the ground, and then, looking a little fatigued, it rises into the air.

It passes overhead making a noise like a thunderstorm, shivering and quaking, barging its way along with a clumsy ineffectualness which gives it the appearance of flying through treacle.

When it is out of sight, go to Waterloo Bridge and watch the gulls.

A gull is a hopelessly uncommercial flying machine. It does not pay, it has no ground organization, it is not fitted with wireless, no control-tower informs it when it may land, no books are kept of its mileage or hours flown, no managers, assistant-managers, clerks, secretaries, typists, accountants, ministers, directors, officials, or meteorologists concern themselves in its safety. No offices, search-lights, flood-lights, neon-lights, leader-cables, or directional wireless stations are set aside for its control and supervision. No treatises are written about its future. A gull is not "a commercial proposition". It is, however, a good machine for flying.

Neither the superficial nor the fundamental defects of the passenger-carrying aeroplane are present in the gull. The gull is a coherent, unified structure without exposed bracing-wires, struts, or engines. It gets off quickly, flies at a great pace (for its power-loading), is fairly silent and very manoeuvrable, can defeat fog, rain, hail, snow, and gale, and can alight anywhere.

As a flying-machine it owes its basic superiority over the aeroplane to a single, ingenious trick: a trick which looks easy, but which, for many years, the scientist found it impossible to reproduce in practical mechanics.

When flying was first thought about this trick engaged much attention. The mechanical difficulties in reproducing it, however, refused to be conquered, and about 1680, Borelli, having this trick in mind, wrote: "The Icarian invention is entirely mythical because impossible", a view which, according to Mr J. E. Hodgson's _History of Aeronautics_, was supported by Leibnitz. Afterwards and until just recently the trick has been almost entirely neglected. I think it probable that it will regain its old importance, and that it will become the pivot upon which the whole future of the heavier-than-air land-going flying-machine will turn.

What is this trick which for centuries baffled the mechanician, yet which the gull finds so simple? What is the one fundamental difference between the means employed by the gull for flying and the means employed by the aeroplane?—It is the difference between the fixed wing and the moving wing.

The gull has the trick of being able to move its wings relative to its body. The gull is a moving-wing flying-machine. The conventional aeroplane is a fixed-wing-flying-machine.

Almost every important advantage which the gull (and any other bird) has over the type of aeroplane which has so far been most popular may be traced to the gull's ability to move its wings. For that reason alone it can get off without a long run, defeat fog and gale, and alight anywhere.

Since the time of the artificial "flying pigeon" of Archytas in the 5th. cent. B.C. the manner of whose flight seems obscure, attempts have been made to build machines which imitate the gull by flapping their wings. Several people, including Bladud, the legendary flying King of Britain, found out in an unpleasant manner that the muscles were not strong enough to actuate man-lifting wings. And in the construction of engine-driven ornithopters the mechanical difficulties invariably proved insuperable. The natural flapping wing has never been exactly imitated by mechanical means in a flying-machine, nor have the leg and foot been exactly imitated by mechanical means in a motor-car.

The motor-mechanician, in using the wheel in place of the leg and foot, imitated the principle employed by nature for land-locomotion but not the means. Will the aeroplane-mechanician imitate the principle employed by nature for flight but not the means?

The aeroplane-mechanician has already accomplished this feat in a rudimentary form in the Cierva Autogiro, which is commonly (and accurately) called the windmill aircraft.

The helicopter has never achieved much success and, for the present purpose, it may be classed with the ornithopter as obsolete. The autogiro, therefore, is the first practical moving-wing aircraft. It accomplishes that which generation after generation of mechanicians found it impossible to accomplish. It has seized on the bird-principle of flight and translated it into practical mechanics.

III

The existing autogiro, although it may not resemble the more developed types which will eventually appear, is the most successful moving-wing flying-machine yet produced. Señor de la Cierva's work was described by an aeronautical engineer as being of secondary importance only to that of the Wright brothers. That first flush of enthusiasm may be over, but there seems little doubt that future generations will regard Señor de la Cierva as the inventor of moving-wing flight. And I believe that there will be a fierce battle, more prolonged and more vigorous than has ever been fought between two machines, the battle between moving-wing flight and fixed-wing flight. The struggle between reciprocating engine and turbine, broad gauge and narrow gauge, lighter-than-air and heavier-than-air, water-cooling and air-cooling will be as nothing compared with the imminent struggle between fixed-wing and moving-wing.

The autogiro obtains lift from a _free_, four-bladed windmill. Each blade of the windmill is a wing and is articulated at the root so that its tip can rise and fall. The autogiro is drawn forward by an ordinary aero-engine and airscrew which are entirely separated from the windmill. As the machine is drawn through the air the relative wind, blowing on the blades or wings, rotates the windmill and it lifts the machine. The wings rise and fall, and this beating motion gives the machine a measure of stability.

To exert lift a wing must move through the air.

The moving-wing aircraft derives lift from wings which can move through the air even though the body of the machine be stationary or nearly stationary. In the fixed-wing aeroplane both body and wings must move if the wings are to exert lift.

[Illustration:

Fig. 1.—Diagrammatic representation of moving-wing and fixed-wing flight. The wings of both machines have travelled equal distances AA and BB but the body of the moving wing machine has remained stationary relative to the ground.]

The difference between moving-wing and fixed-wing aircraft is so important to this discussion that I shall venture to describe it again in different words. A fixed-wing aircraft is like a bird with its wings paralysed or in splints. A moving-wing aircraft is like a bird having the full use of all its faculties. (Fig. 1).

Perhaps the most important advantage which the moving-wing aircraft has over the fixed-wing aircraft is that it can virtually land on one spot. The conventional aeroplane must move forward in still air if it is to keep up; it must still move forward while landing, and afterwards allow its impetus to be dissipated during a run along the ground.

In addition to this ability to land on a spot, the moving wing aircraft is less likely to become uncontrollable while it is in the air. The fixed-wing aircraft must become uncontrollable in the air if its speed drops below a certain point. This point was called by airmen "the stalling speed". It has needed the mathematician to produce the phrase: "control of stalled aeroplanes". In current English a stalled aeroplane is an aeroplane which is uncontrollable, even if the speed must drop to zero before this condition arises. If any fixed stalling-_angle_ can be said to exist outside technical reports, it is the angle at which the lift of the wings is so reduced that the machine must fall to a nearly vertical position before recovering.

The moving-wing aircraft in the rudimentary form we know it to-day could stall, but it would need a major structural failure or violent and prolonged misuse of the controls to make it do so.

And now one of the weapons which will be used in the battle which I predict between the two main types of heavier-than-air flying machines will be recognized. The weapon of the spot-landing.

Taking advantage of its special characteristics, the moving-wing flying-machine within fifteen years will open hostilities by carrying passengers into and from the hearts of cities and by running safely through fog thick enough to stop other transport services. Up till

then the fixed-wing machine with its aerodromes on the outskirts of cities will have held the field almost unchallenged. But whereas the fixed-wing aircraft has now had twenty-two years development, the moving-wing aircraft has had only about three years.

At first, even when it has matured, people will be shy of the moving-wing machine, and only gradually will it begin to attract passengers used to the other type.

Travellers will begin to realize that, when they go by fixed-wing machines, they waste so much time and suffer so much discomfort in the terminal communications that the advantages of the air-passage are largely neutralized.

At present the air-traveller going from Paris to London spends one and a half hours covering the few miles to and from the aerodromes to the centres of the two cities and only two to two and a half hours covering the 225 miles of the air-journey. Moreover, he changes vehicles twice, at Croydon and at Le Bourget, as he does by boat and train at Dover and at Calais. The aircraft's ability to fly over land and sea alike, therefore, has not given the traveller the advantage of a through-journey. He must taxi from his hôtel in Paris to the place where the air-company's car starts, change from car to aeroplane at Le Bourget, change from aeroplane to car at Croydon, and taxi from the car's stopping place to his home. (Fig. 2).

[Illustration:

Fig. 2.—Diagrammatic representation of the advantage in flexibility of an aircraft capable of making spot landings and so of using small aerodromes. Alone among vehicles it could provide a through journey to the centres of cities.]

The aeroplane dare not risk attempting the journey in thick fog or heavy snow or hail because, in order to support itself, it must move forward through the air at a minimum of say 60 miles per hour. At this speed the pilot, even if aided by a leader-cable, has difficulty in finding the aerodrome in thick weather; as much difficulty as a motor-car-driver unable to go slower than 20 miles per hour would have in crossing London in a dense fog.

If he thinks he catches a glimpse of a landmark, the pilot cannot stop or slow down and look again to confirm his impression; he must continue to travel at 60 m.p.h. And if he fail to find the aerodrome he must endeavour to put down his machine—still travelling at 60 m.p.h.—on an area of ground which he cannot see clearly and which he does not know. If a house, ditch, hedge, tree, chimney, shed, road, telegraph wire, pole, or other obstruction is in the way the result is a serious accident.

The disadvantages under which the fixed-wing aircraft suffers when landing and when flying during bad visibility are inherent in the principle of flight it employs. The moving-wing machine will therefore concentrate its attack at these very points. Since it is able to fly slowly, and virtually to hover, it can feel its way through fairly thick fog. Even if the pilot cannot find the aerodrome, comparatively little danger attaches to a forced landing on unknown ground, because the descent can be made vertically or almost vertically and there is almost no run after touching the ground.

Aerodromes on the roofs of buildings have been foretold with tiresome persistence. A Frenchman succeeded in landing a fixed-wing aeroplane on a roof in Paris. Even so I cannot foresee roof-aerodromes for fixed-wing aircraft, which is the purpose for which former prophets have foreseen them; but I emphatically can foresee roof-aerodromes for slow-landing, moving-wing aircraft.

Travellers going by future air-lines will take a taxi from their homes to Charing Cross, step into a moving-wing machine on a roof-aerodrome, fly to Paris, land on another roof-aerodrome near the Place de l'Opéra, and take a taxi to their hotel.

I think it likely that, by the time it reaches maturity, the full speed of the moving-wing aircraft will be below that of the fixed-wing aircraft. But it will make up for this disadvantage by offering travellers the advantages of eliminating terminal communications and changes of vehicle. Part of the time it loses between Croydon and Le Bourget it will regain between Croydon and Charing Cross and between Le Bourget and the Place de l'Opéra. Moreover, on days when, through fog, the fixed-wing aircraft-service is suspended, the moving-wing aircraft will still operate.

By these means the moving-wing aircraft will become a formidable competitor of the fixed-wing aircraft. How will the fixed-wing aircraft reply to the attack?

It will make a supreme effort to increase its speed to such an extent that it will offer to travellers a journey taking from door to door only about two-thirds of the time occupied by the other type. To do this the time lost in terminal communications by motor-car will, at first, be partly recovered by extremely high flying speeds. The 250 miles per hour air-express will make its appearance. The wing-loading of these machines will be high. Dr Rohrbach the German designer, believes that great advantages accrue through

high wing-loadings, and in lectures and papers he has described at length the reasons for his belief. In order to get these highly loaded machines off quickly and to land them within an aerodrome of reasonable size, a form of catapult launching apparatus and an arrester will be employed.

Catapult-launching has been proved, in England, America, Italy, and France, to be practicable with fairly large aircraft. There is no reason to suppose that its development will not continue.

An aircraft-arrester was described by Mr G. H. Dowty in a paper read before the Institution of Aeronautical Engineers in October 1926. It consisted in a drum having wound round it a length of cable. The aeroplane, by some hook and line device similar to that used by Army co-operation machines in picking up messages, will connect itself to the end of the cable. The cable will rotate the drum against a brake, and the aeroplane will be arrested. Mr Dowty calculates that a machine travelling at 90 m.p.h. could by this means, be brought to a standstill in 100 yards without an excessive strain being put on the machine's structure.

The chances of forced landings in these highly loaded fixed-wing machines will be reduced to a negligible quantity by big reserves of power and by providing that power through many engines.

In spite of the acceleration of the fixed-wing services made possible by the use of these express-aeroplanes, the popularity of the moving-wing services will continue to grow. The public will count time well lost against the discomfort of changing twice and motoring long distances through roads as inadequate for the traffic of that day as the existing ones are for the traffic of this. They will continue to take taxis to the Charing Cross roof-aerodrome when they want to travel by air to Paris, York, Manchester, Glasgow, or Dublin.

The drifting of passengers to the moving-wing services will spur the supporters of the fixed-wing services to devise another reply. They will build motor speedways from Croydon reaching into the heart of London and from all the other big aerodromes into the hearts of the cities they serve. These speedways will have no side-turnings or cross-roads. They will be forbidden to pedestrians, bicyclists, lorries, 'buses, and similar vehicles. They will be hedged in on either side like railway lines. The flat-footed influence of policeman and politician will be excluded and along these tracks cars will carry passengers to and from the aerodromes at 100 miles per hour. Assisted by these tracks, the great speed of the fixed-wing services will temporarily prevail, and a fair supply of passengers will be assured although the moving-wing services will still flourish.

The position at this stage of the battle might be described as a deadlock. The next stage will perhaps be the most remarkable of all.

It may have been noticed that, unlike most prophets, I have been exceedingly modest in naming the distances over which these future services will operate. While discussing the battle between fixed-wing and moving-wing, instead of speaking of Empire services, Globe-circling airlines, or non-stop hemispherical flying expresses, I have spoken of trivial routes like London-Paris and London-Glasgow. I have not even mentioned London-Karachi, London-Melbourne, or London-Montreal.

My modesty was only temporarily assumed. I am now about to throw it off in order to describe what I believe will be the most important development of the flying machine. This development will begin during the latter part of the fixed-wing, _v._ moving-wing battle.

IV

I have spoken, in describing the fixed-wing versus moving-wing battle, only of short air-lines, because I think the establishment of the successful short line will precede the establishment of the long.

It is argued that the saving in time effected by the flying-machine becomes valuable only in long journeys, so that no one would bother to go to an aerodrome and take an aeroplane in order to save half an hour or so, and that the train-service in England is so good that the aeroplane-service would be incapable of competing with it successfully. And, while the disadvantages of short air-services are magnified, the disadvantages of long air-services are forgotten or not appreciated.

At present a short journey of three or four hours by aeroplane is all that the average passenger can stand in comfort. There is no room for him to move about much in the present cabins, and the noise of the engines, wires, and airscrews is fatiguing to anyone not used to it. Moreover, the time-basis is not the only basis on which the traveller compares the merits of the means of travel at his disposal. The ship provides its passengers with social intercourse and a high degree of comfort. A long journey by sea is usually a pleasant, invigorating experience. On a journey by air, on the other hand, the passengers get no fresh air, they have no opportunity

for making friends, for conversation, dancing, games, or any other of the fascinating trivialities which flavour life on board a passenger-steamer. The traveller offered the use of a long distance air-line, therefore, is invited to choose between, perhaps, three days discomfort and isolation in the cramped cabin of an aeroplane and three weeks social pleasure and invigorating laziness on board ship.

Now the disadvantages which attend long-distance air-travel in modern type machines are due almost entirely to the small size of passenger aircraft when compared with ships. The aeroplane will not be successful as a long-distance vehicle until it can give its passengers most of the pleasures they would get on board ship. It will not be able to give its passengers even a small fraction of those pleasures until it is as large as or nearly as large as the ship.

The pleasures of long-distance travel vary almost directly as the size of the vehicle. Can the aeroplane ever be made so large that it can offer its passengers the space and freedom of even a small-sized passenger-boat?

I do not think the aeroplane can ever become sufficiently big, but I do think the seaplane or the flying-boat can and will become sufficiently big to offer that degree of space and freedom.

I believe that aircraft will begin to compete successfully with boat and train in carrying the merchandize and passengers of the world only after the coming of the era of the hydro-aeroplane (I use this word to include both seaplane and flying-boat).

The longest flight ever made in one machine was made in a hydro-aeroplane. The largest machines ever built are hydro-aeroplanes. The heavier-than-air machines carrying the greatest weight are hydro-aeroplanes. I am confident that the era of the hydro-aeroplane will come, and that, until it comes, aircraft will not compete successfully with boat and train.

I have based my first conclusion, that the moving-wing aeroplane will become a powerful competitor of the fixed-wing aeroplane for short-distance air-transport, on flexibility. The moving-wing machine can go from door to door, no matter if the journey is partly over the sea and partly over the land. I base my second conclusion, that the hydro-aeroplane will become the pre-eminent vehicle for long-distance air-transport, on size. The hydro-aeroplane can be built as large as may be required.

If people are to journey even for one day in the same vehicle, they need space and freedom of movement. They need wide promenade decks, lounges, restaurants, cabins, smoking-rooms. They cannot be confined to a single basket chair.

For long-distance air-transport the sardine-theory so popular with our London transport controllers must be abandoned. The sardine-theory must be recognized for what it is, a system of getting more money out of the passenger by increasing his discomfort. The more you squeeze the passenger, the more the money oozes out of him.

The aeroplane cannot, I think, become very much larger than the largest machines of to-day because the support of much greater weights on the landing-wheels becomes difficult. At present there are machines in which each landing-wheel must carry 6 tons. If the weight were much increased, the three-point suspension on wheels and tail-skid would become impracticable. The provision of a caterpillar landing-gear and of aerodromes with prepared surfaces might be possible and might assist matters if machines, say eight or nine times the size of the present, were contemplated. But, to obtain the comfort required (and given by the ship) on a long voyage, the machines would need to be some fifty or a hundred times the size of the largest existing types. When those sizes were reached, the problems of supporting the weight on the ground and of manoeuvring on the ground, taking off, and landing would become exceedingly difficult to solve.

Yet these problems are comparatively easy to solve in the large hydro-aeroplane. A large hydro-aeroplane with a high wing-loading could, if necessary, use the open sea as its aerodrome. Since the problem of the forced landing would definitely have been overcome by the power-unit arrangement, the large hydro-aeroplane would fly over land or sea. Its stations would be sea ports, lakes, or wide rivers.

The aeroplane both with moving and fixed wing will certainly grow in size; but nothing seems to me to indicate that it will be able to keep pace with the growth of the hydro-aeroplane. The growth of the hydro-aeroplane is foreshadowed in a French machine and a German machine which have appeared recently. The hundred-passenger hydro-aeroplane is a proven possibility. I can see no insuperable obstacle to the eventual arrival of the 1,000-passenger or the 2,000-passenger hydro-aeroplane. Moreover, the fog-landing problem is easier to solve in the sea-going than in the land-going fixed-wing aircraft. Good automatic landing devices are more easily designed for hydro-aeroplanes than for aeroplanes.

Mr O. E. Simmonds, of the design staff of a firm of British flying-boat constructors, said: "The largest successful flying-boats yet built have weighed about 30,000 lbs. I shall certainly feel that progress has been inordinately slow if we have not constructed a boat of 100,000 lbs. gross weight _by the end of the next decade_."

The first real air-liner, carrying some five or six hundred passengers, will probably appear after or towards the end of the battle between fixed and moving-wing machines. And it will be a flying-boat. The unsolved problems attending high-altitude air-transport seem to be so difficult that I am inclined to believe that high altitude transport will not become a regular method in this generation.

The possibilities of machines capable of travelling at immense speeds in the rarefied air at a height of 15 miles or so from the ground are attractive. But, if a forecast is to be based on research-work actually accomplished at the time, it is made, then high-altitude flying must be excluded.

Among the problems which high-altitude flying involves and which seem to postpone its arrival to the distant future are: the infinitely variable pitch airscrew, the light, positive, infinitely variable gear (without ratchet final drive), the sealed cabin with self-contained ventilating system, the engine altitude supercharger, and the variable camber-wing. Among these the Leitner automatic infinitely variable pitch airscrew is one of the most interesting inventions ever made in airscrew design, but it is at present in its earliest stages. The Constantinesco torque-converter, which is an automatic infinitely variable gear, might be adaptable to aircraft. The sealed cabin presents great practical difficulties, as does the variable camber-wing.

From this brief parenthesis the difficulties of high-altitude transport will be apparent. It is almost certain to come, but its day is likely to be distant, and for that reason I have concentrated on possibilities less remote.

Now that the long and short distance air-liners have been dealt with, I will give a brief sketch of how the traveller will use these vehicles. If Mr X, who lives at Hampstead, desires to go to Melbourne, Australia, he will first pile his luggage onto a taxi and drive to the terminus of some moving-wing aircraft line. This terminus will be close to the centre of London: A highly developed moving-wing aircraft will take him to the coast. The machine will land on the quay beside which will float a flying-boat express. This machine will be a fixed-wing flying-boat of about 1,000 tons. It will be a monoplane, the wings growing from the hull at a sharp dihedral angle and then curving down until they are horizontal.

The engines will be particularly interesting. Most designers, even now, are endeavouring to eliminate reciprocating motion in petrol-engines. The trend of thought is towards substituting the sleeve-valve for the poppet-valve and towards increasing the number of cylinders. More and more inventors "invent" gas-turbines. Their engines have had varying degrees of failure, although a few, the Jean Mély turbine among them, are reported to have gained a measure of success. One of these inventors will soon be completely successful. The movement towards the rotary gas-engine is too vigorous and too general to remain for ever unfruitful. The gas-turbine will be the aero-engine of the future. It will be cooled by an evaporative system.

One pound of water carries only 20 B.T.U., whereas 1 lb. of steam carries 966 B.T.U. Wing Commander Cave-Browne-Cave, in a paper read before the Royal Aeronautical Society, drew attention to the advantages for aircraft of evaporative engine cooling. He said: "By far the lightest way of conveying heat is as the latent heat of steam." On test a standard aero-engine gave the same power and fuel-consumption with evaporative as with water-cooling. The greatest advantage will accrue in reduction of resistance. Panels in the aircraft surface will receive heat in the steam and thus the drag caused by water-radiators even of the wing or strut type, or air-cooled cylinders will be eliminated. The evaporative cooling system will not freeze up at the highest altitudes: it will probably maintain the engine at a more even working temperature than an air-cooling system, and the steam will provide a suitable means of heating the passenger cabins and pilot's cockpit and of cooking.

The flying-boat to which Mr X is now having his luggage transferred then, has twelve evaporative-cooled gas-turbines housed in the wings, six on the starboard and six on the port side. Eight of them will drive tractor airscrews and four will drive propellers through torque-converters. There may be a system of concentrating the whole engine-power at three or four airscrews.

The entire machine, including the wing-coverings, will be built of metal. "I cannot conceive", said M. Dewoitine, the French designer, "that the ultimate aeroplane can be in anything else but metal, in the same way that metal ships to-day completely replace the wooden ships of days gone by." The living quarters in the hull would be arranged on labour-saving lines. The passengers would have drawing-room, dining-saloon, lounge, and promenade deck. The promenade deck on a long-distance air-express will be different from the promenade deck on a liner. It will be enclosed in the hull and will be lighted by a transparent roof and sides.

Mr X finds his cabin arranged in much the same way as in a ship, and, having settled his things, he goes up to the lounge, where the other passengers are congregating. A few minutes later, with a faint hum, two of the tractor-airscrews begin to revolve, and the flying-boat moves slowly away from the quay. Two more airscrews start revolving, and the machine, having taxied out, turns into wind. It pauses a moment as if it were taking breath, then the twelve air-screws spin faster and faster until they appear as discs of light. The machine moves forward heavily, a solid mass of metal, with the passengers watching from the windows of the promenade deck. It lumbers through the water, but throws up but little spray. Then it seems to stretch itself, throw back its head, and to rise bodily out of the water until it runs on the surface of—instead of in—the water. Already it appears lighter and less clumsy. Finally, after giving the water two or three parting pats, it takes to the air and, in spite of its great mass, instantly becomes an agile, graceful flying-machine.

The usual amusements, the usual eating, drinking, reading, and talking will employ the passengers' time in the air. For the daily round goes on in much the same way ashore, afloat or aflight. The night flying is exhilarating, although there is, of course, almost no sense of speed. Though the sea is rough, the machine, at 4,000 ft. is as steady as a rock. As the first stopping place rushes towards the machine, the hum of the engines alters note and the machine dips in a gentle glide. The mouth of a river, with shipping on it and two more flying-boat expresses lying at a quay a short way up the river, comes into view. The machine wheels round and glides closer and closer to the water. Four of the airscrews give a short burst of speed, and then the hull rips the surface of the water with a hiss.

Soon afterwards Mr X has said good-bye to his voyage acquaintances who are disembarking, and the machine is off on the next stage.

The success of the large, long-distance flying-boat will mark the beginning of the concentration of fixed-wing machines on long-distance routes and the concentration of moving-wing machines on short, distance routes. The fixed-wing machine, finding it has no rival in the large flying-boat type and finding that it has a strong rival in the comparatively small land-going type (that rival being the moving-wing machine) will gradually remove itself from the short air-lines. The position will then be that all short air-lines are run by moving-wing land-going aircraft while all long air-lines are run by fixed-wing sea-going aircraft.

The real air-liner, as distinct from the commercial flying soap-box of to-day, will be an immense sea-going air-vessel. It will be a self-contained town offering greater attractions to the pleasure-seeker than any other kind of small town. When that machine makes its appearance the Air Age will have begun.

V

Before I described the passenger-carrying flying-machine towards which contemporary research-work seems directed, I postulated the freedom of the air for that machine. I stipulated that the statesman and the financier should be gagged and bound. Now that I come to private-flying and air-racing, however, the imagination jibs at the notion of a similar freedom of the air. If the statesman were prevented from meddling with the technical development of the passenger-carrying flying-machine, he would most likely turn with redoubled vigour to the task of controlling, organizing, watching over, regulating, and generally bleeding the private, the record-breaking, and the racing aircraft.

I can, therefore, sketch the future of those machines only as the statesman will direct it.

The small fixed-wing private flying-machine, especially in the amphibian form, will gradually become more and more popular and, as it grows more popular, so the statesman will take more notice of it. His first opportunity for direct action will come when a few people get killed in an accident involving a private aircraft.

Taking advantage of the Press outcry, of the screams of the Safety First societies and of the opportunity for personal aggrandizement, Members of Parliament will pass a Flying-Machine Act.

Among the provisions of this Act will be a 40-miles per hour minimum speed-limit. No heavier-than-air craft will be permitted to fly at a speed of less than 40 miles per hour. It is easy to follow the workings of the official mind in setting this speed-limit. A fixed-wing aircraft crashes not because it goes too fast but because it goes too slowly. Therefore, the statesman will reason, if it is illegal to go too slowly, there will be no more accidents.

Another provision will make it illegal for anyone suffering from nicotine-poisoning to be in charge of a flying-machine. (Prohibition will be established in England by this time, so that no clause about "drunk in charge of a flying-machine" will be necessary.)

Further regulations will make it necessary for every private pilot to pass a medical examination once a month as a condition of his having a pilot's licence. Having passed this examination, he will be required to wear, while in charge of an aeroplane, two 8-inch metal discs, with a number stamped upon them. One disc will be worn on the left shoulder and the other on the top of the flying-helmet.

The aeroplane, in addition to its letter markings on wings and fuselage, will be required to exhibit three plaques bearing identification-numbers. One will be on the centre section, one on the undercarriage, and one on the port side of the fuselage. The aeroplane will also carry metropolitan or county police markings on four tablets of given size, besides markings of the appropriate local council on plates of certain specified dimensions, and small circular pieces of paper contained in approved holders on the rear port interplane-strut (or wing-tip in the case of a monoplane), the rear starboard interplane-strut (or wing-tip) the undercarriage port forward-strut, the tail-fin, the fuselage, and the top plane gravity-tank (if any).

In addition to the pilot's logbook, machine logbook, engine logbook, pilot's licence, and airworthiness certificate, there will be a registration-book, travel-triptych, flight-permit, landing-permit, and housing-pass.

These items are, of course, extra to the navigation-lights, wing-tip flares, cockpit-illuminants, parachute-flares, fire-extinguishers, silencers, life-saving parachutes, and other obligatory equipment, such as lifebelts, fire-proof bulkheads, stall-indicators, warning-signals, and Very lights.

These regulations will provide the police with the opportunity of displaying their keen sense of duty. They will ignore the old-fashioned and mundane murders, and will say with Horace Walpole: "Do not wonder that we do not entirely attend to the things of earth; fashion has ascended to a higher element."

Conceive the vigour and elegance with which they will uphold the 40 m.p.h. minimum speed-limit. What their stopwatches (for they will still use them) and observation lacks in accuracy, they will make up for by the free imagery and sweeping poetic fancy of their evidence in Court.

The pilot who flies while suffering from nicotine-poisoning will be the object of universal opprobrium. His social doom will be sealed when the witness says that his breath _smelt of tobacco_ and that he must have been smoking the same morning. The pilot's statement that he only had two cigarettes during the previous month will be completely discountenanced.

But the best chance for the police will come when the private moving-wing machine begins to make an appearance. Then will dawn the true constabulary millennium.

The moving-wing machine, as it has been shown, can almost hover and can fly comfortably at five or ten miles per hour. One day a moving-wing machine will pass through a police-trap while its pilot is admiring the countryside or inquiring from his companion where they will stop for lunch.

The pilot will appear in Court charged with flying at less than 40 miles per hour, and there will be a sensation when the detectives disclose that defendant's speed, which he did not deny, was 8 miles per hour over a measured furlong.

The magistrate will say that, although he had been on that bench for thirty-five years, never in his whole experience, never from the moment that he had accepted those duties, never since the time when he devoted himself to the administration of justice, _never_ had he heard of such a flagrant disregard for the safety of the public. Here was a flying-machine, over a populous area, travelling at 8 miles per hour when everyone knew that a flying-machine gained its lift by virtue of its speed through the air, and that if it travelled at less than forty miles per hour it was liable at any moment to fall upon the heads of the people below.

The pilot might endeavour to explain the technical points in the case. If he did so, his fine would be greater than if he merely pleaded guilty and said no more.

That case will be the signal for a wholesale persecution of moving-wing aircraft-owners. The Home Secretary will issue warnings, magistrates will wish that they could send pilots to prison—in fact there will be the usual process of departmental browbeating which we know so well. The theory that the private flyer will not be summoned for slow flying because there will be moving-wing passenger aircraft also capable of slow flying, does not bear investigation. There are now lorries, motor-buses, charabancs, steam-wagons, and trams which persistently exceed the 20-miles per hour speed limit. They are not prosecuted, nor will the passenger aircraft of the future be prosecuted.

Having given some idea of the delightful future which lies before the private flyer, I will add a few remarks upon air-racing.

After motor-road racing, air-racing is the finest sport yet invented. I give it ten more years life in England.

Before the War air-racing at Hendon was highly successful in that it attracted many entries and large crowds of spectators. Since the War air-racing has been unsuccessful. There are signs, however, that there will soon be a revival of it. Larger and larger crowds will collect to watch it. Special machines will be constructed, the number of entries will increase, continental firms will take part.

Then the statesman will step in and play his part, as he always must when anything becomes popular.

Air-racing is and will remain dangerous. Statesmen and newspapers will discover this and talk about it. Now I am informed upon the best authority that in England no one is allowed to face danger of any kind, whether he wants to or not. The State arranges that all dangers, physical and moral, are kept away from the individual. He may not do, see, hear smell, or taste anything calculated to arouse him from the suety state of mind so highly esteemed by the politician. The Englishman is nursed from birth to death by an army of officials. He is permitted to risk his life only in war.

Air-racing, since it is dangerous, will gradually be stamped out of existence. Air-racing improves the aircraft as a machine-entity; it would have a good effect upon the private flyer's machine and upon the war-machine. When air-racing has been stopped, therefore, a decline in the quality of the private flying-machine and the service-machine will result.

Air-racing (with which I include record-breaking) is as important to pure aeronautical development as anything else. The history of the Schneider Cup seaplane-race is some indication of the technical advance racing achieves. In 1913 at Monaco the Schnieder Cup, was won by France at 45.4 m.p.h. In 1914 (England) at 86.4 m.p.h., in 1919 (Italy) at 124.9 m.p.h. (This race was declared void). In 1920 (Italy) at 107.2 m.p.h. In 1921 (Italy) at 111.4 m.p.h., in 1922 (England) at 146.1 m.p.h., in 1923 (America) 177.4 m.p.h., in 1925 (America) 234.4 m.p.h. and in 1926 (Italy) at 246.5 m.p.h. (Fig. 3).

[Illustration: _Fig. 3 Schneider Cup_]

The Schneider Cup figures show that the much boasted rapidity of progress in the performance of high-speed aircraft during the War is a myth. During the War, progress was almost completely stopped. Even if the Italian win of 1919 at 124.9 m.p.h. be accepted (and the race was declared void because Janello was not observed at one of the turning-points) the rate of progress compares unfavourably with the rates before and after the War. If, on the other hand, the rate be judged by the accepted wins of 1914 and 1920 then the top speed of seaplanes rose only 20.8 m.p.h. in 6 years against 139.3 m.p.h. in 6 years after the War.

Up to 1926 there has been little sign of a falling off in the rate of progress in high-speed seaplane-design, and a rough estimate, puts the probable speed of the winner in 1928 at 290 m.p.h. and in 1930 at 320 m.p.h.

Record-breaking has a similar effect to racing upon technical development. In 1919 Sir John Alcock and Sir A. Whitten Brown flew the Atlantic non-stop for the first time in a heavier-than-air machine. They covered 1,890 miles in about 16 hours. In 1926 M. Dieudonné Coste and Capitaine Rignot covered 3,400 miles non-stop in 32 hours.

Whatever country takes up and encourages private flying, air-racing and record-breaking will play a big part in the future of the flying-machine.

VI

I see no reason to depart from the forecast of the future military flying-machine which I make in my _Strategy and Tactics of Air Fighting_.

Since the fixed-wing machine will probably retain a slightly superior performance over the moving-wing machine (although it is fair to Señor de la Cierva to add that some of the best mathematicians find on theoretical calculation that the moving-wing aircraft should be equal in all-round performance to the fixed-wing type), it is likely that, excepting a proportion of army co-operation machines and a small proportion of night-bombers the moving-wing machine will not in the future be used in large numbers for war purposes.

Before constructing the machine of the future, let us go to the R.A.F. annual Display, and refusing to be fascinated by the intricate shape of the breeches worn by officers and men, let us examine an experimental single-seater fighter of the present. When in the

air the machine is remarkable only for the undercarriage-struts and wheels which hang below the fuselage. They look like a labourer's hands in the drawing-room, they are sturdy but, in the air, they do not seem to know what to do with themselves, they are in unaccustomed surroundings.

Let this machine be compared with the gull. I use the gull for these comparisons because it is common and easily observed and so provides an accessible model. Indeed, it was the gull which instructed Mr A. V. Roe and helped him to become, on June 8th, 1908, the first man to fly over British soil. The experimental single-seater fighter at the R.A.F. Display has very few characteristics of which any bird need be ashamed. One of these characteristics, however, is undoubtedly its undercarriage. The gull folds up its undercarriage when it is in the air; it lets it down only when it is about to land.

But now compare the experimental machine with one of the standard machines in an R.A.F. squadron. The standard service-machine looks as if it has got into the hands of an accessory fiend, one of those who believe that the part is greater than the whole. It is so cluttered up with odds and ends, so cut about, modified, added to, and altered that it resembles no other flying-machine, animal or artificial. It is a sort of winged Air Ministry, a receptacle full of interesting information about everything but the air.

Since this mania for encumbering service-machines is only a superficial failing, it is possible, after remarking it, to go direct to the service-machine of the future.

There is first a new type to be noted, the aerial artillery-machine. This will be a large multi-engined monoplane carrying a single medium-sized gun and a few rounds of ammunition. It will be able to direct close range gunfire from the air at important ground-objectives. The advantage of the aerial big gun over the bomb will be in accuracy, the advantage of the bomb over the aerial big gun will be in the great weight of projectile made possible by the absence of any heavy launching-apparatus like a gun. The height of the aeroplane acts on the bomb as the explosive charge on the projectile. But at long ranges the bomb, with the newest sights and under the best conditions, is inaccurate, and at short ranges its velocity is low. The aerial big gun permits ground-objectives and ships to be attacked at short range with projectiles travelling at a high velocity.

The success of low-flying attacks by machine-guns in the late War was a sufficient demonstration of the potentialities of the low-altitude gun-attack from the air. Experiments were made long ago in mounting small guns in aeroplanes and in arranging for the absorption of the recoil. Against other aircraft the aerial big gun would not be used. In aerial fighting weight of projectile is of less importance than rate of fire.

The night-bombing machine of the future will be an immense flying-boat. It is likely that this type will also be used for day bombing. If so, it will be heavily armed with machine-guns and will not go out without a strong screen and escort of fighting machines.

The fighting aeroplane will be particularly interesting. It will be a small monoplane without external bracing-wires or struts and the undercarriage will be retractable. It will carry one man, and will be an all-metal machine mounting a gas-turbine of some 1,000 h.p.

Performance-figures must be the wildest guess work, because the closest examination of the trend of research gives but small information on the probable rates of progress in speed and climb. Mr A. V. Roe has frequently stated his belief that the future flying-machine will attain 1,000 miles per hour. I will, therefore, give my fighter of this generation 400 miles per hour, 800 miles per hour in the dive, a climb to 20,000 feet in 4 minutes, and a service-ceiling (the height at which the rate of climb falls below 100 feet per minute) of 60,000 feet.

In order that the fighter may operate at high altitudes, and in order that it may be able to change height suddenly by diving or climbing steeply, the pilot will be housed in a pressure-cockpit, from which he will look through a streamline conning-tower made in some transparent material. Unless he were enclosed in some such pressure-chamber or pressure-suit, the pilot would be unable to withstand the cold and the reduced pressure of extreme altitudes, and the sudden changes in temperature and pressure, when the machine was climbing or diving. Pressure-suits are now being experimented with in France and probably elsewhere.

Oxygen would be supplied to the pressure-chamber and an emergency oxygen-apparatus would provide against the chamber being pierced by a bullet. Some form of dessicating apparatus would be essential to prevent the transparent conning-tower from fogging up. The fewest accessories would be carried by these fighters of the future.

In general military aircraft will be more specialized than they are to-day, there will be no many-purpose machines. Instead, the number of specialist machines will steadily increase. In addition to the aerial big guns, there will be flying-tanks or lightly armoured

low-flying machines for attacks on ground-targets. These will be developed from the "Salamander", "Vampire", and other armoured aircraft introduced during the late War.

Armour for fighting and bombing-aircraft will not be employed for many years. The gunners on the large flying-boat bombers, however, will be provided with small shields.

Perhaps a general idea of the future of the flying-machine in war may best be given by quoting a newspaper report of a day air-attack on London in the next war.

I cut the headlines and start with Our Special Correspondent, who, with the printer's assistance, has, if I may be permitted to say so, trodden on it through all four gears:

"The greatest air-raid in history was launched on London yesterday evening by a formation estimated at between six and seven hundred aeroplanes.

"For nearly two hours the earth shook to the thunder of the guns, while far up in the blue vault of Heaven there was the flash of wheeling wings, as the heroic pilots of the Royal Air Force plunged again and again to the attack.

"Never before has the heart of the Empire been the objective of so powerful and so determined an offensive, never before have the British air-forces so covered themselves with glory.

"Owing to the vigorous defence which met the raiders as they neared London, casualties are low. Official figures have not yet been issued, but it is thought that fewer than 1,000 people were killed while only some 7,000 were wounded.

"FIRST WARNING.

"The raiders were first reported by the 'concrete ears' or wireless disc and super-sensitive microphone sentries which encircle the coast. A large formation (there was much doubt as to the number of machines) was said to be approaching Southampton, and with the exception of three emergency squadrons, every R.A.F. fighting-aeroplane rushed to the attack.

"As our machines, sweeping through the freezing blue of the great altitudes, approached the raiders, the raiders turned and made off at full speed. Our machines bent on reaching the enemy, tore after them.

"It was at this moment that ominous news came through. A second hostile formation, far larger than the first, had been detected approaching the East coast south of Harwich.

"Nearly the whole of the defending airforce was far away: London's bosom was bared to the attack.

"The new formation—first given as 400 machines but later corrected to 600—was in four great layers and flying at 170 miles per hour.

"The three emergency R.A.F. squadrons, numbering 54 machines of an old type with five or six experimental machines from Martlesham Heath and Farnborough, went up at once and hurled themselves at the vast enemy formation.

"THREE TO ONE ODDS.

"The second layer of the hostile formation, which consisted of about 150 long-distance fighters, engaged them. A furious battle ensued, while the remainder of the hostile fleet, aerial big guns, flying-boat bombers, and, at an extreme altitude, a further batch of long-distance fighters, continued on their way towards London.

"The old R.A.F. machines were literally butchered by the whip-lashes of lead which cracked and curled from the small-calibre stream-fire enemy guns. One of our machines had both its wings cut off and fell to the ground with such force that the airscrew-boss was buried 18 feet in the earth.

"Meanwhile wireless messages had reached the R.A.F. formation, which had been drawn off by the feint attack on Southampton. _They had turned and were tearing to the rescue at 350 miles per hour._

"The two big formations were in sight of each other when the enemy was about 20 miles south west of Chelmsford. At this time there was no active opposition to the invaders in the air. Anti-aircraft batteries, however, were blackening the sky with shells, and had succeeded in bringing down two enemy machines.

"There seemed now no hope that London would escape the full force of the attack. Already two ten-ton wireless-controlled flying-bombs had struck the city. Even so there was little panic. The gas-mask distribution had worked well, and no one was unprovided. The usual shelters were made full use of, but many people, against the orders of the police, remained in the streets anxiously looking skywards and listening to the almost continuous tear and roar of the guns.

"ANXIOUS MOMENTS.

"For some reason the news that the first hostile formation had retired had not come through on the wireless. And, since no one knew that far the greater part of the R.A.F. defending forces had gone in pursuit of that formation or that the emergency squadrons had been cut to pieces, a good deal of uneasiness prevailed among the watchers.

"Where are the R.A.F. fighters? was the question uppermost in everyone's mind.

"As the noise of the guns grew louder and seemed to vibrate and echo among the houses, considerable alarm was displayed. There were one or two ugly scenes, and some women and children were trampled to death in raid shelters at Hoxton and Liverpool Street.

"A quarter of an hour before dusk the two lower layers of the hostile formation were sighted by some people who had been foolish enough to take up positions on the roof of the _Daily Post_ offices in Fleet Street. Only the trained eyes of the anti-aircraft spotters aided by the new visual detection instruments could distinguish the upper layers.

"Still there was no sign of our aeroplanes. The stories of those irresponsible alarmists who, in books and articles, have prophesied as far back as 1927 that London would be wiped out by aerial attack, seemed likely to prove too true. Excitement among the watchers gave way to a certain grimness. Then came a change in the situation.

"'What's that?'

"THE BATTLE JOINED.

"Someone was pointing immediately overhead. Nothing could at first be distinguished in the blue sky; then someone else waved excitedly.

"'Yes, I caught a glimpse.'

"Just then the light of the setting sun glinted momentarily on some infinitesimal speck like a minute silver fish, rushing through the air at a great height. No one dared to express the hopes which they felt.

"A moment later what looked at first like a small red rose sprang into being high up over the enemy, high over the smoke-blackened sky where the anti-aircraft shells were bursting. Then it fell, like a flaming bomb. There was fighting going on up there, out of sight, in the upper air.

"Still the lower hostile layers came on through the roar and shock of the anti-aircraft fire. They were already over the outskirts of London. Something else fell from above twisting horribly. The white of parachutes drifting fantastically could be observed through high-powered glasses.

"Quite suddenly the continuous thunder of the anti-aircraft fire ceased. It was succeeded by an uncanny calm, and then by a high-pitched metallic scream which grew in an ear-piercing crescendo. _The R.A.F. aerial destroyers were engaging the lower enemy layers._

"The R.A.F. arrows of the upper air plunged into the very heart of the raiders, streaming fire and lead. They wheeled and turned among them with a swift, purposeful agility.

"RAIN OF BOMBS.

"The hostile formation began to split up, and simultaneously the enemy commander gave by wireless the order to bomb. On the outskirts of London huge factories and houses were suddenly transformed into pillars of white dust. The shriek and thump of the falling bombs was heard clearly in Central London.

"'It was as if the ground were being torn up under your feet', said a postman eyewitness. 'The people in the shelters came out and began to run. They didn't stop to think; they just ran like wild beasts, trampling on each other, and hitting out at anyone who got in the way, whether man, woman or child.

"'The rain of bombs was so continuous that for as far as you could see earth and buildings were spouting up in the air with human limbs mixed up in them. The sound of the bombs falling was what knocked people's nerves up as much as anything.

"'The gas-bombs didn't seem so bad, but the incendiary bombs were a nasty sight, at one time it looked as if the whole air had caught fire.'

"According to official information, damage was small. Only the aerial artillery-machines attained an objective of military importance. They completely destroyed the F.E. aircraft factory at Finsbury Park.

"The raiders had timed their attack so as to escape in the dark, and, although the new night detection flood-lights worked well, there is no doubt that the hostile casualties were so few because our fighters were hampered by the darkness.

"According to figures supplied by the Air Department of the War Ministry, 37 hostile machines were brought down while only eighteen of our own aerial destroyers were lost. The three emergency R.A.F. squadrons which first attacked lost 39 machines and had several more severely damaged.

"The raid is regarded by experts as a decisive victory for the British Air-arm and a complete and convincing justification of the policy of the Air-staff. It is pointed out that the raiders were prevented from reaching their objective, and that, apart from the old-type R.A.F. machines, our casualties are smaller than those of the enemy."

In another part of the same paper was this insignificant paragraph.

"A late Central News message, delayed owing to the disorganization caused by yesterday's air-raid, states that the hostile formation which made a feint attack on Southampton and was driven off by our machines, later returned to the same place and bombed it continuously for half an hour, causing many casualties and much material damage."

In the stop-press news was this:

"One a.m. Large hostile formation of aircraft reported approaching mouth of Thames."

In the above skit I have not dwelt on the terrible side of air-warfare in the future. Yet I feel that that is the side upon which all who are competent to do so, and who wish to prevent future wars should dwell. Several novels have given pictures of future aerial warfare, but I have not seen its inevitable horrors realistically portrayed. Unless those horrors are portrayed frequently and in their true and shocking form, people will soon forget the unpleasant side of air-war and think only of its romantic and glorious side.

In the interests of humanity it would be a good thing if some able novelist or film-producer would give us a statement of the crude horrors of air-war. If such a one arises, he will have the satisfaction of having helped the cause of peace and of having his work banned by the Censor.

VII

So far I have spoken only of heavier-than-air flying-machines. There is also the airship to which many people pin their faith for future long-distance air-transport.

The airship was neglected in England after the War because experience seemed to show that it was incapable of playing a useful part in warfare. Its revival was chiefly due to Commander Burney, who continually drew attention to his conviction that the airship could be made a safe and successful long-distance air-transport vehicle.

Most airship advocates believe in the bigger the better theory. If the gas-capacity of an airship is doubled, the disposable lift may be quadrupled, and the size will be only about 1.3 times that of the smaller vessel. For this reason the two English airships now being built are each of 5,000,000 cu. ft. gas-capacity. One is being built by the Government, the other for the Government to Commander Burney's general design.

These airships have provided matter for many speeches on Empire air-ship-routes of the future. At the recent Imperial Conference airships were spoken of as the right vessels for long-distance air-lines. These forecasts are based on slender foundations.

Since 1914 only one successful commercial airship-service has been run. The 'Bodensee' in 1919 made 103 trips between Berlin and Friedrichshafen and carried 2450 passengers. Those 103 trips seem to be an insecure basis upon which to build calculations about voyages halfway round the world. The new airships may go from England to Egypt in 2½ days, and from England to Melbourne in 12½ days, but nothing has occurred in airship-development to strengthen the probability of such events. The two new airships are nothing more than a gigantic experiment.

I must make some unpleasant remarks about airships, but, before doing so, it is necessary to record admiration of the English airship policy. I do not agree with the man with a genius for mixed metaphor who described the airship scheme as the "thin edge of the white elephant". On the contrary, in initiating this experiment the Government has shown imagination and daring. Airship enthusiasts are to have an opportunity of testing their theories. If the experiment is a hopeless failure no money and no time will have been wasted, for the knowledge gained will be of value in directing future aeronautical development.

But to the question: Will the airship become the long-distance air vehicle of the future? I answer No.

I base my view on an examination of airship history and on the opinions of airship pilots. Upon that basis the probable future of the 5,000,000 cu. ft. vessels will be this:

The first one to be completed will make a first flight, and come to its 200 ft. mooring mast successfully. For several months it will cruise periodically, and minor structural modifications will be made. It will fly to India and back. Paying passengers will be accepted, and after considerable delay the first long-distance passenger-flight will be flown. Some two or three years after the airship comes from its shed, it will meet with disaster.

More airships will be designed and built, larger still than those now building. There will be another disaster.

By then the heavier-than-air machine in the moving-wing and fixed-wing forms, will have proved itself capable of doing all that airships can do and doing it more safely, more quickly, more regularly, and more cheaply. The airship will gradually disappear, and its place will be taken by the heavier-than-air craft, as the balloon is gradually disappearing and its place being taken by the airship.

There is only one major difference between balloon and airship, a difference in the amount of control exercised by the airman. The same difference exists between airship and aeroplane. The aeroplane is the more controllable. It can rise and descend with less preliminary juggling; it can turn more quickly; and it can land more quickly.

In support of my pessimistic forecast I append a brief outline of air-ship-history.

Lighter-than-air man-carrying flight started in 1783 when Pilâtre de Rozier, the world's first aeronaut, went up in a Montgolfier balloon. In the same year a hydrogen filled balloon flew from Paris to Nesle. In the following year an oblong balloon propelled by parasols as oars was made by the Duc de Chartres.

In 1852 a small airship propelled by a steam engine was made. In 1882 Tissandier's airship worked by an electric motor was flown, and in 1884 the airship 'La France' was flown. Count Zeppelin built his first airship in 1900. Santos Dumont constructed an airship, and, in 1902, flew it round the Eiffel Tower.

It will be seen that the airship has passed through a longer period of development than the heavier-than-air flying-machine, even if the claim that Clement Ader flew in 1897 be accepted. Lighter-than-air flight, indeed, dates back to 1783.

The result of that longer development period is not such as to warrant too sanguine a belief in the airship's future. The accidents to non-rigids and rigids have been many in proportion to the number of vessels actually flown.

The last type of non-rigid built in England was the North Sea type, one of which was destroyed by lightning soon after the War. Nine people were killed. Among the rigids, R.34, which made the double Atlantic crossing, was damaged beyond repair in 1921. R.33 has had many adventures, among them being her break-away from the mooring-mast in 1925. This was hailed as a proof of the safety of airships. R.33 is still alive, though she is treated with the respect due to her age.

R.36, the first British airship to be adapted for commercial purposes, is still in existence though not in service. R.38 broke up over the Humber in 1921 and forty-four people were killed.

The U.S.A. have the 'Los Angeles', which is the name now given to the German designed and built ZR.3. The 'Shenandoah' broke away from her mast in 1924, and was destroyed in 1926. According to survivors' stories, the 'Shenandoah' was wrecked by the same kind of vertical air-currents that wrecked an early Zeppelin in 1913. In all, nine American airships have perished violently since the War.

The French 'Dixmude' was the ex-Zeppelin L.72. She created a world's record in 1923, and then disappeared off Sicily with all hands (54 people).

Considering how few large airships have been built, and how short a time they are, on the average, kept in service, the proportion of serious accidents is high. In war that proportion is prohibitively high.

The Zeppelin works have turned out more rigid airships than any factory in the world. The fate of every Zeppelin airship completed since 1915 was recently given in a French technical paper. I do not vouch for the figures, but they come from a fairly reliable source. Out of 76 airships no fewer than 37 (or nearly 50%) were put out of service before they had completed one year's work. Only four airships were kept in service for more than three years. This is the record of the firm which knows more about airships than any other firm in the world. Yet airships have had longer to develop than aeroplanes.

How can an airship be said to be superior to a fixed-wing aeroplane? It can hover, it has a longer range, it provides a higher degree of comfort for its passengers. How is it inferior to a fixed-wing aeroplane? It is slower, it requires more elaborate ground organization, it is less controllable. Since the moving-wing aircraft is, as yet, far from fully developed, I leave it out of discussion.

The argument that an aeroplane is always using a part of its power for lifting is counterbalanced by the argument that an airship is always using a part of its power for driving its bulk against the wind. An airship cannot stand still and use no power. There is always some wind at a height, and the airship must either use power or drift. An airship with all its engines stopped is as helpless as an aeroplane with all its engines stopped. The aeroplane, while gliding, still retains a large measure of controllability, and the pilot can select its landing ground within 50 yards. The airship has less controllability when its engines are stopped. Its commander would be lucky if he could select its landing ground within 50 miles.

It is right that the airship should have every chance to develop. If it prove successful, so much the better. I do not think it will prove successful. If it is made to work, it will be at more than ten times the cost in money and lives, at which heavier-than-air machines have been made to work.

Sometimes it seems regrettable that even a small part of the sums spent on developing airships cannot be spent on developing the passenger-carrying aeroplane.

I will give airships the last word by recalling that Sir George Cayley in 1816 expressed his belief that airships would eventually prove the most efficient and safest means of air travel, and by quoting Dr Eckener:

"A modern airship", said Dr Eckener, "is at least as capable in heavy weather as a modern aeroplane. A storm will never have more effect than delaying or speeding a trip, and it can become directly dangerous only inasmuch as it may delay the voyage beyond the reach of fuel supply."

VIII

"_Sans nul doute, l'avenir est a la bête de métal._" People regret the age of the machine: I cannot do so. A well-made machine, in which are struck into life the dreams of its designer, is a vital, individual creation.

A flying machine designed by a man with a sense of flight is more faithful and far more intelligent than a horse or a dog. Thoughts are reflected in it, the careful skill of the executant is expressed in its every component. It is sensitive and quick to feel roughness or gentleness in the hand of him who controls it. Its moods are without number, and it can surprise, please, and irritate. It is susceptible to being coaxed, and it enjoys obeying one whose orders are firmly given. But it can be treacherous to the weak or to one who does not try to understand it or who is persistently cruel to it.

At present there is a tendency to knock the life out of the machine, to subdue it to the level of tooth paste and tin cans. If that tendency makes headway, the flying-machine of the future must lose its individuality, and the age of the machine may eventually prove to be a dark age.

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This candid and unprejudiced survey inquires why the majority of marriages to-day seem to be so unsatisfactory, and finds the answer in the sexual ethic of our civilization which is ill adapted to our social and economic needs. The problems of sex-morality, sex-education, prostitution, in-breeding, birth-control, trial-marriage, and polygamy are all touched upon.

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This imaginary chapter of world-history (1951–64) from the pen of one of the most brilliant living French authors mixes satire and fancy in just proportions. It tells how the press of the world is controlled by five men, how world interest is focussed on an attack on the moon, how thus the threat of world-war is averted. But when the moon retaliates....

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This non-technical but closely-reasoned book is a challenge to the orthodox teaching on evolution known as Neo-Darwinism. The author claims that, although Neo-Darwinian theories can possibly account for the evolution of forms, they are quite inadequate to explain the evolution of functions.

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A survey of contemporary fiction in England and America lends to the conclusion that the literary and scientific influences of the last fifty years have combined to make the novel of to-day predominantly analytic. It has thus gained in psychological subtlety, but lost its form. How this may be regained is put forward in the conclusion.

=Caledonia=, or the Future of the Scots. By G. M. THOMSON.

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All the many forces at work to-day are influencing the planning, appearance, and equipment of the home. This is the main thesis of this stimulating volume, which considers also the labour-saving movement, the 'ideal' house, the influence of women, the servant problem, and the relegation of aesthetic considerations to the background. Disconcerting prognostications follow.

NEARLY READY

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Chemistry as the means of human emancipation is the subject of this book. To-day chemistry is one of the master factors of our existence; to-morrow it will dominate every phase of life, winning for man the goal of all his endeavour, economic freedom. It may also effect a startling change in man himself.

=The Future of Physics.= By L. L. WHYTE.

The last few years have been a critical period in the development of physics. We stand on the eve of a new epoch. Physics, biology, and psychology are converging towards a scientific synthesis of unprecedented importance whose influence on thought and social custom will be so profound as to mark a stage in human evolution. This book interprets these events and should be read in connexion with _Gallio_, by J. W. N. Sullivan, in this series.

=Ikonoclastes=, or the Future of Shakespeare. By HUBERT GRIFFITHS.

Taking as text the recent productions of classical plays in modern dress, the author, a distinguished dramatic critic, suggests that this is the proper way of reviving Shakespeare and other great dramatists of the past, and that their successful revival in modern dress may perhaps be taken as an indication of their value.

IN PREPARATION

=Bacchus=, or the Future of Wine. By P. MORTON SHAND.

=Mercurius=, or the World on Wings. By C. THOMPSON WALKER.

=The Future of Sport.= By G. S. SANDILANDS.

=The Future of India.= By T. EARLE WELBY.

=The Future of Films.= By ERNEST BETTS.

Transcriber's Note (continued)

Errors in punctuation and simple typos have been corrected without note. Archaic or variant spelling, inconsistent hyphenation, etc., has been left as it appears in the original publication unless as noted in the following:

Page 12 – "insistance" changed to "insistence" (The continued insistence that speed)

Page 35 – "persistance" changed to "persistence" (foretold with tiresome persistence)

End matter page 17 – "montrous" changed to "monstrous" (their monstrous slum-evil)

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The organisation of thought, educational and scientific

Alfred North Whitehead

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THE ORGANISATION OF THOUGHT

THE ORGANISATION OF THOUGHT

EDUCATIONAL AND SCIENTIFIC

BY A. N. WHITEHEAD, Sc.D., F.R.S.

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LONDON WILLIAMS AND NORGATE 14 HENRIETTA STREET, COVENT GARDEN, W.C.2 1917

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PREFACE

THE discourses included in this volume have been delivered as addresses on various occasions which are duly noted; the only exception is _The Anatomy of Some Scientific Ideas_, which is now published for the first time. These discourses fall into two sections, the first five chapters deal with education, and the remaining three embody discussions on certain points arising in the philosophy of science. But a common line of reflection extends through the whole, and the two sections influence each other.

I have left in each chapter the reference to the particular occasion of its first production, and I have not sought for a verbal consistency covering perplexity. But the various parts of the book were in fact composed with express reference to each other, so as to form one whole.

I have to thank the Syndics of the Cambridge University Press for permission to republish the contents of Chapter V.

Imperial College of Science and Technology, _April 1917._

TABLE OF CONTENTS

CHAP. PAGE

PREFACE v

I. THE AIMS OF EDUCATION--A PLEA FOR REFORM 1 (Presidential Address to the Mathematical Association, January, 1916.)

II. TECHNICAL EDUCATION AND ITS RELATION TO SCIENCE AND LITERATURE 29 (Presidential Address to the Mathematical Association, January, 1917.)

III. A POLYTECHNIC IN WAR-TIME 58 (Address at the Prize Distribution, Borough Polytechnic Institute, Southwark, February, 1917.)

IV. THE MATHEMATICAL CURRICULUM 69 (Presidential Address to the London Branch of the Mathematical Association, 1912.)

V. THE PRINCIPLES OF MATHEMATICS IN RELATION TO ELEMENTARY TEACHING 92 (Paper read in the Educational Section of the International Congress of Mathematicians, Cambridge, 1912.)

VI. THE ORGANISATION OF THOUGHT 105 (Presidential Address to Section A, British Association, Newcastle, 1916; also read subsequently before the Aristotelian Society.)

VII. THE ANATOMY OF SOME SCIENTIFIC IDEAS 134

VIII. SPACE, TIME, AND RELATIVITY 191 (Paper read to Section A at the Manchester Meeting of Section A, 1915; also, with the appended Commentary, read subsequently before the Aristotelian Society.)

ORGANISATION OF THOUGHT

CHAPTER I

THE AIMS OF EDUCATION--A PLEA FOR REFORM

(_Presidential Address to the Mathematical Association, January, 1916_)

WHEN I had the honour of being made President of the Mathematical Association, I did not foresee the unusual responsibility which it entailed. It was my intention to take as the theme of a presidential address the consideration of some aspect of those special subjects to which my own researches have principally been directed. Events have forced me to abandon that intention. It is useless to discuss abstract questions in the midst of dominant practical preoccupation. We cannot disregard the present crisis in European civilisation. It affects every function of life. In the harder struggle for existence which lies before the nation, all departments of national effort will be reviewed for judgment. The mere necessity for economy in resources will provoke this reformation.

We are concerned with education. This Association, so rich in its membership of educationalists, with the conception of reform as the very reason of its being, is among those bodies which must take the lead in guiding that educational reconstruction which by a sociological law follows every social revolution. We do not want impracticable ideals, only to be realised beyond the clouds in

"Some wild, weird clime, Out of Space, and out of Time."

We require to know what is possible now in England, a nation conscious of its high achievements, and of great failures, shaken to its foundations, distrustful of the old ways, and dreading fantastic novelties.

I will take my courage in both hands, and put before you an outline of educational principles. What I am going to say is of course entirely without your authority, and does not pledge or prejudge any action of the Association. We are primarily concerned only with the intellectual side of education, and, as mathematicians, are naturally concerned to illustrate details more particularly by reference to mathematics. Thus much to explain deliberate omissions in what follows.

Consider now the general and special education of two types of boys, namely those in secondary schools who in after life must form the professional and directing classes in commerce, industry, and public administration, and again those in junior technical schools and later in advanced continuation classes, who are going to form the class of skilled artisans and foremen of workshops. These two sets compose the educated strength of the nation. We must form no ideals which include less than these entire classes within their scope. What I shall say, will in phraseology apply more directly to the secondary schools, but with unessential changes it will apply equally to the other group.

What is the first commandment to be obeyed in any educational scheme? It is this: Do not teach too many subjects. The second command is this: What you teach, teach thoroughly. The devil in the scholastic world has assumed the form of a general education consisting of scraps of a large number of disconnected subjects; and, with the artfulness of the serpent, he has entrenched himself behind the matriculation examination of the University of London, with a wire entanglement formed by the Oxford and Cambridge schools' examination.

Culture is activity of thought, and receptiveness to beauty, and humane feeling. Scraps of information have nothing to do with it. A merely well-informed man is the most useless bore on God's earth. What we should aim at producing is men who possess both culture and expert knowledge in some special direction. Their expert knowledge will give them the ground to start from, and their culture will lead them as deep as philosophy and as high as art. We have to remember that the valuable intellectual development is self-development, and that it mostly takes place between the ages of sixteen and thirty. As to training, the most important part is given by mothers before the age of twelve. A saying due to Archbishop Temple illustrates my meaning. Surprise was expressed at the success in after-life of a man, who as a boy at Rugby had been somewhat undistinguished. He answered, "It is not what they are at eighteen, it is what they become afterwards that matters."

In training a child to activity of thought, above all things we must beware of what I will call "inert ideas"--that is to say, ideas that are merely received into the mind without being utilised, or tested, or thrown into fresh combinations.

In the history of education, the most striking phenomenon is that schools of learning, which at one epoch are alive with a ferment of genius, in a succeeding generation exhibit merely pedantry and routine. The reason is, that they are overladen with inert ideas. Education with inert ideas is not only useless: it is, above all things, harmful--_Corruptio optimi, pessima_. Except at rare intervals of intellectual ferment, education in the past has been radically infected with inert ideas. That is the reason why uneducated clever women, who have seen much of the world, are in middle life so much the most cultured part of the community. They have been saved from this horrible burden of inert ideas. Every intellectual revolution which has ever stirred humanity into greatness has been a passionate protest against inert ideas. Then, alas, with pathetic ignorance of human psychology, it has proceeded by some educational scheme to bind humanity afresh with inert ideas of its own fashioning.

Let us now ask how in our system of education we are to guard against this mental dry rot. We recur to our two educational commandments, "Do not teach too many subjects," and again, "What you teach, teach thoroughly."

The result of teaching small parts of a large number of subjects is the passive reception of disconnected ideas, not illumined with any spark of vitality. Let the main ideas which are introduced into a child's education be few and important, and let them be thrown into every combination possible. The child should make them his own, and should understand their application here and now in the circumstances of his actual life. From the very beginning of his education, the child should experience the joy of discovery. The discovery which he has to make, is that general ideas give an understanding of that stream of events which pours through his life, which is his life. By understanding I mean more than a mere logical analysis, though that is included. I mean "understanding" in the sense in which it is used in the French proverb, "To understand all, is to forgive all." Pedants sneer at an education which is useful. But if education is not useful, what is it? Is it a talent, to be hidden away in a napkin? Of course, education should be useful, whatever your aim in life. It was useful to Saint Augustine and it was useful to Napoleon. It is useful, because understanding is useful.

I pass lightly over that understanding which should be given by the literary side of education. It is not peculiarly the function of this Association to consider it. Nor do I wish to be supposed to pronounce on the relative merits of a classical or a modern curriculum. I would only remark that the understanding which we want is an understanding of an insistent present. The only use of a knowledge of the past is to equip us for the present. No more deadly harm can be done to young minds than by depreciation of the present. The present contains all that there is. It is holy ground; for it is the past, and it is the future. At the same time it must be observed that an age is no less past if it existed two hundred years ago than if it existed two thousand years ago. Do not be deceived by the pedantry of dates. The ages of Shakespeare and of Molière are no less past than are the ages of Sophocles and of Virgil. The communion of saints is a great and inspiring assemblage, but it has only one possible hall of meeting, and that is, the present; and the mere lapse of time through which any particular group of saints must travel to reach that meeting-place, makes very little difference.

Passing now to the scientific and logical side of education, we remember that here also ideas which are not utilised are positively harmful. By utilising an idea, I mean relating it to that stream, compounded of sense perceptions, feelings, hopes, desires, and of mental activities relating thought to thought, which forms our life. I can imagine a set of beings which might fortify their souls by passively reviewing disconnected ideas. Humanity is not built that way--except perhaps some editors of newspapers.

In scientific training, the first thing to do with an idea is to prove it. But allow me for one moment to extend the meaning of "prove"; I mean--to prove its worth. Now an idea is not worth much unless the propositions in which it is embodied are true. Accordingly an essential part of the proof of an idea is the proof, either by experiment or by logic, of the truth of the propositions. But it is not essential that this proof of the truth should constitute the first introduction to the idea. After all, its assertion by the authority of respectable teachers is sufficient evidence to begin with. In our first contact with a set of propositions, we commence by appreciating their importance. That is what we all do in after-life. We do not attempt, in the strict sense, to prove or to disprove anything, unless its importance makes it worthy of that honour. These two processes of proof, in the narrow sense, and of appreciation do not require a rigid separation in time. Both can be proceeded with nearly concurrently. But in so far as either process must have the priority, it should be that of appreciation by use.

Furthermore, we should not endeavour to use propositions in isolation. Emphatically I do not mean, a neat little set of experiments to illustrate Proposition I and then the proof of Proposition I, a neat little set of experiments to illustrate Proposition II and then the

proof of Proposition II, and so on to the end of the book. Nothing could be more boring. Inter-related truths are utilised _en bloc_, and the various propositions are employed in any order, and with any reiteration. Choose some important applications of your theoretical subject; and study them concurrently with the systematic theoretical exposition. Keep the theoretical exposition short and simple, but let it be strict and rigid so far as it goes. It should not be too long for it easily to be known with thoroughness and accuracy. The consequences of a plethora of half-digested theoretical knowledge are deplorable. Also the theory should not be muddled up with the practice. The child should have no doubt when it is proving and when it is utilising. My point is that what is proved should be utilised, and that what is utilised should--so far as is practicable--be proved. I am far from asserting that proof and utilisation are the same thing.

At this point of my discourse, I can most directly carry forward my argument in the outward form of a digression. We are only just realising that the art and science of education require a genius and a study of their own; and that this genius and this science are more than a bare knowledge of some branch of science or of literature. This truth was partially perceived in the past generation; and headmasters, somewhat crudely, were apt to supersede learning in their colleagues by requiring left-hand bowling and a taste for football. But culture is more than cricket, and more than football, and more than extent of knowledge.

Education is the acquisition of the art of the utilisation of knowledge. This is an art very difficult to impart. Whenever a text-book is written of real educational worth, you may be quite certain that some reviewer will say that it will be difficult to teach from it. Of course it will be difficult to teach from it. If it were easy, the book ought to be burned; for it cannot be educational. In education, as elsewhere, the broad primrose path leads to a nasty place. This evil path is represented by a book or a set of lectures which will practically enable the student to learn by heart all the questions likely to be asked at the next external examination. And I may say in passing that no educational system is possible unless every question directly asked of a pupil at any examination is either framed or modified by the actual teacher of that pupil in that subject. The external assessor may report on the curriculum or on the performance of the pupils, but never should be allowed to ask the pupil a question which has not been strictly supervised by the actual teacher, or at least inspired by a long conference with him. There are a few exceptions to this rule, but they are exceptions, and could easily be allowed for under the general rule.

We now return to my previous point, that theoretical ideas should always find important applications within the pupil's curriculum. This is not an easy doctrine to apply, but a very hard one. It contains within itself the problem of keeping knowledge alive, of preventing it from becoming inert, which is the central problem of all education.

The best procedure will depend on several factors, none of which can be neglected, namely, the genius of the teacher, the intellectual type of the pupils, their prospects in life, the opportunities offered by the immediate surroundings of the school, and allied factors of this sort. It is for this reason that the uniform external examination is so deadly. We do not denounce it because we are cranks, and like denouncing established things. We are not so childish. Also, of course, such examinations have their use in testing slackness. Our reason of dislike is very definite and very practical. It kills the best part of culture. When you analyse in the light of experience the central task of education, you find that its successful accomplishment depends on a delicate adjustment of many variable factors. The reason is that we are dealing with human minds, and not with dead matter. The evocation of curiosity, of judgment, of the power of mastering a complicated tangle of circumstances, the use of theory in giving foresight in special cases--all these powers are not to be imparted by a set rule embodied in one schedule of examination subjects.

I appeal to you, as practical teachers. With good discipline, it is always possible to pump into the minds of a class a certain quantity of inert knowledge. You take a text-book and make them learn it. So far, so good. The child then knows how to solve a quadratic equation. But what is the point of teaching a child to solve a quadratic equation? There is a traditional answer to this question. It runs thus: The mind is an instrument, you first sharpen it, and then use it; the acquisition of the power of solving a quadratic equation is part of the process of sharpening the mind. Now there is just enough truth in this answer to have made it live through the ages. But for all its half-truth, it embodies a radical error which bids fair to stifle the genius of the modern world. I do not know who was first responsible for this analogy of the mind to a dead instrument. For aught I know, it may have been one of the seven wise men of Greece, or a committee of the whole lot of them. Whoever was the originator, there can be no doubt of the authority which it has acquired by the continuous approval which it has received from eminent persons. But whatever its weight of authority, whatever the high approval which it can quote, I have no hesitation in denouncing it as one of the most fatal, erroneous, and dangerous conceptions ever introduced into the theory of education. The mind is never passive; it is a perpetual activity, delicate, receptive, responsive to stimulus. You cannot postpone its life until you have sharpened it. Whatever interest attaches to your subject-matter, must be evoked here and now; whatever powers you are strengthening in the pupil, must be exercised here and now; whatever possibilities of mental life your teaching should impart, must be exhibited here and now. That is the golden rule of

education, and a very difficult rule to follow.

The difficulty is just this: the apprehension of general ideas, intellectual habits of mind, and pleasurable interest in mental achievement can be evoked by no form of words, however accurately adjusted. All practical teachers know that education is a patient process of the mastery of details, minute by minute, hour by hour, day by day. There is no royal road to learning through an airy path of brilliant generalisations. There is a proverb about the difficulty of seeing the wood because of the trees. That difficulty is exactly the point which I am enforcing. The problem of education is to make the pupil see the wood by means of the trees.

The solution which I am urging, is to eradicate the fatal disconnection of subjects which kills the vitality of our modern curriculum. There is only one subject-matter for education, and that is Life in all its manifestations. Instead of this single unity, we offer children--Algebra, from which nothing follows; Geometry, from which nothing follows; Science, from which nothing follows; History, from which nothing follows; a Couple of Languages, never mastered; and lastly, most dreary of all, Literature, represented by plays of Shakespeare, with philological notes and short analyses of plot and character to be in substance committed to memory. Can such a list be said to represent Life, as it is known in the midst of the living of it? The best that can be said of it is, that it is a rapid table of contents which a deity might run over in his mind while he was thinking of creating a world, and had not yet determined how to put it together.

Let us now return to quadratic equations. We still have on hand the unanswered question. Why should children be taught their solution? Unless quadratic equations fit into a connected curriculum, of course there is no reason to teach anything about them. Furthermore, extensive as should be the place of mathematics in a complete culture, I am a little doubtful whether for many types of boys algebraic solutions of quadratic equations do not lie on the specialist side of mathematics. I may here remind you that as yet I have not said anything of the psychology or the content of the specialism, which is so necessary a part of an ideal education. But all that is an evasion of our real question, and I merely state it in order to avoid being misunderstood in my answer.

Quadratic equations are part of algebra, and algebra is the intellectual instrument which has been created for rendering clear the quantitative aspects of the world. There is no getting out of it. Through and through the world is infected with quantity. To talk sense, is to talk in quantities. It is no use saying that the nation is large,--How large? It is no use saying that radium is scarce,--How scarce? You cannot evade quantity. You may fly to poetry and to music, and quantity and number will face you in your rhythms and your octaves. Elegant intellects which despise the theory of quantity, are but half developed. They are more to be pitied than blamed. The scraps of gibberish, which in their school-days were taught to them in the name of algebra, deserve some contempt.

This question of the degeneration of algebra into gibberish, both in word and in fact, affords a pathetic instance of the uselessness of reforming educational schedules without a clear conception of the attributes which you wish to evoke in the living minds of the children. A few years ago there was an outcry that school algebra was in need of reform, but there was a general agreement that graphs would put everything right. So all sorts of things were extruded, and graphs were introduced. So far as I can see, with no sort of idea behind them, but just graphs. Now every examination paper has one or two questions on graphs. Personally, I am an enthusiastic adherent of graphs. But I wonder whether as yet we have gained very much. You cannot put life into any schedule of general education unless you succeed in exhibiting its relation to some essential characteristic of all intelligent or emotional perception. It is a hard saying, but it is true; and I do not see how to make it any easier. In making these little formal alterations you are beaten by the very nature of things. You are pitted against too skilful an adversary, who will see to it that the pea is always under the other thimble.

Reformation must begin at the other end. First, you must make up your mind as to those quantitative aspects of the world which are simple enough to be introduced into general education; then a schedule of algebra should be framed which will about find its exemplification in these applications. We need not fear for our pet graphs, they will be there in plenty when we once begin to treat algebra as a serious means of studying the world. Some of the simplest applications will be found in the quantities which occur in the simplest study of society. The curves of history are more vivid and more informing than the dry catalogues of names and dates which comprise the greater part of that arid school study. What purpose is effected by a catalogue of undistinguished kings and queens? Tom, Dick, or Harry, they are all dead. General resurrections are failures, and are better postponed. The quantitative flux of the forces of modern society are capable of very simple exhibition. Meanwhile, the idea of the variable, of the function, of rate of change, of equations and their solution, of elimination, are being studied as an abstract science for their own sake. Not, of course, in the pompous phrases with which I am alluding to them here, but with that iteration of simple special cases proper to teaching.

If this course be followed, the route from Chaucer to the Black Death, from the Black Death to modern Labour troubles, will connect the tales of the mediæval pilgrims with the abstract science of algebra, both yielding diverse aspects of that single theme, Life. I know what most of you are thinking at this point. It is that the exact course which I have sketched out is not the particular one which you would have chosen, or even see how to work. I quite agree. I am not claiming that I could do it myself. But your objection is the precise reason why a common external examination system is fatal to education. The process of exhibiting the applications of knowledge must, for its success, essentially depend on the character of the pupils and the genius of the teacher. Of course I have left out the easiest applications with which most of us are more at home. I mean the quantitative sides of sciences, such as mechanics and physics.

My meaning can be illustrated by looking more closely into a special case of this type of application. In my rough catalogue of the sort of subjects which should form the schedule for algebra, I mentioned Elimination. It was not put there by accident, for it covers a very important body of thought.

In the first place, there is the abstract process of algebraic elimination for suitable simple cases. The pupil acquires a firm grasp of this by the process, inevitable in education, of working an adequate number of examples. Again, there are the graphical solutions of the same problem. Then we consider the significance in the external world. We consider the velocity, time, space, acceleration diagrams. We take uniform acceleration; we eliminate "_t_" between

_v_ = _u_ + _ƒt_, and _s_ = _ut_ + ½_ƒt_^2,

and eliminate "_s_" between

_v_^2 = _u_^2 + 2_ƒs_, and _s_ = _ut_ + ½_ƒt_^2.

Then we remember that constant acceleration is a very special case, and we consider graphical solutions or empirically given variations of _v_ or of _ƒ_. In preference, we use those empirical formulæ which occur in the pupil's experimental work. We compare the strong and weak points of the algebraic and graphical solutions.

Again, in the same connection we plot the statistics of social phenomena against the time. We then eliminate the time between suitable pairs. We can speculate how far we have exhibited a real casual connection, or how far a mere temporal coincidence. We notice that we might have plotted against the time one set of statistics for one country and another set for another country, and thus, with suitable choice of subjects, have obtained graphs which certainly exhibited mere coincidence. Also other graphs exhibit obvious casual connections. We wonder how to discriminate. And so are drawn on as far as we will.

But in considering this description, I must beg you to remember what I have been insisting on above. In the first place, one train of thought will not suit all groups of children. For example, I should expect that artisan children will want something more concrete and, in a sense, swifter than I have set down here. Perhaps I am wrong, but that is what I should guess. In the second place, I am not contemplating one beautiful lecture stimulating, once and for all, an admiring class. That is not the way in which education proceeds. No; all the time the pupils are hard at work solving examples, drawing graphs, and making experiments, until they have a thorough hold on the whole subject. I am describing the interspersed explanations, the directions which should be given to their thoughts. The pupils have got to be made to feel that they are studying something, and are not merely executing intellectual minuets.

In this connection the excellence of some of the most recent text-books on elementary algebra emanating from members of this Association, should create an epoch in the teaching of the subject.

Finally, if you are teaching pupils for some general examination, the problem of sound teaching is greatly complicated. Have you ever noticed the zig-zag moulding round a Norman arch? The ancient work is beautiful, the modern work is hideous. The reason is, that the modern work is done to exact measure, the ancient work is varied according to the idiosyncrasy of the workman. Here it is crowded, and there it is expanded. Now the essence of getting pupils through examinations is to give equal weight to all parts of the schedule. But mankind is naturally specialist. One man sees a whole subject, where another can find only a few detached examples. I know that it seems contradictory to allow for specialism in a curriculum especially designed for a broad culture. Without contradictions the world would be simpler, and perhaps duller. But I am certain that in education wherever you exclude specialism you destroy life.

We now come to the other great branch of a general mathematical education, namely Geometry. The same principles apply. The theoretical part should be clear-cut, rigid, short, and important. Every proposition not absolutely necessary to exhibit the main connection of ideas should be cut out, but the great fundamental ideas should be all there. No omission of concepts, such as those of Similarity and Proportion. We must remember that, owing to the aid rendered by the visual presence of a figure, Geometry is a field of unequalled excellence for the exercise of the deductive faculties of reasoning. Then, of course, there follows Geometrical Drawing, with its training for the hand and eye.

But, like Algebra, Geometry and Geometrical Drawing must be extended beyond the mere circle of geometrical ideas. In an industrial neighbourhood, machinery and workshop practice form the appropriate extension. For example, in the London Polytechnics this has been achieved with conspicuous success. For many secondary schools I suggest that surveying and maps are the natural applications. In particular, plane-table surveying should lead pupils to a vivid apprehension of the immediate application of geometric truths. Simple drawing apparatus, a surveyor's chain, and a surveyor's compass, should enable the pupils to rise from the survey and mensuration of a field to the construction of the map of a small district. The best education is to be found in gaining the utmost information from the simplest apparatus. The provision of elaborate instruments is greatly to be deprecated. To have constructed the map of a small district, to have considered its roads, its contours, its geology, its climate, its relation to other districts, the effects on the status of its inhabitants, will teach more history and geography than any knowledge of Perkin Warbeck or of Behren's Straits. I mean not a nebulous lecture on the subject, but a serious investigation in which the real facts are definitely ascertained by the aid of accurate theoretical knowledge. A typical mathematical problem should be: Survey such and such a field, draw a plan of it to such and such a scale, and find the area. It would be quite a good procedure to impart the necessary geometrical propositions without their proofs. Then, concurrently in the same term, the proofs of the propositions would be learnt while the survey was being made.

Fortunately, the specialist side of education presents an easier problem than does the provision of a general culture. For this there are many reasons. One is that many of the principles of procedure to be observed are the same in both cases, and it is unnecessary to recapitulate. Another reason is that specialist training takes place--or should take place--at a more advanced stage of the pupil's course, and thus there is easier material to work upon. But undoubtedly the chief reason is that the specialist study is normally a study of peculiar interest to the student. He is studying it because, for some reason, he wants to know it. This makes all the difference. The general culture is designed to foster an activity of mind; the specialist course utilises this activity. But it does not do to lay too much stress on these neat antitheses. As we have already seen, in the general course foci of special interest will arise; and similarly in the special study, the external connections of the subject drag thought outwards.

Again, there is not one course of study which merely gives general culture, and another which gives special knowledge. The subjects pursued for the sake of a general education are special subjects specially studied; and, on the other hand, one of the ways of encouraging general mental activity is to foster a special devotion. You may not divide the seamless coat of learning. What education has to impart is an intimate sense for the power of ideas, for the beauty of ideas, and for the structure of ideas, together with a particular body of knowledge which has peculiar reference to the life of the being possessing it.

The appreciation of the structure of ideas is that side of a cultured mind which can only grow under the influence of a special study. I mean that eye for the whole chess-board, for the bearing of one set of ideas on another. Nothing but a special study can give any appreciation for the exact formulation of general ideas, for their relations when formulated, for their service in the comprehension of life. A mind so disciplined should be both more abstract and more concrete. It has been trained in the comprehension of abstract thought and in the analysis of facts.

Finally, there should grow the most austere of all mental qualities; I mean the sense for style. It is an æsthetic sense, based on admiration for the direct attainment of a foreseen end, simply and without waste. Style in art, style in literature, style in science, style in logic, style in practical execution have fundamentally the same æsthetic qualities, namely, attainment and restraint. The love of a subject in itself and for itself, where it is not the sleepy pleasure of pacing a mental quarter-deck, is the love of style as manifested in that study.

Here we are brought back to the position from which we started, the utility of education. Style, in its finest sense, is the last acquirement of the educated mind; it is also the most useful. It pervades the whole being. The administrator with a sense for style, hates waste; the engineer with a sense for style, economises his material; the artisan with a sense for style, prefers good work. Style is the ultimate morality of mind.

But above style, and above knowledge, there is something, a vague shape like fate above the Greek gods. That something is Power. Style is the fashioning of power, the restraining of power. But, after all, the power of attainment of the desired end is fundamental. The first thing is to get there. Do not bother about your style, but solve your problem, justify the ways of God to man, administer your province, or do whatever else is set before you.

Where, then, does style help? In this, with style the end is attained without side issues, without raising undesirable inflammations. With style you attain your end and nothing but your end. With style the effect of your activity is calculable, and foresight is the last gift of gods to men. With style your power is increased, for your mind is not distracted with irrelevancies, and you are more likely to attain your object. Now style is the exclusive privilege of the expert. Whoever heard of the style of an amateur painter, of the style of an amateur poet? Style is always the product of specialist study, the peculiar contribution of specialism to culture.

English education in its present phase suffers from a lack of definite aim, and from an external machinery which kills its vitality. Hitherto in this address I have been considering the aims which should govern education. In this respect England halts between two opinions. It has not decided whether to produce amateurs or experts. The profound change in the world which the nineteenth century has produced is that the growth of knowledge has given foresight. The amateur is essentially a man with appreciation and with immense versatility in mastering a given routine. But he lacks the foresight which comes from special knowledge. The object of this address is to suggest how to produce the expert without loss of the essential virtues of the amateur. The machinery of our secondary education is rigid where it should be yielding, and lax where it should be rigid. Every school is bound on pain of extinction to train its boys for a small set of definite examinations. No headmaster has a free hand to develop his general education or his specialist studies in accordance with the opportunities of his school, which are created by its staff, its environment, its class of boys, and its endowments. I suggest that no system of external tests which aims primarily at examining individual scholars can result in anything but educational waste.

Primarily it is the schools and not the scholars which should be inspected. Each school should grant its own leaving certificates, based on its own curriculum. The standards of these schools should be sampled and corrected. But the first requisite for educational reform is the school as a unit, with its approved curriculum based on its own needs, and evolved by its own staff. If we fail to secure that, we simply fall from one formalism into another, from one dung-hill of inert ideas into another.

In stating that the school is the true educational unit in any national system for the safe-guarding of efficiency, I have conceived the alternative system as being the external examination of the individual scholar. But every Scylla is faced by its Charybdis--or, in more homely language, there is a ditch on both sides of the road. It will be equally fatal to education if we fall into the hands of a supervising department which is under the impression that it can divide all schools into two or three rigid categories, each type being forced to adopt a rigid curriculum. When I say that the school is the educational unit, I mean exactly what I say, no larger unit, no smaller unit. Each school must have the claim to be considered in relation to its special circumstances. The classifying of schools for some purposes is necessary. But no absolutely rigid curriculum, not modified by its own staff, should be permissible. Exactly the same principles apply, with the proper modifications, to universities and to technical colleges.

When one considers in its length and in its breadth the importance of this question of the education of a nation's young, the broken lives, the defeated hopes, the national failures, which result from the frivolous inertia with which it is treated, it is difficult to restrain within oneself a savage rage. In the conditions of modern life the rule is absolute, the race which does not value trained intelligence is doomed. Not all your heroism, not all your social charm, not all your wit, not all your victories on land or at sea, can move back the finger of fate. To-day we maintain ourselves. To-morrow science will have moved forward yet one more step, and there will be no appeal from the judgment which will then be pronounced on the uneducated.

We can be content with no less than the old summary of educational ideal which has been current at any time from the dawn of our civilisation. The essence of education is that it be religious.

Pray, what is religious education?

A religious education is an education which inculcates duty and reverence. Duty arises from our potential control over the course of events. Where attainable knowledge could have changed the issue, ignorance has the guilt of vice. And the foundation of reverence is this perception, that the present holds within itself the complete sum of existence, backwards and forwards, that whole amplitude of time, which is eternity.

CHAPTER II

TECHNICAL EDUCATION AND ITS RELATION TO SCIENCE AND LITERATURE

(_Presidential Address to the Mathematical Association, January, 1917_)

THE subject of this address is Technical Education. I wish to examine its essential nature and also its relation to a liberal education. Such an inquiry may help us to realise the conditions for the successful working of a national system of technical training. It is also a very burning question among mathematical teachers; for mathematics is included in most technological courses.

Now it is unpractical to plunge into such a discussion without framing in our own minds the best ideal towards which we desire to work, however modestly we may frame our hopes as to the result which in the near future is likely to be achieved.

People are shy of ideals; and accordingly we find a formulation of the ideal state of mankind placed by a modern dramatist[1] in the mouth of a mad priest: "In my dreams it is a country where the State is the Church and the Church the people: three in one and one in three. It is a commonwealth in which work is play and play is life: three in one and one in three. It is a temple in which the priest is the worshipper and the worshipper the worshipped: three in one and one in three. It is a godhead in which all life is human and all humanity divine: three in one and one in three. It is, in short, the dream of a madman."

Now the part of this speech to which I would direct attention is embodied in the phrase, "It is a commonwealth in which work is play and play is life." This is the ideal of technical education. It sounds very mystical when we confront it with the actual facts, the toiling millions, tired, discontented, mentally indifferent, and then the employers---- I am not undertaking a social analysis, but I shall carry you with me when I admit that the present facts of society are a long way off this ideal. Furthermore, we are agreed that an employer who conducted his workshop on the principle that "work should be play" would be ruined in a week.

The curse that has been laid on humanity, in fable and in fact, is, that by the sweat of its brow shall it live. But reason and moral intuition have seen in this curse the foundation for advance. The early Benedictine monks rejoiced in their labours because they conceived themselves as thereby made fellow-workers with Christ.

Stripped of its theological trappings, the essential idea remains, that work should be transfused with intellectual and moral vision and thereby turned into a joy, triumphing over its weariness and its pain. Each of us will re-state this abstract formulation in a more concrete shape in accordance with his private outlook. State it how you like, so long as you do not lose the main point in your details. However you phrase it, it remains the sole real hope of toiling humanity; and it is in the hands of technical teachers, and of those who control their spheres of activity, so to mould the nation that daily it may pass to its labours in the spirit of the monks of old.

The immediate need of the nation is a large supply of skilled workmen, of men with inventive genius, and of employers alert in the development of new ideas.

There is one--and only one--way to obtain these admirable results. It is by producing workmen, men of science, and employers who enjoy their work. View the matter practically in the light of our knowledge of average human nature. Is it likely that a tired, bored workman, however skilful his hands, will produce a large output of first-class work? He will limit his production, will scamp his work, and be an adept at evading inspection; he will be slow in adapting himself to new methods; he will be a focus of discontent, full of unpractical revolutionary ideas, controlled by no sympathetic apprehension of the real working of trade conditions. If, in the troubled times which may be before us, you wish appreciably to increase the chance of some savage upheaval, introduce widespread technical education and ignore the Benedictine ideal. Society will then get what it deserves.

Again, inventive genius requires pleasurable mental activity as a condition for its vigorous exercise. "Necessity is the mother of invention" is a silly proverb. "Necessity is the mother of futile dodges" is much nearer to the truth. The basis of the growth of modern invention is science, and science is almost wholly the outgrowth of pleasurable intellectual curiosity.

The third class are the employers, who are to be enterprising. Now it is to be observed that it is the successful employers who are the important people to get at, the men with business connections all over the world, men who are already rich. No doubt there will always be a continuous process of rise and fall of businesses. But it is futile to expect flourishing trade, if in the mass the successful houses of business are suffering from atrophy. Now if these men conceive their businesses as merely indifferent means for acquiring other disconnected opportunities of life, they have no spur to alertness. They are already doing very well, the mere momentum of their present business engagements will carry them on for their time. They are not at all likely to bother themselves with the doubtful chances of new methods. Their real soul is in the other side of their life. Desire for money will produce

hard-fistedness and not enterprise. There is much more hope for humanity from manufacturers who enjoy their work than from those who continue in irksome business with the object of founding hospitals.

Finally, there can be no prospect of industrial peace so long as masters and men in the mass conceive themselves as engaged in a soulless operation of extracting money from the public. Enlarged views of the work performed, and of the communal service thereby rendered, can be the only basis on which to found sympathetic co-operation.

The conclusion to be drawn from this discussion is, that alike for masters and for men a technical or technological education, which is to have any chance of satisfying the practical needs of the nation, must be conceived in a liberal spirit as a real intellectual enlightenment in regard to principles applied and services rendered. In such an education geometry and poetry are as essential as turning lathes.

The mythical figure of Plato may stand for modern liberal education as does that of St. Benedict for technical education. We need not entangle ourselves in the qualifications necessary for a balanced representation of the actual thoughts of the actual men. They are used here as symbolic figures typical of antithetical notions. We consider Plato in the light of the type of culture he now inspires.

In its essence a liberal education is an education for thought and for æsthetic appreciation. It proceeds by imparting a knowledge of the masterpieces of thought, of imaginative literature, and of art. The action which it contemplates is command. It is an aristocratic education implying leisure. This Platonic ideal has rendered imperishable services to European civilisation. It has encouraged art, it has fostered that spirit of disinterested curiosity which is the origin of science, it has maintained the dignity of mind in the face of material force, a dignity which claims freedom of thought. Plato did not, like St. Benedict, bother himself to be a fellow-worker with his slaves; but he must rank among the emancipators of mankind. His type of culture is the peculiar inspiration of the liberal aristocrat, the class from which Europe derives what ordered liberty it now possesses. For centuries, from Pope Nicholas V to the schools of the Jesuits, and from the Jesuits to the modern headmasters of English public schools, this educational ideal has had the strenuous support of the clergy.

For certain people it is a very good education. It suits their type of mind and the circumstances amid which their life is passed. But more has been claimed for it than this. All education has been judged adequate or defective according to its approximation to this sole type.

The essence of the type is a large discursive knowledge of the best literature. The ideal product of the type is the man who is acquainted with the best that has been written. He will have acquired the chief languages, he will have considered the histories of the rise and fall of nations, the poetic expression of human feeling, and have read the great dramas and novels. He will also be well grounded in the chief philosophies, and have attentively read those philosophic authors who are distinguished for lucidity of style.

It is obvious that, except at the close of a long life, he will not have much time for anything else if any approximation is to be made to the fulfilment of this programme. One is reminded of the calculation in a dialogue of Lucian that, before a man could be justified in practising any one of the current ethical systems, he should have spent a hundred and fifty years in examining their credentials.

Such ideals are not for human beings. What is meant by a liberal culture is nothing so ambitious as a full acquaintance with the varied literary expression of civilised mankind from Asia to Europe, and from Europe to America. A small selection only is required; but then, as we are told, it is a selection of the very best. I have my doubts of a selection which includes Xenophon and omits Confucius, but then I have read neither in the original. The ambitious programme of a liberal education really shrinks to a study of some fragments of literature included in a couple of important languages.

But the expression of the human spirit is not confined to literature. There are the other arts, and there are the sciences. Also education must pass beyond the passive reception of the ideas of others. Powers of initiative must be strengthened. Unfortunately initiative does not mean just one acquirement--there is initiative in thought, initiative in action, and the imaginative initiative of art; and these three categories require many subdivisions.

The field of acquirement is large, and the individual so fleeting and so fragmentary: classical scholars, scientists, headmasters are alike ignoramuses.

There is a curious illusion that a more complete culture was possible when there was less to know. Surely the only gain was, that it was more possible to remain unconscious of ignorance. It cannot have been a gain to Plato to have read neither Shakespeare, nor Newton, nor Darwin. The achievements of a liberal education have in recent times not been worsened. The change is that its

pretensions have been found out.

My point is, that no course of study can claim any position of ideal completeness. Nor are the omitted factors of subordinate importance. The insistence in the Platonic culture on disinterested intellectual appreciation is a psychological error. Action and our implication in the transition of events amid the evitable bond of cause to effect are fundamental. An education which strives to divorce intellectual or æsthetic life from these fundamental facts carries with it the decadence of civilisation. Essentially culture should be for action, and its effect should be to divest labour from the associations of aimless toil. Art exists that we may know the deliverances of our senses as good. It heightens the sense-world.

Disinterested scientific curiosity is a passion for an ordered intellectual vision of the connection of events. But the goal of such curiosity is the marriage of action to thought. This essential intervention of action even in abstract science is often overlooked. No man of science wants merely to know. He acquires knowledge to appease his passion for discovery. He does not discover in order to know, he knows in order to discover. The pleasure which art and science can give to toil is the enjoyment which arises from successfully directed intention. Also it is the same pleasure which is yielded to the scientist and to the artist.

The antithesis between a technical and a liberal education is fallacious. There can be no adequate technical education which is not liberal, and no liberal education which is not technical: that is, no education which does not impart both technique and intellectual vision. In simpler language, education should turn out the pupil with something he knows well and something he can do well. This intimate union of practice and theory aids both. The intellect does not work best in a vacuum. The stimulation of creative impulse requires, especially in the case of a child, the quick transition to practice. Geometry and mechanics, followed by workshop practice, gain that reality without which mathematics is verbiage.

There are three main methods which are required in a national system of education, namely, the literary curriculum, the scientific curriculum, the technical curriculum. But each of these curricula should include the other two. What I mean is, that every form of education should give the pupil a technique, a science, an assortment of general ideas, and æsthetic appreciation, and that each of these sides of his training should be illuminated by the others. Lack of time, even for the most favoured pupil, makes it impossible to develop fully each curriculum. Always there must be a dominant emphasis. The most direct æsthetic training naturally falls in the technical curriculum in those cases when the training is that requisite for some art or artistic craft. But it is of high importance in both a literary and a scientific education.

The educational method of the literary curriculum is the study of language, that is, the study of our most habitual method of conveying to others our states of mind. The technique which should be acquired is the technique of verbal expression, the science is the study of the structure of language and the analysis of the relations of language to the states of mind conveyed. Furthermore, the subtle relations of language to feeling, and the high development of the sense organs to which written and spoken words appeal, lead to keen æsthetic appreciations being aroused by the successful employment of language. Finally, the wisdom of the world is preserved in the masterpieces of linguistic composition.

This curriculum has the merit of homogeneity. All its various parts are co-ordinated and play into each other's hands. We can hardly be surprised that such a curriculum, when once broadly established, should have claimed the position of the sole perfect type of education. Its defect is unduly to emphasise the importance of language. Indeed the varied importance of verbal expression is so overwhelming that its sober estimation is difficult. Recent generations have been witnessing the retreat of literature, and of literary forms of expression, from their position of unique importance in intellectual life. In order truly to become a servant and a minister of nature something more is required than literary aptitudes.

A scientific education is primarily a training in the art of observing natural phenomena, and in the knowledge and deduction of laws concerning the sequence of such phenomena. But here, as in the case of a liberal education, we are met by the limitations imposed by shortness of time. There are many types of natural phenomena, and to each type there corresponds a science with its peculiar modes of observation, and its peculiar types of thought employed in the deduction of laws. A study of science in general is impossible in education, all that can be achieved is the study of two or three allied sciences. Hence the charge of narrow specialism urged against any education which is primarily scientific. It is obvious that the charge is apt to be well-founded; and it is worth considering how, within the limits of a scientific education and to the advantage of such an education, the danger can be avoided.

Such a discussion requires the consideration of technical education. A technical education is in the main a training in the art of utilising knowledge for the manufacture of material products. Such a training emphasises manual skill, and the co-ordinated action of hand and eye, and judgment in the control of the process of construction. But judgment necessitates knowledge of those natural

processes of which the manufacture is the utilisation. Thus somewhere in technical training an education in scientific knowledge is required. If you minimise the scientific side, you will confine it to the scientific experts; if you maximise it, you will impart it in some measure to the men, and--what is of no less importance--to the directors and managers of the businesses.

Technical education is not necessarily allied exclusively to science on its mental side. It may be an education for an artist or for apprentices to an artistic craft. In that case æsthetic appreciation will have to be cultivated in connection with it.

An evil side of the Platonic culture has been its total neglect of technical education as an ingredient in the complete development of ideal human beings. This neglect has arisen from two disastrous antitheses, namely, that between mind and body, and that between thought and action. I will here interject, solely to avoid criticism, that I am well aware that the Greeks highly valued physical beauty and physical activity. They had, however, that perverted sense of values which is the nemesis of slave-owning.

I lay it down as an educational axiom that in teaching you will come to grief as soon as you forget that your pupils have bodies. This is exactly the mistake of the post-renaissance Platonic curriculum. But nature can be kept at bay by no pitchfork; so in English education, being expelled from the classroom, she returned with a cap and bells in the form of all-conquering athleticism.

The connections between intellectual activity and the body, though diffused in every bodily feeling, are focussed in the eyes, the ears, the voice, and the hands. There is a co-ordination of senses and thought, and also a reciprocal influence between brain activity and material creative activity. In this reaction the hands are peculiarly important. It is a moot point whether the human hand created the human brain, or the brain created the hand. Certainly the connection is intimate and reciprocal. Such deep-seated relations are not widely atrophied by a few hundred years of disuse in exceptional families.

The disuse of hand-craft is a contributory cause to the brain-lethargy of aristocracies, which is only mitigated by sport where the concurrent brain-activity is reduced to a minimum and the hand-craft lacks subtlety. The necessity for constant writing and vocal exposition is some slight stimulus to the thought-power of the professional classes. Great readers, who exclude other activities, are not distinguished by subtlety of brain. They tend to be timid conventional thinkers. No doubt this is partly due to their excessive knowledge outrunning their powers of thought; but it is partly due to the lack of brain-stimulus from the productive activities of hand or voice.

In estimating the importance of technical education we must rise above the exclusive association of learning with book-learning. First-hand knowledge is the ultimate basis of intellectual life. To a large extent book-learning conveys second-hand information, and as such can never rise to the importance of immediate practice. Our goal is to see the immediate event of our lives as instances of our general ideas. What the learned world tends to offer is one second-hand scrap of information illustrating ideas derived from another second-hand scrap of information. The second-handedness of the learned world is the secret of its mediocrity. It is tame because it has never been scared by facts. The main importance of Francis Bacon's influence does not lie in any peculiar theory of inductive reasoning which he happened to express, but in the revolt against second-hand information of which he was a leader.

The peculiar merit of a scientific education should be, that it bases thought upon first-hand observation; and the corresponding merit of a technical education is, that it follows our deep natural instinct to translate thought into manual skill, and manual activity into thought.

We are a Mathematical Association, and it is natural to ask: Where do we come in? We come in just at this point.

The thought which science evokes is logical thought. Now logic is of two kinds: the logic of discovery and the logic of the discovered.

The logic of discovery consists in the weighing of probabilities, in discarding details deemed to be irrelevant, in divining the general rules according to which events occur, and in testing hypotheses by devising suitable experiments. This is inductive logic.

The logic of the discovered is the deduction of the special events which, under certain circumstances, would happen in obedience to the assumed laws of nature. Thus when the laws are discovered or assumed, their utilisation entirely depends on deductive logic. Without deductive logic science would be entirely useless. It is merely a barren game to ascend from the particular to the general, unless afterwards we can reverse the process and descend from the general to the particular, ascending and descending like the angels on Jacob's ladder. When Newton had divined the law of gravitation he at once proceeded to calculate the earth's attractions on an apple at its surface and on the moon. We may note in passing that inductive logic would be impossible without

deductive logic. Thus Newton's calculations were an essential step in his inductive verification of the great law.

Now mathematics is nothing else than the more complicated parts of the art of deductive reasoning, especially where it concerns number, quantity, and space.

In the teaching of science, the art of thought should be taught: namely, the art of forming clear conceptions applying to first-hand experience, the art of divining the general truths which apply, the art of testing divinations, and the art of utilising general truths by reasoning to more particular cases of some peculiar importance. Furthermore, a power of scientific exposition is necessary, so that the relevant issues from a confused mass of ideas can be stated clearly, with due emphasis on important points.

By the time a science, or a small group of sciences, has been taught thus amply, with due regard to the general art of thought, we have gone a long way towards correcting the specialism of science. The worst of a scientific education based, as necessarily must be the case, on one or two particular branches of science, is that the teachers under the influence of the examination system are apt merely to stuff their pupils with the narrow results of these special sciences. It is essential that the generality of the method be continually brought to light and contrasted with the speciality of the particular application. A man who only knows his own science, as a routine peculiar to that science, does not even know that. He has no fertility of thought, no power of quickly seizing the bearing of alien ideas. He will discover nothing, and be stupid in practical applications.

This exhibition of the general in the particular is extremely difficult to effect, especially in the case of younger pupils. The art of education is never easy. To surmount its difficulties, especially those of elementary education, is a task worthy of the highest genius. It is the training of human souls.

Mathematics, well taught, should be the most powerful instrument in gradually implanting this generality of idea. The essence of mathematics is perpetually to be discarding more special ideas in favour of more general ideas, and special methods in favour of general methods. We express the conditions of a special problem in the form of an equation, but that equation will serve for a hundred other problems, scattered through diverse sciences. The general reasoning is always the powerful reasoning, because deductive cogency is the property of abstract form.

Here, again, we must be careful. We shall ruin mathematical education if we use it merely to impress general truths. The general ideas are the means of connecting particular results. After all, it is the concrete special cases which are important. Thus in the handling of mathematics in your results you cannot be too concrete, and in your methods you cannot be too general. The essential course of reasoning is to generalise what is particular, and then to particularise what is general. Without generality there is no reasoning, without concreteness there is no importance.

Concreteness is the strength of technical education. I would remind you that truths which lack the highest generality are not necessarily concrete facts. For example, _x_ + _y_ = _y_ + _x_ is an algebraic truth more general than 2 + 2 = 4. But "two and two make four" is itself a highly general proposition lacking any element of concreteness. To obtain a concrete proposition immediate intuition of a truth concerning particular objects is requisite; for example, "these two apples and those apples together make four apples" is a concrete proposition, if you have direct perception or immediate memory of the apples.

In order to obtain the full realisation of truths as applying, and not as empty formulæ, there is no alternative to technical education. Mere passive observation is not sufficient. In creation only is there vivid insight into the properties of the object thereby produced. If you want to understand anything, make it yourself, is a sound rule. Your faculties will be alive, your thoughts gain vividness by an immediate translation into acts. Your ideas gain that reality which comes from seeing the limits of their application.

In elementary education this doctrine has long been put into practice. Young children are taught to familiarise themselves with shapes and colours by simple manual operations of cutting out and of sorting. But good though this is, it is not quite what I mean. That is practical experience before you think, experience antecedent to thought in order to create ideas, a very excellent discipline. But technical education should be much more than that: it is creative experience while you think, experience which realises your thought, experience which teaches you to co-ordinate act and thought, experience leading you to associate thought with foresight and foresight with achievement. Technical education gives theory, and a shrewd insight as to where theory fails.

A technical education is not to be conceived as a maimed alternative to the perfect Platonic culture: namely, as a defective training unfortunately made necessary by cramped conditions of life. No human being can attain to anything but fragmentary knowledge and a fragmentary training of his capacities. There are, however, three main roads along which we can proceed with good hope of advancing towards the best balance of intellect and character: these are the way of literary culture, the way of scientific culture, the

way of technical culture. No one of these methods can be exclusively followed without grave loss of intellectual activity and of character. But a mere mechanical mixture of the three curricula will produce bad results in the shape of scraps of information never interconnected or utilised. We have already noted as one of the strong points of the traditional literary culture that all its parts are co-ordinated. The problem of education is to retain the dominant emphasis, whether literary, scientific, or technical, and without loss of co-ordination to infuse into each way of education something of the other two.

To make definite the problem of technical education fix attention on two ages: one thirteen, when elementary education ends; and the other seventeen, when technical education ends so far as it is compressed within a school curriculum. I am aware that for artisans in junior technical schools a three-years' course would be more usual. On the other hand, for naval officers, and for directing classes generally, a longer time can be afforded. We want to consider the principles to govern a curriculum which shall land these children at the age of seventeen in the position of having technical skill useful to the community.

Their technical manual training should start at thirteen, bearing a modest proportion to the rest of their work, and should increase in each year finally to attain to a substantial proportion. Above all things it should not be too specialised. Workshop finish and workshop dodges, adapted to one particular job, should be taught in the commercial workshop, and should form no essential part of the school course. A properly trained worker would pick them up in no time. In all education the main cause of failure is staleness. Technical education is doomed if we conceive it as a system for catching children young and for giving them one highly specialised manual aptitude. The nation has need of a fluidity of labour, not merely from place to place, but also within reasonable limits of allied aptitudes, from one special type of work to another special type. I know that here I am on delicate ground, and I am not claiming that men while they are specialising on one sort of work should spasmodically be set to other kinds. That is a question of trade organisation with which educationalists have no concern. I am only asserting the principles that training should be broader than the ultimate specialisation, and that the resulting power of adaptation to varying demands is advantageous to the workers, to the employers, and to the nation.

In considering the intellectual side of the curriculum we must be guided by the principle of the co-ordination of studies. In general, the intellectual studies most immediately related to manual training will be some branches of science. More than one branch will, in fact, be concerned; and even if that be not the case, it is impossible to narrow down scientific study to a single thin line of thought. It is possible, however, provided that we do not press the classification too far, roughly to classify technical pursuits according to the dominant science involved. We thus find a sixfold division, namely, (1) Geometrical techniques, (2) Mechanical techniques, (3) Physical techniques, (4) Chemical techniques, (5) Biological techniques, (6) Techniques of commerce and of social service.

By this division, it is meant that apart from auxiliary sciences some particular science requires emphasis in the training for most occupations. We can, for example, reckon carpentry, ironmongery, and many artistic crafts among geometrical techniques. Similarly agriculture is a biological technique. Probably cookery, if it includes food catering, would fall midway between biological, physical, and chemical sciences, though of this I am not sure.

The sciences associated with commerce and social service would be partly algebra, including arithmetic and statistics, and partly geography and history. But this section is somewhat heterogeneous in its scientific affinities. Anyhow the exact way in which technical pursuits are classified in relation to science is a detail. The essential point is, that with some thought it is possible to find scientific courses which illuminate most occupations. Furthermore, the problem is well understood, and has been brilliantly solved in many of the schools of technology and junior technical schools throughout the country.

In passing from science to literature, in our review of the intellectual elements of technical education, we note that many studies hover between the two: for example, history and geography. They are both of them very essential in education, provided that they are the right history and the right geography. Also books giving descriptive accounts of general results, and trains of thought in various sciences fall in the same category. Such books should be partly historical and partly expository of the main ideas which have finally arisen. Prof. R. A. Gregory's recent book, _Discovery_, and the _Home University Library_ series illustrate my meaning. Their value in education depends on their quality as mental stimulants. They must not be inflated with gas on the wonders of science, and must be informed with a broad outlook.

It is unfortunate that the literary element in education has rarely been considered apart from grammatical study. The historical reason is, that when the modern Platonic curriculum was being formed Latin and Greek were the sole keys which rendered great literature accessible. But there is no necessary connection between literature and grammar. The great age of Greek literature was already past before the arrival of the grammarians of Alexandria. Of all types of men to-day existing, classical scholars are the most

remote from the Greeks of the Periclean times.

Mere literary knowledge is of slight importance. The only thing that matters is, how it is known. The facts related are nothing. Literature only exists to express and develop that imaginative world which is our life, the kingdom which is within us. It follows that the literary side of a technical education should consist in an effort to make the pupils enjoy literature. It does not matter what they know, but the enjoyment is vital. The great English Universities, under whose direct authority school-children are examined in plays of Shakespeare, to the certain destruction of their enjoyment, should be prosecuted for soul-murder.

Now there are two kinds of intellectual enjoyment: the enjoyment of creation, and the enjoyment of relaxation. They are not necessarily separated. A change of occupation may give the full tide of happiness which comes from the concurrence of both forms of pleasure. The appreciation of literature is really creation. The written word, its music, and its associations, are only the stimuli. The vision which they evoke is our own doing. No one, no genius other than our own, can make our own life live. But except for those engaged in literary occupations, literature is also a relaxation. It gives exercise to that other side which any occupation must suppress during the working hours. Art also has the same function in life as has literature.

To obtain the pleasure of relaxation requires no help. The pleasure is merely to cease doing. Some such pure relaxation is a necessary condition of health. Its dangers are notorious, and to the greater part of the necessary relaxation nature has affixed, not enjoyment, but the oblivion of sleep. Creative enjoyment is the outcome of successful effort and requires help for its initiation. Such enjoyment is necessary for high-speed work and for original achievement.

To speed up production with unrefreshed workmen is a disastrous economic policy. Temporary success will be at the expense of the nation, which, for long years of their lives, will have to support worn-out artisans--unemployables. Equally disastrous is the alternation of spasms of effort with periods of pure relaxation. Such periods are the seed-times of degeneration, unless rigorously curtailed. The normal recreation should be change of activity, satisfying the cravings of instincts. Games afford such activity. Their disconnection emphasises the relaxation, but their excess leaves us empty.

It is here that literature and art should play an essential part in a healthily organised nation. Their services to economic production would be only second to those of sleep or of food. I am not now talking of the training of an artist, but of the use of art as a condition of healthy life. It is analogous to sunshine in the physical world.

When we have once rid our minds of the idea that knowledge is to be exacted, there is no especial difficulty or expense involved in helping the growth of artistic enjoyment. All school-children could be sent at regular intervals to neighbouring theatres where suitable plays could be subsidised. Similarly for concerts and cinema films. Pictures are more doubtful in their popular attraction; but interesting representations of scenes or ideas which the children have read about would probably appeal. The pupils themselves should be encouraged in artistic efforts. Above all the art of reading aloud should be cultivated. The Roger de Coverley essays of Addison are perfect examples of readable prose.

Art and literature have not merely an indirect effect on the main energies of life. Directly, they give vision. The world spreads wide beyond the deliverances of material sense, with subtleties of reaction and with pulses of emotion. Vision is the necessary antecedent to control and to direction. In the contest of races which in its final issues will be decided in the workshops and not on the battle-field, the victory will belong to those who are masters of stores of trained nervous energy, working under conditions favourable to growth. One such essential condition is Art.

If there had been time, there are other things which I should like to have said: for example, to advocate the inclusion of one foreign language in all education. From direct observation I know this to be possible for artisan children. But enough has been put before you, to make plain the principles with which we should undertake national education.

In conclusion, I recur to the thought of the Benedictines, who saved for mankind the vanishing civilisation of the ancient world by linking together knowledge, labour, and moral energy. Our danger is to conceive practical affairs as the kingdom of evil, in which success is only possible by the extrusion of ideal aims. I believe that such a conception is a fallacy directly negatived by practical experience. In education this error takes the form of a mean view of technical training. Our forefathers in the dark ages saved themselves by embodying high ideals in great organisations. It is our task, without servile imitation, boldly to exercise our creative energies, remembering amid discouragements that the coldest hour immediately precedes the dawn.

FOOTNOTES:

[Footnote 1: _Cf._ BERNARD SHAW: _John Bull's Other Island_.]

CHAPTER III

A POLYTECHNIC IN WAR-TIME

Address at the Prize Distribution, Borough Polytechnic Institute, Southwark, 16th February, 1917

I WILL commence by drawing your attention to some of the satisfactory features of the Principal's report on the work of the Institute during the past year. It has been a year of great difficulties. Some of our staff are serving with the colours, and our classes have been depleted. But in spite of everything, we have done very well. First, the average result in the examinations has been good, surprisingly good in view of the present circumstances. The Governors attach great importance to the maintenance of a high average result; it is the best single test of efficiency. Again, our individual successes have been notable. We have gained--I say _we_ because we are all one in our pleasure at these successes--we have gained two £80 L.C.C. scholarships, nineteen exhibitions, in addition to a first-place, and medals, prizes and certificates. All this is very satisfactory. It tells of efficient teaching, and of hard work and regular attendance on the part of the students. We know that we are keeping up the standard of efficiency which in the past has been a source of pride to every one connected with this Institute.

Now all this good work does not come about by itself without any one making an effort. Such a record requires our skilled staff of teachers and organisers. They have worked very hard during the last session under great difficulties, in order to create the successful result which we are here to celebrate. I know something about teaching. It is very exacting work, and can be made successful only by continual devotion. I am sure that I am voicing your feelings, and I know that I am expressing those of the Governors, when I thank the ladies and gentlemen of the staff very heartily for their services during the last session.

Prize-givings are always pleasant occasions. We have come here to think about our successes, and to congratulate our students. There is no more satisfactory Governors' Meeting in the course of the year than when we meet on this occasion, and face our friends and tell them how pleased we are at the successful result of their hard work. This evening I am in a doubly happy position, for my colleagues have asked me to be their spokesman in tendering our good wishes to the prize-winners. You have worked hard and you have done well, and I am sure that you all deserve your successes; they are a pleasure not only to you, but in your homes and to your companions and fellow-students.

Successful work here will enable you to acquire skill in your trades, and thereby the better to earn your living. Earning a living is on the average no bad test of service rendered to the community. A man who has made himself skilful in his trade and has done well for himself in his walk of life, has in general good reason to believe that he is a citizen who has benefited his country. It is an evil day for a nation when it loses respect for success in industry.

But if you steer your lives by the compass which points steadily to the North Pole of personal success, you will have missed your greatest chances in life. The genial climate is in the south.

What I mean is this: you must make up your mind to find the best part of your happiness in kindly helpful relations with others. It should be our ambition to leave our own small corner of the world a little tidier and a little happier than when we entered it. I am well aware that this is an old story; but old stories are sometimes true, and this is the biggest truth in the whole world. The warm kindly feelings are the happy feelings. The fortunate people are those whose minds are filled with thoughts in which they forget themselves and remember others. It is not true that nature is a mere scene of struggle in which every one competes with his neighbour. Those communities thrive best and last longest which are filled with a spirit of mutual help.

The future of the country lies with you. The crown of your success is the promise of future work, often unrecognised work, done under discouragement, but done steadily and cheerfully. It is on you that the country depends for the maintenance and the growth of those ideals without which a race withers. Do not be discouraged by difficulties which seem unsurmountable. The conditions of life which mould us all are modified by our will, by our energy, and by the purity of our intentions.

If we may judge of intensity of feeling by length of memory, the enjoyment of receiving a prize bites very deep. Across the space of more than forty years, before many of your parents were born, or when they were being carried about in long clothes, I can remember, as if it were yesterday, the occasion when I received my first prize at school. I can see the mediæval school-room, the headmaster, and my companions. Perhaps some of you, when a generation has passed by, will remember the scene to-night--this Stanley Gymnasium recalling the memory of Miss Maude Stanley, who devoted to our welfare so much of her energy and her

thought--the adjoining Edric Hall associated with the name of Mr. Edric Bayley, the Father of the Institute; Mr. Millis and Miss Smith, the first Principal and the first Lady Superintendent, the architects of our prosperity; Mr. Leonard Spicer, our Chairman and member of a family and of a firm known throughout the world, and respected in proportion as they are known. And the cause why to-night we are a small gathering is one more reason why this assembly can never slip from your memory. We meet at a moment when England stands in as deadly a peril as in any previous moment of her history--such peril as when the Spanish ships of the Armada rode in the English Channel, or when Napoleon watched our coast across the Strait of Dover. The present danger can be overcome only by the same courage as that which saved our freedom in those former times.

Therefore, to-night, in recalling the activities of the various sections of our society which form this great Polytechnic Institute, our thoughts go further afield. They travel by land and by sea, till they bring before our minds the gallant band whom this Institute has sent to the Front--more than 800 of our members are with the Colours. What our fighting men have done for us, for the world in general, and for the future of England, is so overwhelming that words cannot praise them enough. I will just say one thing to you: When you read of great deeds done in past times, of perils encountered, of adventures, of undaunted courage, of patriotism, of self-sacrifice, of suffering endured for noble cause, you each can say--I, too, have known such heroes; they are among my countrymen, they are among my fellow-workers, they are among my fellow-students and companions, they are among the dear inmates of my home. And for those who have fallen, it is for us to erect a monument sufficient to transmit to future ages the memory of their sacrifice. For this purpose there is only one memorial which can suffice, namely, the cause for which they died. The greatness of England, the future of England, has been left by them to our keeping. Guard it well.

The greatness of a country is nothing else than the greatness of the lives of the men and of the women who compose it. Do not look round and think who ought to be great Englishmen--be great yourselves--you are the people to achieve it, you who are sitting here to-night. There can be no substitute service for this purpose. It is the collective energy of the whole people that will be needed to fashion a new England worthy of the sufferings which for its sake have been endured.

A few days ago I asked a man who has worked in Egypt for many years under Lord Kitchener, what he would pick out as the best sign of Lord Kitchener's greatness. He answered, whatever Kitchener set himself to do, thereby became important. Now that is the secret of it all--take hold of your opportunities and make them important.

Here we are in this Borough Polytechnic. What an opportunity it represents. This Institute is a centre for social meeting, a centre for recreation, a centre for education, a centre for discussion. We will not sacrifice any one of our sides. They must all be part of the greatness which we claim. Make them all first-rate.

Consider first the social and recreative sides. For heaven's sake don't think that you must be dull in order to be great. There is no finer test of a nation than the way in which it fashions its amusements. Three centuries ago after the Armada we made a good start in Southwark. Shakespeare had his theatre here and wrote his plays to be acted in this borough. He has walked these streets, and if you had met him in Westminster he would, quite likely, have told you that he was going down to the "Elephant." And even now the performances given at the "Old Vic" are among the best in London for the purpose of seeing his plays properly acted. What Southwark has done for the drama, she can do for the other arts, by using this Institute as the instrument for her energies. Why should we not be a centre for artistic enterprise--I mean for our own art and our own enterprise, thought of by ourselves and enjoyed by ourselves and carried through by ourselves? We shall not always enjoy each others' creations, but the great point is to make our own efforts. Of course all efforts require preparation and stimulus and knowledge of what others are doing.

At the present time--interrupted for the moment by the war--a great revolution in the art of painting is in progress throughout the world. Its centres are Paris and Italy and London and Munich, and its origin in the far east, in China and Japan. There are two sides as in every revolution, the Conservatives and the Revolutionists. Our own frescoes in a neighbouring room represent an early stage of the movement in London. Why should we not know all about it--obtain loans of pictures which illustrate its phases and its cross currents, and compare these with examples of the old style?

But pictures are only one phase of art, and not the sort of art which we ourselves can produce most easily. There are music, dancing, recitation, literature, carving and modelling, and the various decorative arts, such as embroidery, bookbinding, dress-making and upholstery. This list, incomplete as it is, tells us two great truths--you cannot separate art and recreation, and you cannot separate art and business. The list includes items which we consider as amusements, and items which we think of as business. We began with dancing and ended with upholstery. Make them all beautiful.

Beautiful things have dignity. Enjoy the rhythm of your dancing and admire the beauty of your embroidery or your bookbinding. In whatever you do, have an ideal of excellence. Any separation between art and work is not only an error, but it is very bad business. Our brave allies, the French, have made Paris the art centre of the world. They have built up and maintain their large and lucrative trade in the decorative products of France, mainly by reason of three qualities which they possess. In the first place, they enjoy art themselves, and reverence it. In the second place, they have a tremendous power of hard work. And in the third place, every Frenchman, and still more every Frenchwoman, have within them an immense fund of common sense. The threefold secret is, Love of Art, Industry, and Common Sense.

To make available our industry and common sense in the trades where they are wanted, rigorous training in schools of design and technique are necessary. We have such departments here. But all such training of you will be a failure unless you yourselves enjoy art and beauty as a natural recreation. A technical school of training is like a deep, narrow well, sunk with careful labour to tap the underground river of water which flows below the surface of our natures. But your well will be dry unless the bright warm sun has first drawn up the vapour from the wide ocean, and the free untrammelled breezes have carried the clouds hither and thither, until at length they break, as it were by chance over the distant hills and soak the land with their downpour.

What I have said about art is a parable which applies to other occupations and other studies. It is more than a parable; it is the literal truth. The love of art is the love of excellence, it is the enjoyment of the triumph of design over the shapeless products of chance forces. An engineer, who is worth his salt, loves the beauty of his machines, shown in their adjustment of parts and in their swift, smooth motions. He loves also the sense of foresight and of insight which knowledge can give him. People say that machinery and commerce are driving beauty out of the modern world. I do not believe it. A new beauty is being added, a more intellectual beauty, appealing to the understanding as much as to the eye.

The wonder of London ever takes the mind with fresh astonishment. The city possesses parks, and palaces, and cathedrals. But no other parts of it surpass in wonder its houses of business and its workshops and its factories.

In the next few years the future of the world will be decided for centuries to come. The battles of this war are only the first part of the contest between races, and between the ways of life for which those races stand. We believe that England, with its various peoples and communities scattered in islands and continents beyond the seas, stands for ways of life infinitely precious, the way of humanity, the way of liberty, the way of self-government, the way of good order based on toleration and kindly feeling, the way of peaceful industry. The final decision in this struggle will be found in the workshops of the world. It lies in your hands. Statesmen and emperors will only register the results which you have achieved. Your weapons will be skill, and energy, and knowledge. You will require a sane understanding of your own rights, and a sane understanding of the rights and the difficulties of other classes. The greatness of England will be your greatness, and its success your success.

The arsenal for war is at Woolwich. This Polytechnic Institute is an arsenal for peace, where you can find the weapons for the conquest of your lives.

CHAPTER IV

THE MATHEMATICAL CURRICULUM

(_Presidential Address to the London Branch of the Mathematical Association, 1912_)

THE situation in regard to education at the present time cannot find its parallel without going back for some centuries to the break-up of the mediæval traditions of learning. Then, as now, the traditional intellectual outlook, despite the authority which it had justly acquired from its notable triumphs, had grown to be too narrow for the interests of mankind. The result of this shifting of human interest was a demand for a parallel shifting of the basis of education, so as to fit the pupils for the ideas which later in life would in fact occupy their minds. Any serious fundamental change in the intellectual outlook of human society must necessarily be followed by an educational revolution. It may be delayed for a generation by vested interests or by the passionate attachment of some leaders of thought to the cycle of ideas within which they received their own mental stimulus at an impressionable age. But the law is inexorable that education to be living and effective must be directed to informing pupils with those ideas, and to creating for them those capacities which will enable them to appreciate the current thought of their epoch.

There is no such thing as a successful system of education in a vacuum, that is to say, a system which is divorced from immediate contact with the existing intellectual atmosphere. Education which is not modern shares the fate of all organic things which are kept

too long.

But the blessed word "modern" does not really solve our difficulties. What we mean is, relevant to modern thought, either in the ideas imparted or in the aptitudes produced. Something found out only yesterday may not really be modern in this sense. It may belong to some bygone system of thought prevalent in a previous age, or, what is very much more likely, it may be too recondite. When we demand that education should be relevant to modern thought, we are referring to thoughts broadly spread throughout cultivated society. It is this question of the unfitness of recondite subjects for use in general education which I wish to make the keynote of my address this afternoon.

It is in fact rather a delicate subject for us mathematicians. Outsiders are apt to accuse our subject of being recondite. Let us grasp the nettle at once and frankly admit that in general opinion it is the very typical example of reconditeness. By this word I do not mean difficulty, but that the ideas involved are of highly special application, and rarely influence thought.

This liability to reconditeness is the characteristic evil which is apt to destroy the utility of mathematics in liberal education. So far as it clings to the educational use of the subject, so far we must acquiesce in a miserably low level of mathematical attainment among cultivated people in general. I yield to no one in my anxiety to increase the educational scope of mathematics. The way to achieve this end is not by a mere blind demand for more mathematics. We must face the real difficulty which obstructs its extended use.

Is the subject recondite? Now, viewed as a whole, I think it is. _Securus judicat orbis terrarum_--the general judgment of mankind is sure.

The subject as it exists in the minds and in the books of students of mathematics _is_ recondite. It proceeds by deducing innumerable special results from general ideas, each result more recondite than the preceding. It is not my task this afternoon to defend mathematics as a subject for profound study. It can very well take care of itself. What I want to emphasise is, that the very reasons which make this science a delight to its students are reasons which obstruct its use as an educational instrument--namely, the boundless wealth of deductions from the interplay of general theorems, their complication, their apparent remoteness from the ideas from which the argument started, the variety of methods, and their purely abstract character which brings, as its gift, eternal truth.

Of course, all these characteristics are of priceless value to students; for ages they have fascinated some of the keenest intellects. My only remark is that, except for a highly selected class, they are fatal in education. The pupils are bewildered by a multiplicity of detail, without apparent relevance either to great ideas or to ordinary thoughts. The extension of this sort of training in the direction of acquiring more detail is the last measure to be desired in the interests of education.

The conclusion at which we arrive is, that mathematics, if it is to be used in general education, must be subjected to a rigorous process of selection and adaptation. I do not mean, what is of course obvious, that however much time we devote to the subject the average pupil will not get very far. But that, however limited the progress, certain characteristics of the subject, natural at any stage, must be rigorously excluded. The science as presented to young pupils must lose its aspect of reconditeness. It must, on the face of it, deal directly and simply with a few general ideas of far-reaching importance.

Now, in this matter of the reform of mathematical instruction, the present generation of teachers may take a very legitimate pride in its achievements. It has shown immense energy in reform, and has accomplished more than would have been thought possible in so short a time. It is not always recognised how difficult is the task of changing a well-established curriculum entrenched behind public examinations.

But for all that, great progress has been made, and, to put the matter at its lowest, the old dead tradition has been broken up. I want to indicate this afternoon the guiding idea which should direct our efforts at reconstruction. I have already summed it up in a phrase, namely, we must aim at the elimination of reconditeness from the educational use of the subject.

Our courses of instruction should be planned to illustrate simply a succession of ideas of obvious importance. All pretty divagations should be rigorously excluded. The goal to be aimed at is that the pupil should acquire familiarity with abstract thought, should realise how it applies to particular concrete circumstances, and should know how to apply general methods to its logical investigation. With this educational ideal nothing can be worse than the aimless accretion of theorems in our text-books, which acquire their position merely because the children can be made to learn them and examiners can set neat questions on them. The bookwork to be learnt should all be very important as illustrating ideas. The examples set--and let there be as many examples as teachers find necessary--should be direct illustrations of the theorems, either by way of abstract particular cases or by way of

application to concrete phenomena. Here it is worth remarking that it is quite useless to simplify the bookwork, if the examples set in examinations in fact require an extended knowledge of recondite details. There is a mistaken idea that problems test ability and genius, and that bookwork tests cram. This is not my experience. Only boys who have been specially crammed for scholarships can ever do a problem paper successfully. Bookwork properly set, not in mere snippets according to the usual bad plan, is a far better test of ability, provided that it is supplemented by direct examples. But this is a digression on the bad influence of examinations on teaching.

The main ideas which lie at the base of mathematics are not at all recondite. They are abstract. But one of the main objects of the inclusion of mathematics in a liberal education is to train the pupils to handle abstract ideas. The science constitutes the first large group of abstract ideas which naturally occur to the mind in any precise form. For the purposes of education, mathematics consists of the relations of number, the relations of quantity, and the relations of space. This is not a general definition of mathematics, which, in my opinion, is a much more general science. But we are now discussing the use of mathematics in education. These three groups of relations, concerning number, quantity, and space, are interconnected.

Now, in education we proceed from the particular to the general. Accordingly, children should be taught the use of these ideas by practice among simple examples. My point is this: The goal should be, not an aimless accumulation of special mathematical theorems, but the final recognition that the preceding years of work have illustrated those relations of number, and of quantity, and of space, which are of fundamental importance. Such a training should lie at the base of all philosophical thought. In fact elementary mathematics rightly conceived would give just that philosophical discipline of which the ordinary mind is capable. But what at all costs we ought to avoid, is the pointless accumulation of details. As many examples as you like; let the children work at them for terms, or for years. But these examples should be direct illustrations of the main ideas. In this way, and this only, can the fatal reconditeness be avoided.

I am not now speaking in particular of those who are to be professional mathematicians, or of those who for professional reasons require a knowledge of certain mathematical details. We are considering the liberal education of all students, including these two classes. This general use of mathematics should be the simple study of a few general truths, well illustrated by practical examples. This study should be conceived by itself, and completely separated in idea from the professional study mentioned above, for which it would make a most excellent preparation. Its final stage should be the recognition of the general truths which the work done has illustrated. As far as I can make out, at present the final stage is the proof of some property of circles connected with triangles. Such properties are immensely interesting to mathematicians. But are they not rather recondite, and what is the precise relation of such theorems to the ideal of a liberal education? The end of all the grammatical studies of the student in classics is to read Virgil and Horace--the greatest thoughts of the greatest men. Are we content, when pleading for the adequate representation in education of our own science, to say that the end of a mathematical training is that the student should know the properties of the nine-point circle? I ask you frankly, is it not rather a "come down"?

This generation of mathematical teachers has done so much strenuous work in the way of reorganising mathematical instruction that there is no need to despair of its being able to elaborate a curriculum which shall leave in the minds of the pupils something even nobler than "the ambiguous case."

Let us think how this final review, closing the elementary course, might be conducted for the more intelligent pupils. Partly no doubt it requires a general oversight of the whole work done, considered without undue detail so as to emphasise the general ideas used, and their possibilities of importance when subjected to further study. Also the analytical and geometrical ideas find immediate application in the physical laboratory where a course of simple experimental mechanics should have been worked through. Here the point of view is twofold, the physical ideas and the mathematical ideas illustrate each other.

The mathematical ideas are essential to the precise formulation of the mechanical laws. The idea of a precise law of nature, the extent to which such laws are in fact verified in our experience, and the rôle of abstract thought in their formulation, then become practically apparent to the pupil. The whole topic of course requires detailed development with full particular illustration, and is not suggested as requiring merely a few bare abstract statements.

It would, however, be a grave error to put too much emphasis on the mere process of direct explanation of the previous work by way of final review. My point is, that the latter end of the course should be so selected that in fact the general ideas underlying all the previous mathematical work should be brought into prominence. This may well be done by apparently entering on a new subject. For example, the ideas of quantity and the ideas of number are fundamental to all precise thought. In the previous stages

they will not have been sharply separated; and children are, rightly enough, pushed on to algebra without too much bother and quantity. But the more intelligent among them at the end of their curriculum would gain immensely by a careful consideration of those fundamental properties of quantity in general which lead to the introduction of numerical measurement. This is a topic which also has the advantage that the necessary books are actually to hand. Euclid's fifth book is regarded by those qualified to judge as one of the triumphs of Greek mathematics. It deals with this very point. Nothing can be more characteristic of the hopelessly illiberal character of the traditional mathematical education than the fact that this book has always been omitted. It deals with ideas, and therefore was ostracised. Of course a careful selection of the more important propositions and a careful revision of the argument are required. This also is to hand in the publications of my immediate predecessor in the office of president, Prof. Hill. Furthermore, in Sir T. L. Heath's complete edition of Euclid, there is a full commentary embodying most of what has been said and thought on the point. Thus it is perfectly easy for teachers to inform themselves generally on the topic. The whole book would not be wanted, but just the few propositions which embody the fundamental ideas. The subject is not fit for backward pupils; but certainly it could be made interesting to the more advanced class. There would be great scope for interesting discussion as to the nature of quantity, and the tests which we should apply to ascertain when we are dealing with quantities. The work would not be at all in the air, but would be illustrated at every stage by reference to actual examples of cases where the quantitative character is absent, or obscure, or doubtful, or evident. Temperature, heat, electricity, pleasure and pain, mass and distance could all be considered.

Another idea which requires illustration is that of functionality. A function in analysis is the counterpart of a law in the physical universe, and of a curve in geometry. Children have studied the relations of functions to curves from the first beginning of their study of algebra, namely in drawing graphs. Of recent years there has been a great reform in respect to graphs. But at its present stage it has either gone too far or not far enough. It is not enough merely to draw a graph. The idea behind the graph--like the man behind the gun--is essential in order to make it effective. At present there is some tendency merely to set the children to draw curves, and there to leave the whole question.

In the study of simple algebraic functions and of trigonometrical functions we are initiating the study of the precise expression of physical laws. Curves are another way of representing these laws. The simple fundamental laws--such as the inverse square and the direct distance--should be passed under review, and the applications of the simple functions to express important concrete cases of physical laws considered. I cannot help thinking that the final review of this topic might well take the form of a study of some of the main ideas of the differential calculus applied to simple curves. There is nothing particularly difficult about the conception of a rate of change; and the differentiation of a few powers of _x_, such as _x_^2, _x_^3, etc., could easily be effected; perhaps by the aid of geometry even sin _x_ and cos _x_ could be differentiated. If we once abandon our fatal habit of cramming the children with theorems which they do not understand, and will never use, there will be plenty of time to concentrate their attention on really important topics. We can give them familiarity with conceptions which really influence thought.

Before leaving this topic of physical laws and mathematical functions, there are other points to be noticed. The fact that the precise law is never really verified by observation in its full precision is capable of easy illustration and of affording excellent examples. Again, statistical laws, namely laws which are only satisfied on the average by large numbers, can easily be studied and illustrated. In fact a slight study of statistical methods and their application to social phenomena affords one of the simplest examples of the application of algebraic ideas.

Another way in which the students' ideas can be generalised is by the use of the History of Mathematics, conceived not as a mere assemblage of the dates and names of men, but as an exposition of the general current of thought which occasioned the subjects to be objects of interest at the time of their first elaboration. The use of the History of Mathematics is to be considered at a later stage of our proceedings this afternoon. Accordingly I merely draw attention to it now, to point out that perhaps it is the very subject which may best obtain the results for which I am pleading.

We have indicated two main topics, namely general ideas of quantity and of laws of nature, which should be an object of study in the mathematical curriculum of a liberal education. But there is another side to mathematics which must not be overlooked. It is the chief instrument for discipline in logical method.

Now, what is logical method, and how can any one be trained in it?

Logical method is more than the mere knowledge of valid types of reasoning and practice in the concentration of mind necessary to follow them. If it were only this, it would still be very important; for the human mind was not evolved in the bygone ages for the sake of reasoning, but merely to enable mankind with more art to hunt between meals for fresh food supplies. Accordingly few people

can follow close reasoning without considerable practice.

More than this is wanted to make a good reasoner, or even to enlighten ordinary people with knowledge of what constitutes the essence of the art. The art of reasoning consists in getting hold of the subject at the right end, of seizing on the few general ideas which illuminate the whole, and of persistently marshalling all subsidiary facts round them. Nobody can be a good reasoner unless by constant practice he has realised the importance of getting hold of the big ideas and of hanging on to them like grim death. For this sort of training geometry is, I think, better than algebra. The field of thought of algebra is rather obscure, whereas space is an obvious insistent thing evident to all. Then the process of simplification, or abstraction, by which all irrelevant properties of matter, such as colour, taste, and weight, are put aside is an education in itself. Again, the definitions and the propositions assumed without proof illustrate the necessity of forming clear notions of the fundamental facts of the subject-matter and of the relations between them. All this belongs to the mere prolegomena of the subject. When we come to its development, its excellence increases. The learner is not initially confronted with any symbolism which bothers the memory by its rules, however simple they may be. Also, from the very beginning the reasoning, if properly conducted, is dominated by well-marked ideas which guide each stage of development. Accordingly the essence of logical method receives immediate exemplification.

Let us now put aside for the moment the limitations introduced by the dullness of average pupils and the pressure on time due to other subjects, and consider what geometry has to offer in the way of a liberal education. I will indicate some stages in the subject, without meaning that necessarily they are to be studied in this exclusive order. The first stage is the study of _congruence_. Our perception of congruence is in practice dependent on our judgments of the invariability of the intrinsic properties of bodies when their external circumstances are varying. But however it arises, congruence is in essence the correlation of two regions of space, point by point, so that all homologous distances and all homologous angles are equal. It is to be noticed that the definition of the equality of lengths and angles is their congruence, and all tests of equality, such as the use of the yard measure, are merely devices for making immediate judgments of congruence easy. I make these remarks to suggest that apart from the reasoning connected with it, congruence, both as an example of a larger and very far-reaching idea and also for its own sake, is well worthy of attentive consideration. The propositions concerning it elucidate the elementary properties of the triangle, the parallelogram, and the circle, and of the relations of two planes to each other. It is very desirable to restrict the proved propositions of this part within the narrowest bounds, partly by assuming redundant axiomatic propositions, and partly by introducing only those propositions of absolutely fundamental importance.

The second stage is the study of similarity. This can be reduced to three or four fundamental propositions. Similarity is an enlargement of the idea of congruence, and, like that idea, is another example of a one-to-one correlation of points of spaces. Any extension of study of this subject might well be in the direction of the investigation of one or two simple properties of similar and similarly situated rectilinear figures. The whole subject receives its immediate applications in plans and maps. It is important, however, to remember that trigonometry is really the method by which the main theorems are made available for use.

The third stage is the study of the elements of trigonometry. This is the study of the periodicity introduced by rotation and of properties preserved in a correlation of similar figures. Here for the first time we introduce a slight use of the algebraic analysis founded on the study of number and quantity. The importance of the periodic character of the functions requires full illustration. The simplest properties of the functions are the only ones required for the solution of triangles, and the consequent applications to surveying. The wealth of formulæ, often important in themselves, but entirely useless for this type of study, which crowd our books should be rigorously excluded, except so far as they are capable of being proved by the pupils as direct examples of the bookwork.

This question of the exclusion of formulæ is best illustrated by considering this example of Trigonometry, though of course I may well have hit on an unfortunate case in which my judgment is at fault. A great part of the educational advantage of the subject can be obtained by confining study to Trigonometry of one angle and by exclusion of the addition formulæ for the sine and cosine of the sum of two angles. The functions can be graphed, and the solution of triangles effected. Thus the aspects of the science as (1) embodying analytically the immediate results of some of the theorems deduced from congruence and similarity, (2) as a solution of the main problem of surveying, (3) as a study of the fundamental functions required to express periodicity and wave motion, will all be impressed on the pupils' minds both by bookwork and example.

If it be desired to extend this course, the addition formulæ should be added. But great care should be taken to exclude specialising the pupils in the wealth of formulæ which comes in their train. By "exclude" is meant that the pupils should not have spent time or energy in acquiring any facility in their deduction. The teacher may find it interesting to work a few such examples before a class. But such results are not among those which learners need retain. Also, I would exclude the whole subject of circumscribed and

inscribed circles both from Trigonometry and from the previous geometrical courses. It is all very pretty, but I do not understand what its function is in an elementary non-professional curriculum.

Accordingly, the actual bookwork of the subject is reduced to very manageable proportions. I was told the other day of an American college where the students are expected to know by heart ninety formulæ or results in Trigonometry alone. We are not quite so bad as that. In fact, in Trigonometry we have nearly approached the ideal here sketched out as far as our elementary courses are concerned.

The fourth stage introduces Analytical Geometry. The study of graphs in algebra has already employed the fundamental notions, and all that is now required is a rigorously pruned course on the straight line, the circle, and the three types of conic sections, defined by the forms of their equations. At this point there are two remarks to be made. It is often desirable to give our pupils mathematical information which we do not prove. For example, in co-ordinate geometry, the reduction of the general equation of the second degree is probably beyond the capacities of most of the type of students whom we are considering. But that need not prevent us from explaining the fundamental position of conics, as exhausting the possible types of such curves.

The second remark is to advocate the entire sweeping away of geometrical conics as a separate subject. Naturally, on suitable occasions the analysis of analytical geometry will be lightened by the use of direct deduction from some simple figure. But geometrical conics, as developed from the definition of a conic section by the focus and directrix property, suffers from glaring defects. It is hopelessly recondite. The fundamental definition of a conic, _SP_ = _e_ · _PM_, usual in this subject at this stage, is thoroughly bad. It is very recondite, and has no obvious importance. Why should such curves be studied at all, any more than those defined by an indefinite number of other formulæ? But when we have commenced the study of the Cartesian methods, the equations of the first and second degrees are naturally the first things to think about.

In this ideal course of Geometry, the fifth stage is occupied with the elements of Projective Geometry. The general ideas of cross ratio and of projection are here fundamental. Projection is yet a more general instance of that one-to-one correlation which we have already considered under congruence and similarity. Here again we must avoid the danger of being led into a bewildering wealth of detail.

The intellectual idea which projective geometry is to illustrate is the importance in reasoning of the correlation of all cases which can be proved to possess in common certain identical properties. The preservation of the projective properties in projection is the one important educational idea of the subject. Cross ratio only enters as the fundamental metrical property which is preserved. The few propositions considered are selected to illustrate the two allied processes which are made possible by this procedure. One is proof by simplification. Here the simplification is psychological and not logical--for the general case is logically the simplest. What is meant is: Proof by considering the case which is in fact the most familiar to us, or the easiest to think about. The other procedure is the deduction of particular cases from known general truths, as soon as we have a means of discovering such cases or a criterion for testing them.

The projective definition of conic sections and the identity of the results obtained with the curves derived from the general equation of the second degree are capable of simple exposition, but lie on the border-line of the subject. It is the sort of topic on which information can be given, and the proofs suppressed.

The course of geometry as here conceived in its complete ideal--and ideals can never be realised--is not a long one. The actual amount of mathematical deduction at each stage in the form of bookwork is very slight. But much more explanation would be given, the importance of each proposition being illustrated by examples, either worked out or for students to work, so selected as to indicate the fields of thought to which it applies. By such a course the student would gain an analysis of the leading properties of space, and of the chief methods by which they are investigated.

The study of the elements of mathematics, conceived in this spirit, would constitute a training in logical method together with an acquisition of the precise ideas which lie at the base of the scientific and philosophical investigations of the universe. Would it be easy to continue the excellent reforms in mathematical instruction which this generation has already achieved, so as to include in the curriculum this wider and more philosophic spirit? Frankly, I think that this result would be very hard to achieve as the result of single individual efforts. For reasons which I have already briefly indicated, all reforms in education are very difficult to effect. But the continued pressure of combined effort, provided that the ideal is really present in the minds of the mass of teachers, can do much, and effects in the end surprising modification. Gradually the requisite books get written, still more gradually the examinations are reformed so as to give weight to the less technical aspects of the subject, and then all recent experience has shown that the

majority of teachers are only too ready to welcome any practicable means of rescuing the subject from the reproach of being a mechanical discipline.

CHAPTER V

THE PRINCIPLES OF MATHEMATICS IN RELATION TO ELEMENTARY TEACHING

(_International Congress of Mathematicians, Cambridge, August, 1912_)

WE are concerned not with the advanced teaching of a few specialist mathematical students, but with the mathematical education of the majority of boys in our secondary schools. Again these boys must be divided into two sections: one section consists of those who desire to restrict their mathematical education; the other section is made up of those who will require some mathematical training for their subsequent professional careers, either in the form of definite mathematical results or in the form of mathematically trained minds.

I shall call the latter of these two sections the mathematical section, and the former the non-mathematical section. But I must repeat that by the mathematical section is meant that large number of boys who desire to learn more than the minimum amount of mathematics. Furthermore, most of my remarks about these sections of boys apply also to elementary classes of our University students.

The subject of this paper is the investigation of the place which should be occupied by modern investigations respecting mathematical principles in the education of both of these sections of school-boys.

To find a foothold from which to start the inquiry, let us ask why the non-mathematical section should be taught any mathematics at all beyond the barest elements of arithmetic. What are the qualities of mind which a mathematical training is designed to produce when it is employed as an element in a liberal education?

My answer, which applies equally to both sections of students, is that there are two allied forms of mental discipline which should be acquired by a well-designed mathematical course. These two forms though closely allied are perfectly distinct.

The first form of discipline is not in its essence logical at all. It is the power of clearly grasping abstract ideas, and of relating them to particular circumstances. In other words, the first use of mathematics is to strengthen the power of abstract thought. I repeat that in its essence this has nothing to do with logic, though as a matter of fact a logical discipline is the best method of producing the desired effect. It is not the philosophical theory of abstract ideas which is to be acquired, but the habit and the power of using them. There is one and only way of acquiring the habit and the power of using anything, that is by the simple common-place method of habitually using it. There is no other short cut. If in education we desire to produce a certain conformation of mind, we must day by day, and year by year, accustom the students' minds to grow into the desired structural shape. Thus to teach the power of grasping abstract ideas and the habit of using them, we must select a group of such ideas, which are important and are also easy to think about because they are clear and definite.

The fundamental mathematical truths concerning geometry, ratio, quantity, and number, satisfy these conditions as do no others. Hence, the fundamental universal position held by mathematics as an element of a liberal education.

But what are the fundamental mathematical truths concerning geometry, quantity and number?

At this point we come to the great question of the relation between the modern science of the principles of mathematics and a mathematical education.

My answer to the question as to these fundamental mathematical truths is, that in any absolute sense there are none. There is no unique small body of independent primitive unproved propositions which are the necessary starting points of all mathematical reasoning on these subjects. In mathematical reasoning the only absolute necessary pre-suppositions are those which make logical deduction possible. Between these absolute logical truths and so-called fundamental truths concerning geometry, quantity and number, there is a whole new world of mathematical subjects concerning the logic of propositions, of classes, and of relations.

But this subject is too abstract to form an elementary training ground in the difficult art of abstract thought.

It is for this reason that we have to make a compromise and start from such obvious general ideas as naturally occur to all men when they perceive objects with their senses.

In geometry, the ideas elaborated by the Greeks and presented by Euclid are, roughly speaking, those adapted for our purpose, namely, ideas of volumes, surfaces, lines, of straightness and of curvature, of intersection and of congruence, of greater and less, of similarity, shape, and scale. In fact, we use in education those general ideas of spatial properties which must be habitually present in the mind of any one who is to observe the world of phenomena with understanding.

Thus we come back to Plato's opinion that for a liberal education, geometry, as he knew it, is the queen of sciences.

In addition to geometry, there remain the ideas of quantity, ratio, and of number. This in practice means, elementary algebra. Here the prominent ideas are those of "any number," in other words, the use of the familiar _x_, _y_, _z_, and of the dependence of variables on each other, or otherwise, the idea of functionality. All this is to be gradually acquired by the continual use of the very simplest functions which we can devise: of linear functions, graphically represented by straight lines; of quadratic functions, graphically represented by parabolas; and of those simple implicit functions, graphically represented by conic sections. Thence, with good fortune and a willing class, we can advance to the ideas of rates of increase, still confining ourselves to the simplest possible cases.

I wish here emphatically to remind you that both in geometry and in algebra a clear grasp of these general ideas is not what the pupil starts from, it is the goal at which he is to arrive. The method of progression is continual practice in the consideration of the simplest particular cases, and the goal is not philosophical analysis but the power of use.

But how is he to practise himself in their use? He cannot simply sit down and think of the relation _y_ = _x_ + 1, he must employ it in some simple obvious way.

This brings us to the second power of mind which is to be produced by a mathematical training, namely, the power of logical reasoning. Here again, it is not the knowledge of the philosophy of logic which it is essential to teach, but the habit of thinking logically. By logic, I mean deductive logic.

Deductive logic is the science of certain relations, such as implication, etc., between general ideas. When logic begins, definite particular individual things have been banished. I cannot relate logically this thing to that thing, for example this pen to that pen, except by the indirect way of relating some general idea which applies to this pen to some general idea which applies to that pen. And the individualities of the two pens are quite irrelevant to the logical process. This process is entirely concerned with the two general ideas. Thus the practice of logic is a certain way of employing the mind in the consideration of such ideas; and an elementary mathematical training is in fact nothing else but the logical use of the general ideas respecting geometry and algebra which we have enumerated above. It has therefore, as I started this paper by stating, a double advantage. It makes the mind capable of abstract thought, and it achieves this object by training the mind in the most important kind of abstract thought, namely, deductive logic.

I may remind you that other choices of a type of abstract thought might be made. We might train the children to contemplate directly the beauty of abstract moral ideas, in the hope of making them religious mystics. The general practice of education has decided in favour of logic, as exemplified in elementary mathematics.

We have now to answer the further question, what is the rôle of logical precision in the teaching of mathematics? Our general answer to the implied question is obvious: logical precision is one of the two objects of the teaching of mathematics, and it is the only weapon by which the teaching of mathematics can achieve its other object. To teach mathematics is to teach logical precision. A mathematical teacher who has not taught that has taught nothing.

But having stated this thesis in this unqualified way, its meaning must be carefully explained; for otherwise its real bearing on the problem will be entirely misunderstood.

Logical precision is the faculty to be acquired. It is the quality of mind which it is the object of the teaching to impart. Thus the habit of reading great literature is the goal at which a literary education aims. But we do not expect a child to start its first lesson by reading for itself Shakespeare. We recognise that reading is impossible till the pupil has learnt its alphabet and can spell, and then we start it with books of one syllable.

In the same way, a mathematical education should grow in logical precision. It is folly to expect the same careful logical analysis at the commencement of the training as would be appropriate at the end. It is an entire misconception of my thesis to construe it as meaning that a mathematical training should assume in the pupil a power of concentrated logical thought. My thesis is in fact the exact opposite, namely, that this power cannot be assumed, and has got to be acquired, and that a mathematical training is nothing else than the process of acquiring it. My whole groundwork of assumption is that this power does not initially exist in a fully developed state. Of course like every other power which is acquired, it must be developed gradually.

The various stages of development must be guided by the judgment and the genius of the teacher. But what is essential is, that the teacher should keep clearly in his mind that it is just this power of logical precise reasoning which is the whole object of his efforts. If his pupils have in any measure gained this, they have gained all.

We have not yet, however, fully considered this part of our subject. Logical precision is the full realisation of the steps of the argument. But what are the steps of the argument? The full statement of all the steps is far too elaborate and difficult an operation to be introduced into the mathematical reasoning of an educational curriculum. Such a statement involves the introduction of abstract logical ideas which are very difficult to grasp, because there is so rarely any need to make them explicit in ordinary thought. They are therefore not a fit subject-ground for an elementary education.

I do not think that it is possible to draw any theoretical line between those logical steps which form a theoretically full logical investigation, and those which are full enough for most practical purposes, including that of education. The question is one of psychology, to be solved by a process of experiment. The object to be attained is to gain that amount of logical alertness which will enable its possessors to detect fallacy and to know the types of sound logical deduction. The objects of going further are partly philosophical, and also partly to lay bare abstract ideas whose investigation is in itself important. But both these objects are foreign to education.

My opinion is, that, on the whole, the type of logical precision handed down to us by the Greek mathematicians is, roughly speaking, what we want. In geometry, this means the sort of precision which we find in Euclid. I do not mean that we should use his famous _Elements_ as a text-book, nor that here and there a certain compression in his mode of exposition is not advisable. All this is mere detail. What I do mean is, that the sort of logical transition which he made explicit, we should make explicit, and that the sort of transition which he omits, we should omit.

I doubt, however, whether it is desirable to plunge the student into the full rigour of euclidean geometry without some mitigation. It is for this reason that the modern habit, at least in England, of laying great stress in the initial stages on training the pupil in simple constructions from numerical data is to be praised. It means that after a slight amount of reasoning on the euclidean basis of accuracy, the mind of the learner is relieved by doing the things in various special cases, and noting by rough measurements that the desired results are actually attained. It is important, however, that the measurements be not mistaken for the proofs. Their object is to make the beginner apprehend what the abstract ideas really mean.

Again in algebra, the notation and the practical use of the symbols should be acquired in the simplest cases, and the more theoretical treatment of the symbolism reserved to a suitable later stage. My rule would be initially to learn the meaning of the ideas by a crude practice in simple ways, and to refine the logical procedure in preparation for an advance to greater generality. In fact the thesis of my paper can be put in another way thus, the object of a mathematical education is, to acquire the powers of analysis, of generalisation, and of reasoning. The two processes of analysis and generalisation were in my previous statement put together as the power of grasping abstract ideas.

But in order to analyse and to generalise, we must commence with the crude material of ideas which are to be analysed and generalised. Accordingly it is a positive error in education to start with the ultimate products of this process, namely the ideas in their refined analysed and generalised forms. We are thereby skipping an important part of the training, which is to take the ideas as they actually exist in the child's mind, and to exercise the child in the difficult art of civilising them and clothing them.

The schoolmaster is in fact a missionary, the savages are the ideas in the child's mind; and the missionary shirks his main task if he refuse to risk his body among the cannibals.

At this point I should like to turn your attention to those pupils forming the mathematical section. There is an idea, widely prevalent, that it is possible to teach mathematics of a relatively advanced type--such as differential calculus, for instance--in a way useful to physicists and engineers without any attention to its logic or its theory.

This seems to me to be a profound mistake. It implies that a merely mechanical knowledge without understanding of ways of arriving at mathematical results is useful in applied science. It is of no use whatever. The results themselves can all be found stated in the appropriate pocket books and in other elementary works of reference. No one when applying a result need bother himself as to why it is true. He accepts it and applies it. What is of supreme importance in physics and in engineering is a mathematically trained mind, and such a mind can only be acquired by a proper mathematical discipline.

I fully admit that the proper way to start such a subject as the differential calculus is to plunge quickly into the use of the notation in a few absurdly simple cases, with a crude explanation of the idea of rates of increase. The notation as thus known can then be used by the lecturers in the Physical and Engineering Laboratories. But the mathematical training of the applied scientists consists in making these ideas precise and the proofs accurate.

I hope that the thesis of this paper respecting the position of logical precision in the teaching of mathematics has been rendered plain. The habit of logical precision with its necessary concentration of thought upon abstract ideas is not wholly possible in the initial stages of learning. It is the ideal at which the teacher should aim. Also logical precision, in the sense of logical explicitness, is not an absolute thing: it is an affair of more or less. Accordingly the quantity of explicitness to be introduced at each stage of progress must depend upon the practical judgment of the teacher. Lastly, in a sense, the instructed mind is less explicit; for it travels more quickly over a well-remembered path, and may save the trouble of putting into words trains of thought which are very obvious to it. But on the other hand it atones for this rapidity by a concentration on every subtle point where a fallacy can lurk. The habit of logical precision is the instinct for the subtle difficulty.

CHAPTER VI

THE ORGANISATION OF THOUGHT

(_Presidential Address to Section A, British Association, Newcastle, 1916_)

THE subject of this address is the organisation of thought, a topic evidently capable of many diverse modes of treatment. I intend more particularly to give some account of that department of logical science with which some of my own studies have been connected. But I am anxious, if I can succeed in so doing, to handle this account so as to exhibit the relation with certain considerations which underlie general scientific activities.

It is no accident that an age of science has developed into an age of organisation. Organised thought is the basis of organised action. Organisation is the adjustment of diverse elements so that their mutual relations may exhibit some predetermined quality. An epic poem is a triumph of organisation, that is to say, it is a triumph in the unlikely event of its being a good epic poem. It is the successful organisation of multitudinous sounds of words, associations of words, pictorial memories of diverse events and feelings ordinarily occurring in life, combined with a special narrative of great events: the whole so disposed as to excite emotions which, as defined by Milton, are simple, sensuous, and passionate. The number of successful epic poems is commensurate, or rather, is inversely commensurate, with the obvious difficulty of the task of organisation.

Science is the organisation of thought. But the example of the epic poem warns us that science is not any organisation of thought. It is an organisation of a certain definite type which we will endeavour to determine.

Science is a river with two sources, the practical source and the theoretical source. The practical source is the desire to direct our actions to achieve predetermined ends. For example, the British nation, fighting for justice, turns to science, which teaches it the importance of compounds of nitrogen. The theoretical source is the desire to understand. Now I am going to emphasise the importance of theory in science. But to avoid misconception I most emphatically state that I do not consider one source as in any sense nobler than the other, or intrinsically more interesting. I cannot see why it is nobler to strive to understand than to busy oneself with the right ordering of one's actions. Both have their bad sides; there are evil ends directing actions, and there are ignoble curiosities of the understanding.

The importance, even in practice, of the theoretical side of science arises from the fact that action must be immediate, and takes place under circumstances which are excessively complicated. If we wait for the necessities of action before we commence to arrange our ideas, in peace we shall have lost our trade, and in war we shall have lost the battle. Success in practice depends on theorists who, led by other motives of exploration, have been there before, and by some good chance have hit upon the relevant ideas. By a theorist I do not mean a man who is up in the clouds, but a man whose motive for thought is the desire to formulate

correctly the rules according to which events occur. A successful theorist should be excessively interested in immediate events, otherwise he is not at all likely to formulate correctly anything about them. Of course, both sources of science exist in all men.

Now, what is this thought organisation which we call science? The first aspect of modern science which struck thoughtful observers was its inductive character. The nature of induction, its importance, and the rules of inductive logic have been considered by a long series of thinkers, especially English thinkers: Bacon, Herschel, J. S. Mill, Venn, Jevons, and others. I am not going to plunge into an analysis of the process of induction. Induction is the machinery and not the product, and it is the product which I want to consider. When we understand the product we shall be in a stronger position to improve the machinery.

First, there is one point which it is necessary to emphasise. There is a tendency in analysing scientific processes to assume a given assemblage of concepts applying to nature, and to imagine that the discovery of laws of nature consists in selecting by means of inductive logic some one out of a definite set of possible alternative relations which may hold between the things in nature answering to these obvious concepts. In a sense this assumption is fairly correct, especially in regard to the earlier stages of science. Mankind found itself in possession of certain concepts respecting nature--for example, the concept of fairly permanent material bodies--and proceeded to determine laws which related the corresponding percepts in nature. But the formulation of laws changed the concepts, sometimes gently by an added precision, sometimes violently. At first this process was not much noticed, or at least was felt to be a process curbed within narrow bounds, not touching fundamental ideas. At the stage where we now are, the formulation of the concepts can be seen to be as important as the formulation of the empirical laws connecting the events in the universe as thus conceived by us. For example, the concepts of life, of heredity, of a material body, of a molecule, of an atom, of an electron, of energy, of space, of time, of quantity, and of number. I am not dogmatising about the best way of getting such ideas straight. Certainly it will only be done by those who have devoted themselves to a special study of the facts in question. Success is never absolute, and progress in the right direction is the result of a slow, gradual process of continual comparison of ideas with facts. The criterion of success is that we should be able to formulate empirical laws, that is, statements of relations, connecting the various parts of the universe as thus conceived, laws with the property that we can interpret the actual events of our lives as being our fragmentary knowledge of this conceived interrelated whole.

But, for the purpose of science, what is the actual world? Has science to wait for the termination of the metaphysical debate till it can determine its own subject-matter? I suggest that science has a much more homely starting-ground. Its task is the discovery of the relations which exist within that flux of perceptions, sensations, and emotions which forms our experience of life. The panorama yielded by sight, sound, taste, smell, touch, and by more inchoate sensible feelings, is the sole field of activity. It is in this way that science is the thought organisation of experience. The most obvious aspect of this field of actual experience is its disorderly character. It is for each person a _continuum_, fragmentary, and with elements not clearly differentiated. The comparison of the sensible experiences of diverse people brings its own difficulties. I insist on the radically untidy, ill-adjusted character of the fields of actual experience from which science starts. To grasp this fundamental truth is the first step in wisdom, when constructing a philosophy of science. This fact is concealed by the influence of language, moulded by science, which foists on us exact concepts as though they represented the immediate deliverances of experience. The result is, that we imagine that we have immediate experience of a world of perfectly defined objects implicated in perfectly defined events which, as known to us by the direct deliverance of our senses, happen at exact instants of time, in a space formed by exact points, without parts and without magnitude: the neat, trim, tidy, exact world which is the goal of scientific thought.

My contention is, that this world is a world of ideas, and that its internal relations are relations between abstract concepts, and that the elucidation of the precise connection between this world and the feelings of actual experience is the fundamental question of scientific philosophy. The question which I am inviting you to consider is this: How does exact thought apply to the fragmentary, vague _continua_ of experience? I am not saying that it does not apply: quite the contrary. But I want to know how it applies. The solution I am asking for is not a phrase, however brilliant, but a solid branch of science, constructed with slow patience, showing in detail how the correspondence is effected.

The first great steps in the organisation of thought were due exclusively to the practical source of scientific activity, without any admixture of theoretical impulse. Their slow accomplishment was the cause and also the effect of the gradual evolution of moderately rational beings. I mean the formation of the concepts of definite material objects, of the determinate lapse of time, of simultaneity, of recurrence, of definite relative position, and of analogous fundamental ideas, according to which the flux of our experience is mentally arranged for handy reference: in fact, the whole apparatus of commonsense thought. Consider in your mind some definite chair. The concept of that chair is simply the concept of all the interrelated experiences connected with that chair--namely, of the experience of the folk who made it, of the folk who sold it, of the folk who have seen it or used it, of the man

who is now experiencing a comfortable sense of support, combined with our expectations of an analogous future, terminated finally by a different set of experiences when the chair collapses and becomes firewood. The formation of that type of concept was a tremendous job, and zoologists and geologists tell us that it took many tens of millions of years. I can well believe it.

I now emphasise two points. In the first place, science is rooted in what I have just called the whole apparatus of commonsense thought. That is the _datum_ from which it starts, and to which it must recur. We may speculate, if it amuses us, of other beings in other planets who have arranged analogous experiences according to an entirely different conceptual code--namely, who have directed their chief attention to different relations between their various experiences. But the task is too complex, too gigantic, to be revised in its main outlines. You may polish up commonsense, you may contradict it in detail, you may surprise it. But ultimately your whole task is to satisfy it.

In the second place, neither commonsense nor science can proceed with their task of thought organisation without departing in some respect from the strict consideration of what is actual in experience. Think again of the chair. Among the experiences upon which its concept is based, I included our expectations of its future history. I should have gone further and included our imagination of all the possible experiences which in ordinary language we should call perceptions of the chair which might have occurred. This is a difficult question, and I do not see my way through it. But, at present, in the construction of a theory of space and of time there seem insuperable difficulties if we refuse to admit ideal experiences.

This imaginative perception of experiences, which, if they occurred, would be coherent with our actual experiences, seems fundamental in our lives. It is neither wholly arbitrary, nor yet fully determined. It is a vague background which is only made in part definite by isolated activities of thought. Consider, for example, our thoughts of the unseen flora of Brazil.

Ideal experiences are closely connected with our imaginative reproduction of the actual experiences of other people, and also with our almost inevitable conception of ourselves as receiving our impressions from an external complex reality beyond ourselves. It may be that an adequate analysis of every source and every type of experience yields demonstrative proof of such a reality and of its nature. Indeed, it is hardly to be doubted that this is the case. The precise elucidation of this question is the problem of metaphysics. One of the points which I am urging in this address is, that the basis of science does not depend on the assumption of any of the conclusions of metaphysics; but that both science and metaphysics start from the same given groundwork of immediate experience, and in the main proceed in opposite directions on their diverse tasks.

For example, metaphysics inquires how our perceptions of the chair relate us to some true reality. Science gathers up these perceptions into a determinate class, adds to them ideal perceptions of analogous sort, which under assignable circumstances would be obtained, and this single concept of that set of perceptions is all that science needs; unless indeed you prefer that thought find its origin in some legend of those great twin brethren, the Cock and Bull.

My immediate problem is to inquire into the nature of the texture of science. Science is essentially logical. The nexus between its concepts is a logical nexus, and the grounds for its detailed assertions are logical grounds. King James said, "No bishops, no king." With greater confidence we can say, "No logic, no science." The reason for the instinctive dislike which most men of science feel towards the recognition of this truth is, I think, the barren failure of logical theory during the past three or four centuries. We may trace this failure back to the worship of authority, which in some respects increased in the learned world at the time of the Renaissance. Mankind then changed its authority, and this fact temporally acted as an emancipation. But the main fact, and we can find complaints[2] of it at the very commencement of the modern movement, was the establishment of a reverential attitude towards any statement made by a classical author. Scholars became commentators on truths too fragile to bear translation. A science which hesitates to forget its founders is lost. To this hesitation I ascribe the barrenness of logic. Another reason for distrust of logical theory and of mathematics is the belief that deductive reasoning can give you nothing new. Your conclusions are contained in your premises, which by hypothesis are known to you.

In the first place this last condemnation of logic neglects the fragmentary, disconnected character of human knowledge. To know one premise on Monday, and another premise on Tuesday, is useless to you on Wednesday. Science is a permanent record of premises, deductions, and conclusions, verified all along the line by its correspondence with facts. Secondly, it is untrue that when we know the premises we also know the conclusions. In arithmetic, for example, mankind are not calculating boys. Any theory which proves that they are conversant with the consequences of their assumptions must be wrong. We can imagine beings who possess such insight. But we are not such creatures. Both these answers are, I think, true and relevant. But they are not satisfactory. They are too much in the nature of bludgeons, too external. We want something more explanatory of the very real

difficulty which the question suggests. In fact, the true answer is embedded in the discussion of our main problem of the relation of logic to natural science.

It will be necessary to sketch in broad outline some relevant features of modern logic. In doing so I shall try to avoid the profound general discussions and the minute technical classifications which occupy the main part of traditional logic. It is characteristic of a science in its earlier stages--and logic has become fossilised in such a stage--to be both ambitiously profound in its aims and trivial in its handling of details.

We can discern four departments of logical theory. By an analogy which is not so very remote I will call these departments or sections the arithmetic section, the algebraic section, the section of general-function theory, the analytical section. I do not mean that arithmetic arises in the first section, algebra in the second section, and so on; but the names are suggestive of certain qualities of thought in each section which are reminiscent of analogous qualities in arithmetic, in algebra, in the general theory of a mathematical function, and in the mathematical analysis of the properties of particular functions.

The first section--namely, the arithmetic stage--deals with the relations of definite propositions to each other, just as arithmetic deals with definite numbers. Consider any definite proposition; call it "_p_." We conceive that there is always another proposition which is the direct contradictory to "_p_"; call it "not-_p_." When we have got two propositions, _p_ and _q_, we can form derivative propositions from them, and from their contradictories. We can say, "At last one of _p_ or _q_ is true, and perhaps both." Let us call this proposition "_p_ or _q_." I may mention as an aside that one of the greatest living philosophers has stated that this use of the word "or"--namely, "_p_ or _q_" in the sense that either or both may be true--makes him despair of exact expression. We must brave his wrath, which is unintelligible to me.

We have thus got hold of four new propositions, namely, "_p_ or _q_," and "not-_p_ or _q_," and "_p_ or not-_q_," and "not-_p_ or not-_q_." Call these the set of disjunctive derivatives. There are, so far, in all eight propositions, _p_, not-_p_, _q_, not-_q_, and the four disjunctive derivatives. Any pair of these eight propositions can be taken, and substituted for _p_ and _q_ in the foregoing treatment. Thus each pair yields eight propositions, some of which may have been obtained before. By proceeding in this way we arrive at an unending set of propositions of growing complexity, ultimately derived from the two original propositions _p_ or _q_. Of course, only a few are important. Similarly we can start from three propositions, _p_, _q_, _r_, or from four propositions, _p_, _q_, _r_, _s_, and so on. Any one of the propositions of these aggregates may be true or false. It has no other alternative. Whichever it is, true or false, call it the "truth-value" of the proposition.

The first section of logical inquiry is to settle what we know of the truth-values of these propositions, when we know the truth-values of some of them. The inquiry, so far as it is worth while carrying it, is not very abstruse, and the best way of expressing its results is a detail which I will not now consider. This inquiry forms the arithmetic stage.

The next section of logic is the algebraic stage. Now, the difference between arithmetic and algebra is, that in arithmetic definite numbers are considered, and in algebra symbols--namely, letters--are introduced which stand for any numbers. The idea of a number is also enlarged. These letters, standing for any numbers, are called sometimes variables and sometimes parameters. Their essential characteristic is that they are undetermined, unless, indeed, the algebraic conditions which they satisfy implicitly determine them. Then they are sometimes called unknowns. An algebraic formula with letters is a blank form. It becomes a determinate arithmetic statement when definite numbers are substituted for the letters. The importance of algebra is a tribute to the study of form. Consider now the following proposition--

The specific heat of mercury is 0·033.

This is a definite proposition which, with certain limitations, is true. But the truth-value of the proposition does not immediately concern us. Instead of mercury put a mere letter which is the name of some undetermined thing: we get--

The specific heat of _x_ is 0·033.

This is not a proposition; it has been called by Russell a propositional function. It is the logical analogy of an algebraic expression. Let us write $f(_x_)$ for any propositional function.

We could also generalise still further, and say,

The specific heat of _x_ is _y_.

We thus get another propositional function, F(_x_, _y_), of two arguments _x_ and _y_, and so on for any number of arguments.

Now, consider f(_x_). There is the range of values of _x_, for which f(_x_) is a proposition, true or false. For values of _x_ outside this range, f(_x_) is not a proposition at all, and is neither true nor false. It may have vague suggestions for us, but it has no unit meaning of definite assertion. For example,

The specific heat of water is 0·033

is a proposition which is false; and--

The specific heat of virtue is 0·033

is, I should imagine, not a proposition at all; so that it is neither true nor false, though its component parts raise various associations in our minds. This range of values, for which f(_x_) has sense, is called the "type" of the argument _x_.

But there is also a range of values of _x_ for which f(_x_) is a true proposition. This is the class of those values of the argument which _satisfy_ f(_x_). This class may have no members, or, in the other extreme, the class may be the whole type of the arguments.

We thus conceive two general propositions respecting the indefinite number of propositions which share in the same logical form, that is, which are values of the same propositional function. One of these propositions is,

f(_x_) yields a true proposition for each value of _x_ of the proper type;

the other proposition is,

There is a value of _x_ for which f(_x_) is true.

Given two, or more, propositional functions f(_x_) and φ(_x_) with the same argument _x_, we form derivative propositional functions, namely,

f(_x_) or φ(_x_), f(_x_) or not-φ(_x_),

and so on with the contradictories, obtaining, as in the arithmetical stage, an unending aggregate of propositional functions. Also each propositional function yields two general propositions. The theory of the interconnection between the truth-values of the general propositions arising from any such aggregate of propositional functions forms a simple and elegant chapter of mathematical logic.

In this algebraic section of logic the theory of types crops up, as we have already noted. It cannot be neglected without the introduction of error. Its theory has to be settled at least by some safe hypothesis, even if it does not go to the philosophic basis of the question. This part of the subject is obscure and difficult, and has not been finally elucidated, though Russell's brilliant work has opened out the subject.

The final impulse to modern logic comes from the independent discovery of the importance of the logic variable by Frege and Peano. Frege went further than Peano, but by an unfortunate symbolism rendered his work so obscure that no one fully recognised his meaning who had not found it out for himself. But the movement has a large history reaching back to Leibniz and even to Aristotle. Among English contributors are De Morgan, Boole, and Sir Alfred Kempe; their work is of the first rank.

The third logical section is the stage of general-function theory. In logical language, we perform in this stage the transition from intension to extension, and investigate the theory of denotation. Take the propositional function, f(_x_). There is the class, or range of values for _x_, whose members satisfy f(_x_). But the same range may be the class whose members satisfy another propositional function φ(_x_). It is necessary to investigate how to indicate the class by a way which is indifferent as between the various propositional functions which are satisfied by any member of it, and of it only. What has to be done is to analyse the nature of propositions about a class--namely, those propositions whose truth-values depend on the class itself and not on the particular meaning by which the class is indicated.

Furthermore, there are propositions about alleged individuals indicated by descriptive phrases: for example, propositions about "the present King of England," who does exist, and "the present Emperor of Brazil," who does not exist. More complicated, but analogous, questions involving propositional functions of two variables involve the notion of "correlation," just as functions of one

argument involve classes. Similarly functions of three arguments yield three-cornered correlations, and so on. This logical section is one which Russell has made peculiarly his own by work which must always remain fundamental. I have called this the section of functional theory, because its ideas are essential to the construction of logical denoting functions which include as a special case ordinary mathematical functions, such as sine, logarithm, etc. In each of these three stages it will be necessary gradually to introduce an appropriate symbolism, if we are to pass on to the fourth stage.

The fourth logical section, the analytic stage, is concerned with the investigation of the properties of special logical constructions, that is, of classes and correlations of special sorts. The whole of mathematics is included here. So the section is a large one. In fact, it is mathematics, neither more nor less, but it includes an analysis of mathematical ideas not hitherto included in the scope of that science, nor, indeed, contemplated at all. The essence of this stage is construction. It is by means of suitable constructions that the great framework of applied mathematics, comprising the theories of number, quantity, time, and space, is elaborated.

It is impossible, even in brief outline, to explain how mathematics is developed from the concepts of class and correlation, including many-cornered correlations, which are established in the third section. I can only allude to the headings of the process, which is fully developed in the work, _Principia Mathematica_, by Mr. Russell and myself. There are in this process of development seven special sorts of correlations which are of peculiar interest. The first sort comprises one-to-many, many-to-one, and one-to-one correlations. The second sort comprises serial relations, that is, correlations by which the members of some field are arranged in serial order, so that, in the sense defined by the relation, any member of the field is either before or after any other member. The third class comprises inductive relations, that is, correlations on which the theory of mathematical induction depends. The fourth class comprises selective relations, which are required for the general theory of arithmetic operations, and elsewhere. It is in connection with such relations that the famous multiplicative axiom arises for consideration. The fifth class comprises vector relations, from which the theory of quantity arises. The sixth class comprises ratio relations, which interconnect number and quantity. The seventh class comprises three-cornered and four-cornered relations which occur in geometry.

A bare enumeration of technical names, such as the above, is not very illuminating, though it may help to a comprehension of the demarcations of the subject. Please remember that the names are technical names, meant, no doubt, to be suggestive, but used in strictly defined senses. We have suffered much from critics who consider it sufficient to criticise our procedure on the slender basis of a knowledge of the dictionary meanings of such terms. For example, a one-to-one correlation depends on the notion of a class with only one member, and this notion is defined without appeal to the concept of the number one. The notion of diversity is all that is wanted. Thus the class α has only one member, if (1) the class of values of _x_ which satisfies the propositional function,

_x_ is not a member of α,

is not the whole type of relevant values of _x_, and if (2) the propositional function,

_x_ and _y_ are members of α, and _x_ is diverse from _y_

is false, whatever be the values of _x_ and _y_ in the relevant type.

Analogous procedures are obviously possible for higher finite cardinal members. Thus, step by step, the whole cycle of current mathematical ideas is capable of logical definition. The process is detailed and laborious, and, like all science, knows nothing of a royal road of airy phrases. The essence of the process is, first, to construct the notion in terms of the forms of propositions, that is, in terms of the relevant propositional functions, and secondly, to prove the fundamental truths which hold about the notion by reference to the results obtained in the algebraic section of logic.

It will be seen that in this process the whole apparatus of special indefinable mathematical concepts, and special _a priori_ mathematical premises, respecting number, quantity, and space, has vanished. Mathematics is merely an apparatus for analysing the deductions which can be drawn from any particular premises, supplied by commonsense, or by more refined scientific observation, so far as these deductions depend on the forms of the propositions. Propositions of certain forms are continually occurring in thought. Our existing mathematics is the analysis of deductions which concern those forms and in some way are important, either from practical utility or theoretical interest. Here I am speaking of the science as it in fact exists. A theoretical definition of mathematics must include in its scope any deductions depending on the mere forms of propositions. But, of course no one would wish to develop that part of mathematics which in no sense is of importance.

This hasty summary of logical ideas suggests some reflections. The question arises, How many forms of propositions are there? The answer is, An unending number. The reason for the supposed sterility of logical science can thus be discerned. Aristotle

founded the science by conceiving the idea of the form of a proposition, and by conceiving deduction as taking place in virtue of the forms. But he confined propositions to four forms, now named A, I, E, O. So long as logicians were obsessed by this unfortunate restriction, real progress was impossible. Again, in their theory of form, both Aristotle and subsequent logicians came very near to the theory of the logical variable. But to come very near to a true theory, and to grasp its precise application, are two very different things, as the history of science teaches us. Everything of importance has been said before by somebody who did not discover it.

Again, one reason why logical deductions are not obvious is, that logical form is not a subject which ordinarily enters into thought. Commonsense deduction probably moves by blind instinct from concrete proposition to concrete proposition, guided by some habitual association of ideas. Thus commonsense fails in the presence of a wealth of material.

A more important question is the relation of induction, based on observation, to deductive logic. There is a tradition of opposition between adherents of induction and of deduction. In my view, it would be just as sensible for the two ends of a worm to quarrel. Both observation and deduction are necessary for any knowledge worth having. We cannot get at an inductive law without having recourse to a propositional function. For example, take the statement of observed fact,

This body is mercury, and its specific heat is 0·033.

The propositional function is formed,

Either _x_ is not mercury, or its specific heat is 0·033.

The inductive law is the assumption of the truth of the general proposition, that the above propositional function is true for every value of _x_ in the relevant type.

But it is objected that this process and its consequences are so simple that an elaborate science is out of place. In the same way, a British sailor knows the salt sea when he sails over it. What, then, is the use of an elaborate chemical analysis of sea-water? There is the general answer, that you cannot know too much of methods which you always employ; and there is the special answer, that logical forms and logical implications are not so very simple, and that the whole of mathematics is evidence to this effect.

One great use of the study of logical method is not in the region of elaborate deduction, but to guide us in the study of the formation of the main concepts of science. Consider geometry, for example. What are the points which compose space? Euclid tells us that they are without parts and without magnitude. But how is the notion of a point derived from the sense-perceptions from which science starts? Certainly points are not direct deliverances of the senses. Here and there we may see or unpleasantly feel something suggestive of a point. But this is a rare phenomenon, and certainly does not warrant the conception of space as composed of points. Our knowledge of space properties is not based on any observations of relations between points. It arises from experience of relations between bodies. Now a fundamental space-relation between bodies is that one body may be part of another. We are tempted to define the "whole and part" relation by saying that the points occupied by the part are some of the points occupied by the whole. But "whole and part" being more fundamental than the notion of "point," this definition is really circular and vicious.

We accordingly ask whether any other definition of "spatial whole and part" can be given. I think that it can be done in this way, though, if I be mistaken, it is unessential to my general argument. We have come to the conclusion that an extended body is nothing else than the class of perception of it by all its percipients, actual or ideal. Of course, it is not any class of perceptions, but a certain definite sort of class which I have not defined here, except by the vicious method of saying that they are perceptions of body. Now, the perceptions of a part of a body are among the perceptions which compose the whole body. Thus two bodies _a_ and _b_ are both classes of perceptions; and _b_ is part of _a_ when the class which is _b_ is contained in the class which is _a_. It immediately follows from the logical form of this definition that if _b_ is part of _a_, and _c_ is part of _b_, then _c_ is part of _a_. Thus the relation "whole to part" is transitive. Again, it will be convenient to allow that a body is part of itself. This is a mere question of how you draw the definition. With this understanding, the relation is reflexive. Finally, if _a_ is part of _b_, and _b_ is part of _a_, then _a_ and _b_ must be identical. These properties of "whole and part" are not fresh assumptions, they follow from the logical form of our definition.

One assumption has to be made if we assume the ideal infinite divisibility of space. Namely, we assume that every class of perceptions which is an extended body contains other classes of perceptions which are extended bodies diverse from itself. This assumption makes rather a large draft on the theory of ideal perceptions. Geometry vanishes unless in some form you make it. The assumption is not peculiar to my exposition.

It is then possible to define what we mean by a point. A point is the class of extended objects which, in ordinary language, contain that point. The definition, without presupposing the idea of a point, is rather elaborate, and I have not now time for its statement.

The advantage of introducing points into geometry is the simplicity of the logical expression of their mutual relations. For science, simplicity of definition is of slight importance, but simplicity of mutual relations is essential. Another example of this law is the way physicists and chemists have dissolved the simple idea of an extended body, say of a chair, which a child understands, into a bewildering notion of a complex dance of molecules and atoms and electrons and waves of light. They have thereby gained notions with simpler logical relations.

Space as thus conceived is the exact formulation of the properties of the apparent space of the commonsense world of experience. It is not necessarily the best mode of conceiving the space of the physicist. The one essential requisite is that the correspondence between the commonsense world in its space and the physicists' world in its space should be definite and reciprocal.

I will now break off the exposition of the function of logic in connection with the science of natural phenomena. I have endeavoured to exhibit it as the organising principle, analysing the derivation of the concepts from the immediate phenomena, examining the structure of the general propositions which are the assumed laws of nature, establishing their relations to each other in respect to reciprocal implications, deducing the phenomena we may expect under given circumstances.

Logic, properly used, does not shackle thought. It gives freedom, and above all, boldness. Illogical thought hesitates to draw conclusions, because it never knows either what it means, or what it assumes, or how far it trusts its own assumptions, or what will be the effect of any modification of assumptions. Also the mind untrained in that part of constructive logic which is relevant to the subject in hand will be ignorant of the sort of conclusions which follow from various sorts of assumptions, and will be correspondingly dull in divining the inductive laws. The fundamental training in this relevant logic is, undoubtedly, to ponder with an active mind over the known facts of the case, directly observed. But where elaborate deductions are possible, this mental activity requires for its full exercise the direct study of the abstract logical relations. This is applied mathematics.

Neither logic without observation, nor observation without logic, can move one step in the formation of science. We may conceive humanity as engaged in an internecine conflict between youth and age. Youth is not defined by years but by the creative impulse to make something. The aged are those who, before all things, desire not to make a mistake. Logic is the olive branch from the old to the young, the wand which in the hands of youth has the magic property of creating science.

FOOTNOTES:

[Footnote 2: _E.g._ in 1551 by Italian schoolmen; cf. Sarpi's _History of the Council of Trent_, under that date.]

CHAPTER VII

THE ANATOMY OF SOME SCIENTIFIC IDEAS

I. Fact

THE characteristic of physical science is, that it ignores all judgments of value: for example, æsthetic or moral judgments. It is purely matter-of-fact, and this is the sense in which we must interpret the sonorous phrase, "Man, the servant and the minister of Nature."

The sphere of thought which is thus left is even then too wide for physical science. It would include Ontology, namely, the determination of the nature of what truly exists; in other words, Metaphysics. From an abstract point of view this exclusion of metaphysical inquiry is a pity. Such an inquiry is a necessary critique of the worth of science, to tell us what it all comes to. The reasons for its careful separation from scientific thought are purely practical; namely, because we can agree about science--after due debate--whereas in respect to metaphysics debate has hitherto accentuated disagreement. These characteristics of science and metaphysics were unexpected in the early days of civilised thought. The Greeks thought that metaphysics was easier than physics, and tended to deduce scientific principles from _a priori_ conceptions of the nature of things. They were restrained in this disastrous tendency by their vivid naturalism, their delight in first-hand perception. Mediæval Europe shared the tendency without the restraint. It is possible that some distant generations may arrive at unanimous conclusions on ontological questions, whereas scientific progress may have led to ingrained opposing veins of thought which can neither be reconciled nor abandoned. In such times metaphysics and physical science will exchange their rôles. Meanwhile we must take the case as we find it.

But a problem remains. How can mankind agree about science without a preliminary determination of what really is? The answer must be found in an analysis of the facts which form the field of scientific activity. Mankind perceives, and finds itself thinking about its perceptions. It is the thought that matters and not that element of perception which is not thought. When the immediate judgment has been formed--Hullo, red!--it does not matter if we can imagine that in other circumstances--in better circumstances, perhaps--the judgment would have been--Hullo, blue!--or even--Hullo, nothing! For all intents and purposes, at the time it was red. Everything else is hypothetical reconstruction. The field of physical science is composed of these primary thoughts, and of thoughts about these thoughts.

But--to avoid confusion--a false simplicity has been introduced above into the example given of a primary perceptive thought. "Hullo, red!" is not really a primary perceptive thought, though it often is the first thought which finds verbal expression even silently in the mind. Nothing is in isolation. The perception of red is of a red object in its relations to the whole content of the perceiving consciousness.

Among the most easily analysed of such relations are the space relations. Again the red object is in immediate perception nothing else than a red object. It is better termed an "object of redness." Thus a better approximation to an immediate perceptive judgment is, "Hullo, object of redness there!" But, of course, in this formulation other more complex relations are omitted.

This tendency towards a false simplicity in scientific analysis, to an excessive abstraction, to an over-universalising of universals, is derived from the earlier metaphysical stage. It arises from the implicit belief that we are endeavouring to qualify the real with appropriate adjectives. In conformity with this tendency we think, "this real thing is red." Whereas our true goal is to make explicit our perception of the apparent in terms of its relations. What we perceive is redness related to other apparents. Our object is the analysis of the relations.

One aim of science is the harmony of thought, that is, to secure that judgments which are logical contraries should not be thought-expressions of consciousness. Another aim is the extension of such harmonised thought.

Some thoughts arise directly from sense-presentation, and are part of the state of consciousness which is perception. Such a thought is, "An object of redness is there." But in general the thought is not verbal, but is a direct apprehension of qualities and relations within the content of consciousness.

Amid such thoughts there can be no lack of harmony. For direct apprehension is in its essence unique, and it is impossible to apprehend an object as both red and blue. Subsequently it may be judged that if other elements of the consciousness had been different, the apprehension would have been of a blue object. Then--under certain circumstances--the original apprehension will be called an error. But for all that the fact remains, there was an apprehension of a red object.

When we speak of sense-presentation, we mean these primary thoughts essentially involved in its perception. But there are thoughts about thoughts, and thoughts derived from other thoughts. These are secondary thoughts. At this point it is well explicitly to discriminate between an actual thought-expression, namely, a judgment actually made, and a mere proposition which is a hypothetical thought-expression, namely, an imagined possibility of thought-expression. Note that the actual complete thought-content of the consciousness is explicitly neither affirmed or denied. It is just what _is_ thought. Thus, to think "two and two make four" is distinct from affirming that two and two make four. In the first case the proposition is the thought-expression, in the second case the affirmation of the proposition is the thought-expression, and the proposition has been degraded to a mere proposition, namely, to a hypothetical thought-expression which is reflected upon.

A distinction is sometimes made between facts and thoughts. So far as physical science is concerned, the facts are thoughts, and thoughts are facts. Namely, the facts of sense-presentation as they affect science are those elements in the immediate apprehensions which are thoughts. Also, actual thought-expressions, primary or secondary, are the material facts which science interprets.

The distinction that facts are given, but thoughts are free, is not absolute. We can select and modify our sense-presentation, so that facts--in the narrower sense of immediate apprehension of sense-presentation--are to some degree subject to volition. Again, our stream of thought-expression is only partially modified by explicit volition. We can choose our physical experience, and we find ourselves thinking; namely, on the one hand there is selection amid the dominant necessity of sense, and on the other hand, the thought-content of consciousness (so far as secondary thoughts are concerned) is not wholly constituted by the selection of will.

Thus, on the whole there is a large primary region of secondary thought, as well as of the primary thoughts of sense-presentation, which is given in type. That is the way in which we do think of things, not wholly from any abstract necessity, so far as we know, but because we have inherited the method from an environment. It is the way we find ourselves thinking, a way which can only be fundamentally laid aside by an immense effort, and then only for isolated short periods of time. This is what I have called the "whole apparatus of commonsense thought."

It is this body of thought which is assumed in science. It is a way of thinking rather than a set of axioms. It is, in fact, the set of concepts which commonsense has found useful in sorting out human experience. It is modified in detail, but assumed in gross. The explanations of science are directed to finding conceptions and propositions concerning nature which explain the importance of these common sense notions. For example, a chair is a common sense notion, molecules and electrons explain our vision of chairs.

Now science aims at harmonising our reflective and derivative thoughts with the primary thoughts involved in the immediate apprehension of sense-presentation. It also aims at producing such derivative thoughts, logically knit together. This is scientific theory; and the harmony to be achieved is the agreement of theory with observation, which is the apprehension of sense-presentation.

Thus there is a twofold scientific aim: (1) the production of theory which agrees with experience; and (2) the explanation of commonsense concepts of nature, at least in their main outlines. This explanation consists in the preservation of the concepts in a scientific theory of harmonised thought.

It is not asserted that this is what scientists in the past meant to achieve, or thought that they could achieve. It is suggested as the actual result of scientific effort, so far as that effort has had any measure of success. In short, we are here discussing the natural history of ideas and not volitions of scientists.

II. Objects

We perceive things in space. For example, among such things are dogs, chairs, curtains, drops of water, gusts of air, flames, rainbows, chimes of bells, odours, aches and pains. There is a scientific explanation of the origin of these perceptions. This explanation is given in terms of molecules, atoms, electrons, and their mutual relations, in particular of their space-relations, and waves of disturbance of these space-relations which are propagated through space. The primary elements of the scientific explanation--molecules, etc.--are not the things directly perceived. For example, we do not perceive a wave of light; the sensation of sight is the resultant effect of the impact of millions of such waves through a stretch of time. Thus the object directly perceived corresponds to a series of events in the physical world, events which are prolonged through a stretch of time. Nor is it true that a perceived object always corresponds to the same group of molecules. After a few years we recognise the same cat, but we are thereby related to different molecules.

Again, neglecting for a moment the scientific explanation, the perceived object is largely the supposition of our imagination. When we recognised the cat, we also recognised that it was glad to see us. But we merely heard its mewing, saw it arch its back, and felt it rubbing itself against us. We must distinguish, therefore, between the many direct objects of sense, and the single indirect object of thought which is the cat.

Thus, when we say that we perceived the cat and understood its feelings, we mean that we heard a sense-object of sound, that we saw a sense-object of sight, that we felt a sense-object of touch, and that we thought of a cat and imagined its feelings.

Sense-objects are correlated by time-relations and space-relations. Three simultaneous sense-objects which are also spatially coincident, are combined by thought into the perception of one cat. Such combination of sense-objects is an instinctive immediate judgment in general without effort of reasoning. Sometimes only one sense-object is present. For example, we hear mewing and say there must be a cat in the room. The transition from the sense-object to the cat has then been made, by deliberate ratiocination. Even the concurrence of sense-objects may provoke such a self-conscious effort. For example, in the dark we feel something, and hear mewing from the same place, and think, Surely this is a cat. Sight is more bold; when we see a cat, we do not think further. We identify the sight with the cat, whereas the cat and the mew are separate. But such immediate identification of a sight object and an object of thought may lead to error; the birds pecked at the grapes of Apelles.

A single sense-object is a complex entity. The sight-object of a tile on the hearth may remain unchanged as we watch it in a steady light, remaining ourselves unchanged in position. Even then it is prolonged in time, and has parts in space. Also it is somewhat

arbitrarily distinguished from a larger whole of which it forms part. But the glancing fire-light and a change in our position alters the sight-object. We judge that the tile thought-object remains unchanged. The sight-object of the coal on the fire gradually modifies, though within short intervals it remains unchanged. We judge that the coal thought-object is changing. The flame is never the same, and its shape is only vaguely distinguishable.

We conclude that a single self-identical sight-object is already a phantasy of thought. Consider the unchanging sight-object of the tile, as we remain still in a steady light. Now a sense-object perceived at one time is a distinct object from a sense-object seen at another time. Thus the sight of the tile at noon is distinct from its sight at 12.30. But there is no such thing as a sense-object at an instant. As we stare at the tile, a minute, or a second, or a tenth of a second, has flown by: essentially there is a duration. There is a stream of sight, and we can distinguish its parts. But the parts also are streams, and it is only in thought that the stream separates into a succession of elements. The stream may be "steady" as in the case of the unchanging sight-tile, or may be "turbulent" as in the case of the glancing sight-flame. In either case a sight-object is some arbitrarily small part of the stream.

Again, the stream which forms the succession of sight-tiles is merely a distinguishable part of the whole stream of sight-presentation.

So, finally, we conceive ourselves each experiencing a complete time-flux (or stream) of sense-presentation. This stream is distinguishable into parts. The grounds of distinction are differences of sense--including within that term, differences of types of sense, and differences of quality and of intensity within the same type of sense--and differences of time-relations, and differences of space-relations. Also the parts are not mutually exclusive and exist in unbounded variety.

The time-relation between the parts raises the questions of memory and recognition, subjects too complex for discussion here. One remark must be made. If it be admitted, as stated above, that we live in durations and not in instants, namely, that the present essentially occupies a stretch of time, the distinction between memory and immediate presentation cannot be quite fundamental; for always we have with us the fading present as it becomes the immediate past. This region of our consciousness is neither pure memory nor pure immediate presentation. Anyhow, memory is also a presentation in consciousness.

Another point is to be noted in connection with memory. There is no directly perceived time-relation between a present event and a past event. The present event is only related to the memory of the past event. But the memory of a past event is itself a present element in consciousness. We assert the principle that directly perceived relations can only exist between elements of consciousness, both in that present during which the perception occurs. All other relations between elements of perception are inferential constructions. It thus becomes necessary to explain how the time stream of events establishes itself in thought, and how the apparent world fails to collapse into one single present. The solution of the difficulty is arrived at by observing that the present is itself a duration, and therefore includes directly perceived time-relations between events contained within it. In other words we put the present on the same footing as the past and the future in respect to the inclusion within it of antecedent and succeeding events, so that past, present, and future are in this respect exactly analogous ideas. Thus there will be two events _a_ and _b_, both in the same present, but the event _a_ will be directly perceived to precede the event _b_. Again time flows on, and the event _a_ fades into the past, and in the new present duration events _b_ and _c_ occur, event _b_ preceding event _c_, also in the same present duration there is the memory of the time-relation between _a_ and _b_. Then by an inferential construction the event _a_ in the past precedes the event _c_ in the present. By proceeding according to this principle the time-relations between elements of consciousness, not in the same present, are established. The method of procedure here explained is a first example of what we will call the Principle of Aggregation. This is one of the fundamental principles of mental construction according to which our conception of the external physical world is constructed. Other examples will later on be met with.

The space-relations between the parts are confused and fluctuating, and in general lack determinate precision. The master-key by which we confine our attention to such parts as possess mutual relations sufficiently simple for our intellects to consider is the principle of convergence to simplicity with diminution of extent. We will call it the "principle of convergence." This principle extends throughout the whole field of sense-presentation.

The first application of the principle occurs in respect to time. The shorter the stretch of time, the simpler are the aspects of the sense-presentation contained within it. The perplexing effects of change are diminished and in many cases can be neglected. Nature has restricted the acts of thought which endeavour to realise the content of the present, to stretches of time sufficiently short to secure this static simplicity over the greater part of the sense-stream.

Spatial relations become simplified within the approximately static sense-world of the short time. A further simplicity is gained by partitioning this static world into parts of restricted space-content. The various parts thus obtained have simpler mutual space-relations, and again the principle of convergence holds.

Finally, the last simplicity is obtained by partitioning the parts, already restricted as to space and time, into further parts characterised by homogeneity in type of sense, and homogeneity in quality and intensity of sense. These three processes of restriction yield, finally, the sense-objects which have been mentioned above. Thus the sense-object is the result of an active process of discrimination made in virtue of the principle of convergence. It is the result of the quest for simplicity of relations within the complete stream of sense-presentation.

The thought-objects of perception are instances of a fundamental law of nature, the law of objective stability. It is the law of the coherence of sense-objects. This law of stability has an application to time and an application to space; also it must be applied in conjunction with that other law, the principle of convergence to simplicity from which sense-objects are derived.

Some composite partial streams of sense-presentation can be distinguished with the following characteristics: (1) the time-succession of sense-objects, belonging to a single sense, involved in any such a composite partial stream, is composed of very similar objects whose modifications increase only gradually, and thus forms a homogeneous component stream within the composite stream; (2) the space-relations of those sense-objects (of various senses) of such a composite stream which are confined within any sufficiently short time are identical so far as they are definitely apprehended, and thus these various component streams, each homogeneous, "cohere" to form the whole composite partial stream; (3) there are other sense-presentations occurring in association with that composite partial stream which can be determined by rules derived from analogous composite partial streams, with other space and time relations, provided that the analogy be sufficiently close. Call these the "associated sense-presentations." A partial stream of this sort, viewed as a whole, is here called a "first crude thought-object of perception."

For example, we look at an orange for half a minute, handle it, and smell it, note its position in the fruit-basket, and then turn away. The stream of sense-presentation of the orange during that half-minute is a first crude thought-object of perception. Among the associated sense presentations are those of the fruit-basket which we conceive as supporting the orange.

The essential ground of the association of sense-objects of various types, perceived within one short duration, into a first crude thought-object of perception is the coincidence of their space-relations, that is, in general an approximate coincidence of such relations perhaps only vaguely apprehended. Thus coincident space-relations associate sense-objects into a first crude thought-object, and diverse space-relations dissociate sense-objects from aggregation into a first crude thought-object. In respect to some groups of sense-objects the association may be an immediate judgment devoid of all inference, so that the primary perceptual thought is that of the first crude thought-object, and the separate sense-objects are the result of reflective analysis acting on memory. For example sense-objects of sight and sense-objects of touch are often thus primarily associated and only secondarily dissociated in thought. But sometimes the association is wavering and indeterminate, for example, that between the sound-object of the mew of the cat and the sight-object of the cat. Thus to sum up, the partial stream of sense-perceptions coalesces into that first crude thought-object of perception which is the momentary cat because the sense-perceptions belonging to this stream are in the same place, but equally it would be true to say that they are in the same place because they belong to the same momentary cat. This analysis of the complete stream of sense-presentation in any small present duration into a variety of first crude thought-objects only partially fits the facts; for one reason because many sense-objects, such as sound for instance, have vague and indeterminate space-relations, for example vaguely those space-relations which we associate with our organs of sense and also vaguely those of the origin from which (in the scientific explanation) they proceed.

The procedure by which the orange of half a minute is elaborated into the orange in the ordinary sense of the term involves in addition the two principles of aggregation and of hypothetical sense-presentation.

The principle of aggregation, as here employed, takes the form that many distinct first crude thought-objects of perception are conceived as one thought-object of perception, if the many partial streams forming these objects are sufficiently analogous, if their times of occurrence are distinct, and if the associated sense-presentations are sufficiently analogous.

For example, after leaving the orange, in five minutes we return. A new first crude thought-object of perception presents itself to us, indistinguishable from the half-minute orange we previously experienced; it is in the same fruit-basket. We aggregate the two presentations of an orange into the same orange. By such aggregations we obtain "second crude thought-objects of perception." But however far we can proceed with aggregation of this type, the orange is more than that. For example, what do we mean when

we say, The orange is in the cupboard, if Tom has not eaten it?

The world of present fact is more than a stream of sense-presentation. We find ourselves with emotions, volitions, imaginations, conceptions, and judgments. No factor which enters into consciousness is by itself or even can exist in isolation. We are analysing certain relations between sense-presentation and other factors of consciousness. Hitherto we have taken into account merely the factors of concept and judgment. Imagination is necessary to complete the orange, namely, the imagination of hypothetical sense-presentations. It is beside the point to argue whether we ought to have such imaginations, or to discuss what are the metaphysical truths concerning reality to which they correspond. We are here only concerned with the fact that such imaginations exist and essentially enter into the formation of the concepts of the thought-objects of perception which are the first data of science. We conceive the orange as a permanent collection of sense-presentations existing as if they were an actual element in our consciousness, which they are not. The orange is thus conceived as in the cupboard with its shape, odour, colour, and other qualities. Namely, we imagine hypothetical possibilities of sense-presentation, and conceive their want of actuality in our consciousness as immaterial to their existence in fact. The fact which is essential for science is our conception; its meaning in regard to the metaphysics of reality is of no scientific importance, so far as physical science is concerned.

The orange completed in this way is the thought-object of perception.

It must be remembered that the judgments and concepts arising in the formation of thought-objects of perception are in the main instinctive judgments, and instinctive concepts, and are not concepts and judgments consciously sought for and consciously criticised before adoption. Their adoption is facilitated by and interwoven with the expectation of the future in which the hypothetical passes into the actual, and also with the further judgment of the existence of other consciousnesses, so that much that is hypothetical to one consciousness is judged to be actual to others.

The thought-object of perception is, in fact, a device to make plain to our reflective consciousness relations which hold within the complete stream of sense-presentation. Concerning the utility of this weapon there can be no question; it is the rock upon which the whole structure of commonsense thought is erected. But when we consider the limits of its application the evidence is confused. A great part of our sense-presentation can be construed as perception of various persistent thought-objects. But hardly at any time can the sense-presentations be construed wholly in that way. Sights lend themselves easily to this construction, but sight can be baffled: for example, consider reflections in looking-glasses, apparently bent sticks half in and half out of water, rainbows, brilliant patches of light which conceal the object from which they emanate, and many analogous phenomena. Sound is more difficult; it tends largely to disengage itself from any such object. For example, we see the bell, but we hear the sound which comes from the bell; yet we also say that we hear the bell. Again, a toothache is largely by itself, and is only indirectly a perception of the nerve of the tooth. Illustrations to the same effect can be accumulated from every type of sensation.

Another difficulty arises from the fact of change. The thought-object is conceived as one thing, wholly actual at each instant. But since the meat has been bought it has been cooked, the grass grows and then withers, the coal burns in the fire, the pyramids of Egypt remain unchanged for ages, but even the pyramids are not wholly unchanged. The difficulty of change is merely evaded by affixing a technical Latin name to a supposed logical fallacy. A slight cooking leaves the meat the same object, but two days in the oven burns it to a cinder. When does the meat cease to be? Now the chief use of the thought-object is the concept of it as one thing, here and now, which later can be recognised, there and then. This concept applies sufficiently well to most things for short times, and to many things for long times. But sense-presentation as a whole entirely refuses to be patient of the concept.

We have now come to the reflective region of explanation, which is science.

A great part of the difficulty is at once removed by applying the principle of convergence to simplicity. We habitually make our thought-objects too large; we should think in smaller parts. For example, the Sphinx has changed by its nose becoming chipped, but by proper inquiry we could find the missing part in some private house of Western Europe or Northern America. Thus, either part, the rest of the Sphinx or the chip, regains its permanence. Furthermore, we enlarge this explanation by conceiving parts so small that they can only be observed under the most favourable circumstances. This is a wide extension of the principle of convergence in its application to nature; but it is a principle amply supported by the history of exact observation.

Thus, change in thought-objects of perception is largely explained as a disintegration into smaller parts, themselves thought-objects of perception. The thought-objects of perception which are presupposed in the common thought of civilised beings are almost wholly hypothetical. The material universe is largely a concept of the imagination which rests on a slender basis of direct sense-presentation. But none the less it is a fact; for it is a fact that actually we imagine it. Thus it is actual in our consciousness just

as sense-presentation also is actual there. The effort of reflective criticism is to make these two factors in our consciousness agree where they are related, namely, to construe our sense-presentation as actual realisation of the hypothetical thought-objects of perception.

The wholesale employment of purely hypothetical thought-objects of perception enables science to explain some of the stray sense-objects which cannot be construed as perceptions of a thought-object of perception: for example, sounds. But the phenomena as a whole defy explanation on these lines until a further fundamental step is taken, which transforms the whole concept of the material universe. Namely, the thought-object of perception is superseded by the thought-object of science.

The thought-objects of science are molecules, atoms, and electrons. The peculiarity of these objects is that they have shed all the qualities which are capable of direct sense-representation in consciousness. They are known to us only by their associated phenomena, namely, series of events in which they are implicated are represented in our consciousness by sense-presentations. In this way, the thought-objects of science are conceived as the causes of sense-representation. The transition from thought-objects of perception to thought-objects of science is decently veiled by an elaborate theory concerning primary and secondary qualities of bodies.

This device, by which sense-presentations are represented in thought as our perception of events in which thought-objects of science are implicated, is the fundamental means by which a bridge is formed between the fluid vagueness of sense and the exact definition of thought. In thought a proposition is either true or false, an entity is exactly what it is, and relations between entities are expressible (in idea) by definite propositions about distinctly conceived entities. Sense-perception knows none of these things, except by courtesy. Accuracy essentially collapses at some stage of inquiry.

III. Time and Space

Recapitulation.--Relations of time and relations of space hold between sense-objects of perception. These sense-objects are distinguished as separate objects by the recognition of either (1) differences of sense-content, or (2) time-relations between them other than simultaneity, or (3) space-relations between them other than coincidence. Thus sense-objects arise from the recognition of contrast within the complete stream of sense-presentation, namely, from the recognition of the objects as related terms, by relations which contrast them. Differences of sense-content are infinitely complex in their variety. Their analysis under the heading of general ideas is the unending task of physical science. Time-relations and space-relations are comparatively simple, and the general ideas according to which their analysis should proceed are obvious.

This simplicity of time and space is perhaps the reason why thought chooses them as the permanent ground for objectival distinction, throwing the various sense-objects thus obtainable into one heap, as a first crude thought-object of perception, and thence, as described above, obtaining a thought-object of perception. Thus a thought-object of perception conceived as in the present of a short duration is a first crude thought-object of perception either actual or hypothetical. Such a thought-object of perception, confined within a short duration, takes on the space-relations of its component sense-objects within that same duration. Accordingly thought-objects of perception, conceived in their whole extents, have to each other the time-relationships of their complete existences, and within any small duration have to each other the space-relationships of their component sense-objects which lie within that duration.

Relations bind together: thus thought-objects of perception are connected in time and in space. The genesis of the objectival analysis of sense-presentation is the recognition of sense-objects as distinct terms in time-relations and space-relations: thus thought-objects of perception are separated by time and by space.

Whole and Part.--A sense-object is part of the complete stream of presentation. This concept of being a part is merely the statement of the relation of the sense-object to the complete sense-presentation for that consciousness. Also a sense-object can be part of another sense-object. It can be a part in two ways, namely, a part in time and a part in space. It seems probable that both these concepts of time-part and space-part are fundamental; that is, are concepts expressing relations which are directly presented to us, and are not concepts about concepts. In that case no further definition of the actual presentation is possible. It may even then be possible to define an adequate criterion of the occurrence of such a presentation. For example, adopting for the moment a realist metaphysic as to the existence of the physical world of molecules and electrons, the vision of a chair as occurring for some definite person at some definite time is essentially indefinable. It is his vision, though each of us guesses that it must be uncommonly like our vision under analogous circumstances. But the existence of the definable molecules and waves of light in certain definable relations to his bodily organs of sense, his body also being in a certain definable state, forms an adequate criterion

of the occurrence of the vision, a criterion which is accepted in Courts of Law and for physical science is tacitly substituted for the vision.

The connection between the relations "whole and part" and "all and some" is intimate. It can be explained thus so far as concerns directly presented sense-objects. Call two sense-objects "separated" if there is no third sense-object which is a part of both of them. Then an object A is composed of the two objects B and C, if (1) B and C are both parts of A, (2) B and C are separated, and (3) there is no part of A which is separated both from B and from C. In such a case the class α which is composed of the two objects B and C is often substituted in thought for the sense-object A. But this process presupposes the fundamental relation "whole and part." Conversely the objects B and C may be actual sense-objects, but the sense-object A which corresponds to the class α may remain hypothetical. For example, the round world on which we live remains a conception corresponding to no single sense-object at any time presented in any human being's consciousness.

It is possible, however, that some mode of conceiving the whole-and-part relation between extended objects as the all-and-some relation of logical classes can be found. But in this case the extended objects as here conceived cannot be the true sense-objects which are present to consciousness. For as here conceived a part of a sense-object is another sense-object of the same type; and therefore one sense-object cannot be a class of other sense-objects, just as a tea-spoon cannot be a class of other tea-spoons. The ordinary way in thought by which whole-and-part is reduced to all-and-some is by the device of points, namely, the part of an object occupies some of the points occupied by the whole object. If any one holds that in his consciousness the sense-presentation is a presentation of point-objects, and that an extended object is merely a class of such point-objects collected together in thought, then this ordinary method is completely satisfactory. We shall proceed on the assumption that this conception of directly perceived point-objects has no relation to the facts.

In the preceding address on "The Organisation of Thought," another mode is suggested. But this method would apply only to the thought-object of perception, and has no reference to the primary sense-objects here considered. Accordingly it must reckon as a subordinate device for a later stage of thought.

Thus the point-object in time and the point-object in space, and the double point-object both in time and space, must be conceived as intellectual constructions. The fundamental fact is the sense-object, extended both in time and space, with the fundamental relation of whole-to-part to other such objects, and subject to the law of convergence to simplicity as we proceed in thought through a series of successively contained parts.

The relation whole-to-part is a temporal or spatial relation, and is therefore primarily a relation holding between sense-objects of perception, and it is only derivatively ascribed to the thought-objects of perception of which they are components. More generally, space and time relations hold primarily between sense-objects of perception and derivatively between thought-objects of perception.

Definition of Points.--The genesis of points of time and of space can now be studied. We must distinguish (1) sense-time and sense-space, and (2) thought-time of perception and thought-space of perception.

Sense-time and sense-space are the actually observed time-relations and space-relations between sense-objects. Sense-time and sense-space have no points except, perhaps, a few sparse instances, sufficient to suggest the logical idea; also, sense-time and sense-space are discontinuous and fragmentary.

Thought-time of perception and thought-space of perception are the time and space relations which hold between thought-objects of perception. Thought-time of perception and thought-space of perception are each continuous. By "continuous" is here meant that all thought-objects of perception have to each other a time (or space) relation.

The origin of points is the effort to take full advantage of the principle of convergence to simplicity. In so far as this principle does not apply, a point is merely a cumbrous way of directing attention to a set of relations between a certain set of thought-objects of perception, which set of relations, though actual so far as a thought-object is actual, is (under this supposition) of no particular importance. Thus the proved importance in physical science of the concepts of points in time and points in space is a tribute to the wide applicability of this principle of convergence.

Euclid defines a point as without parts and without magnitude. In modern language a point is often described as an ideal limit by indefinitely continuing the process of diminishing a volume (or area). Points as thus conceived are often called convenient fictions. This language is ambiguous. What is meant by a fiction? If it means a conception which does not correspond to any fact, there is

some difficulty in understanding how it can be of any use in physical science. For example, the fiction of a red man in a green coat inhabiting the moon can never be of the slightest scientific service, simply because--as we may presume--it corresponds to no fact. By calling the concept of points a convenient fiction, it must be meant that the concept does correspond to some important facts. It is, then, requisite, in the place of such vague allusiveness, to explain exactly what are the facts to which the concept corresponds.

We are not much helped by explaining that a point is an ideal limit. What is a limit? The idea of a limit has a precise meaning in the theory of series, and in the theory of the values of functions; but neither of these meanings apply here. It may be observed that, before the ordinary mathematical meanings of limit had received a precise explanation, the idea of a point as a limit might be considered as one among other examples of an idea only to be apprehended by direct intuition. This view is not now open to us. Thus, again, we are confronted with the question: What are the precise properties meant when a point is described as an ideal limit? The discussion which now follows is an attempt to express the concept of a point in terms of thought-objects of perception related together by the whole-and-part relation, considered either as a time-relation or as a space-relation. If it is so preferred, it may be considered that the discussion is directed towards a precise elucidation of the term "ideal limit" as often used in this connection.

The subsequent explanations can be made easier to follow by a small piece of symbolism: Let _aEb_ mean that "_b_ is part of _a_." We need not decide whether we are talking of time-parts or space-parts, but whichever choice is supposed to be made must be conceived as adhered to throughout any connected discussion. The symbol _E_ may be considered as the initial letter of "encloses," so we read "_aEb_" as "_a_ encloses _b_." Again the "field of _E_" is the set of things which either enclose or are enclosed, _i. e._ everything "_a_," which is such that _x_ can be found so that either _aEx_ or _xEa_. A member of the field of _E_ is called "an enclosure-object."

Now, we assume that this relation of whole-to-part, which in the future we will call "enclosure," always satisfies the conditions in that the relation _E_ is (1) transitive, (2) asymmetrical, and (3) with its domain including its converse domain.

These four conditions deserve some slight consideration; only the first two of them embody hypotheses which enter vitally into the reasoning.

Condition (1) may be stated as the condition that _aEb_ and _bEc_ always implies _aEc_. The fact that an entity _b_ can be found such that _aEb_ and _bEc_ may be conceived as a relation between _a_ and _c_. It is natural to write _E_^2 for this relation. Thus the condition is now written: If _aE_^2_c_, then _aEc_. This can be still otherwise expressed by saying that the relation _E_^2 implies, whenever it holds, that the relation _E_ also holds.

Condition (2) is partly a mere question of trivial definition, and partly a substantial assumption. The asymmetrical relation (_E_) is such that _aEb_ and _bEa_ can never hold simultaneously. This property splits up into two parts: (1) that no instance of _aEb_ and _bEa_ and "_a_ diverse from _b_," can occur, and (2) that _aEa_ cannot occur. The first part is a substantial assumption, the second part (so far as we are concerned) reduces to the trivial convention that we shall not consider an object as part of itself, but will confine attention to "proper parts."

Condition (3) means that _aEb_ always implies that _c_ can be found such that _bEc_. This condition, taken in conjunction with the fact that we are only considering proper parts, is the assertion of the principle of the indefinite divisibility of extended objects, both in space and in time.

An indivisible part will lack duration in time, and extension in space, and is thus an entity of essentially a different character to a divisible part. If we admit such indivisibles as the only true sense-objects, our subsequent procedure is an unnecessary elaboration.

It will be found that a fourth condition is necessary owing to logical difficulties connected with the theory of an infinite number of choices. It will not be necessary for us to enter further on this question, which involves difficult considerations of abstract logic. The outcome is, that apart from hypothesis we cannot prove the existence of the sets, each containing an infinite number of objects, which are here called points, as will be explained immediately.

Now consider a set of enclosure objects which is such that (1) of any two of its members one encloses the other, and (2) there is no member which is enclosed by all the others, and (3) there is no enclosure-object, not a member of the set which is enclosed by every member of the set. Call such a set a "convergent set of enclosure-objects." As we pass along the series from larger to smaller members, evidently we converge towards an ideal simplicity to any degree of approximation to which we like to proceed, and the series as a whole embodies the complete ideal along that route of approximation. In fact, to repeat, the series is a _route of

approximation_.

We have now to inquire if the principle of convergence to simplicity may be expected to yield the same type of simplicity for every such convergent route. The answer is, as we might expect, namely, that this depends upon the nature of the properties which are to be simplified.

For example, consider the application to time. Now, time is one-dimensional; so when this property of one-dimensionality has been expressed by the proper conditions, not here stated, a convergent set of enclosure-objects must, considered as a route of approximation, exhibit the properties of one unique instant of time, as ordinarily conceived by the euclidean definition. Accordingly, whatever simplicity is to be achieved by the application to time of the principle of convergence to simplicity must be exhibited among the properties of any such route of approximation.

For space, different considerations arise. Owing to its multiple dimensions, we can show that different convergent sets of enclosure-objects, indicating different routes of approximation, may exhibit convergence to different types of simplicity, some more complex than others.

For example, consider a rectangular box of height _h_ ft., breadth _b_ ft., and thickness _c_ ft. Now, keep _h_ and _b_ constant, and let the central plane (height _h_, breadth _b_) perpendicular to the thickness be fixed, then make _c_ diminish indefinitely. We thus obtain a convergent series of an indefinitely large number of boxes, and there is no smallest box. Thus this convergent series exhibits the route of approximation towards the type of simplicity expressed as being a plane area of height _h_, breadth _b_, and no thickness.

Again, by keeping the central line of height _h_ fixed, and by making _b_ and _c_ diminish indefinitely, the series converges to the segment of a straight line of length _h_.

Finally, by keeping only the central point fixed, and by making _h_, _b_, and _c_ diminish indefinitely, the series converges to a point.

Furthermore, we have introduced as yet no concept which would prevent an enclosure-object being formed of detached fragments in space. Thus we can easily imagine a convergent set which converges to a number of points in space. For example, each object of the set might be formed of two not overlapping spheres of radius _r_, with centres _A_ and _B_. Then by diminishing _r_ indefinitely, and keeping _A_ and _B_ fixed, we have convergence to the pair of points _A_ and _B_.

It remains now to consider how those convergent sets which converge to a single point can be discriminated from all the other types of such sets, merely by utilising concepts founded on the relation of enclosure.

Let us name convergent sets by Greek letters; by proceeding "forward" along any such set let us understand the process of continually passing from the larger to the smaller enclosure-objects which form the set.

The convergent set α will be said to "cover" the convergent set β, if every member of α encloses some members of β. We notice that if an enclosure-object _x_ encloses any member (_y_) of β, then every member of the "tail-end" of β, found by proceeding forward along β from _y_, must be enclosed by _x_. Thus if α covers β, every member of α encloses every member of the tail-end of β, starting from the largest member of β which is enclosed by that member of α.

It is possible for each of two convergent sets to cover the other. For example, let one set (α) be a set of concentric spheres converging to their centre _A_, and the other set (β) be a set of concentric cubes, similarly situated, converging to the same centre _A_. Then α and β will each cover the other.

Let two convergent sets which are such that each covers the other be called "equal."

Then it is a sufficient condition to secure that a convergent set α possesses the point type of convergence, if every convergent set covered by it is also equal to it, namely, α is a convergent set with the punctual type of convergence, if "α covers β" always implies that β covers α.

It can easily be seen by simple examples that the other types of convergence to surfaces or lines or sets of points cannot possess this property. Consider, for example, the three convergent sets of boxes in the preceding illustration, which converge respectively to a central plane, a central line in the central plane, and the central point in the central line. The first set covers the second and third sets, and the second set covers the third set, but no two of the sets are equal.

It is a more difficult question to determine whether the condition here indicated as sufficient to secure the punctual type of convergence is also necessary. The question turns on how far thought-objects of perception possess exact boundaries prior to the elaboration of exact mathematical concepts of space. If they are to be conceived as possessing such exact boundaries, then convergent sets converging to points on such boundaries must be allowed for. The procedure necessary for the specification of the complete punctual condition becomes then very elaborate,[3] and will not be considered here.

But such exact determination as is involved in the conception of an exact spatial boundary does not seem to belong to the true thought-object of perception. The ascription of an exact boundary really belongs to the transition stage of thought as it passes from the thought-object of perception to the thought-object of science. The transition from the sense-object immediately presented to the thought-object of perception is historically made in a wavering indeterminate line of thought. The definite stages here marked out simply serve to prove that a logically explicable transition is possible.

We accordingly assume that the condition laid down above to secure the punctual convergence of a convergent set of enclosure-objects is not only sufficient, but necessary.

It can be proved that, if two convergent sets of enclosure-objects are both equal to a third convergent set, they are equal to each other. Consider now any punctual convergent set (α). We want to define the "point" to which α is a route of approximation in a way which is neutral between α and all the convergent sets which are equal to α. Each of these sets is a route of approximation to the same "point" as α. This definition is secured if we define the point as the class formed by all the enclosure-objects which belong either to α or to any convergent set which is equal to α. Let _P_ be this class of enclosure-objects. Then any convergent set (β) which consists of enclosure-objects entirely selected from members of the class _P_ must be a route of approximation to the same "point" as does the original punctual set α; namely, provided that we choose a small enough enclosure-object in β, we can always find a member of α which encloses it; and provided that we choose a small enough enclosure-object in α, we can always find a member of β which encloses it. Thus _P_ only includes convergent sets of the punctual type, and the route of approximation indicated by any two convergent sets selected from _P_ converges to identical results.

The Uses of Points.--The sole use of points is to facilitate the employment of the principle of Convergence to Simplicity. By this principle some simple relations in appropriate circumstances become true, when objects are considered which are sufficiently restricted in time or in space. The introduction of points enables this principle to be carried through to its ideal limit. For example, suppose _g_ (_a_, _b_, _c_) represents some statement concerning three enclosure-objects, _a_, _b_, _c_, which may be true if the objects are sufficiently restricted in extent. Let _A_, _B_, _C_ be three given points, then we define _g_ (_A_, _B_, _C_) to mean that _whatever_ three enclosure-objects _a_, _b_, _c_ are chosen, such that _a_ is a member of _A_, _b_ of _B_, and _c_ of _C_, it is _always possible_ to find three other members of _A_, _B_, _C_, namely, _x_ a member of _A_, _y_ of _B_, and _z_ of _C_, such that _aEx_, _bEy_, _cEz_, and _g_ (_x_, _y_, _z_). So by going far enough down in the tail-ends of _A_, _B_, _C_ we can always secure three objects _x_, _y_, _z_ for which _g_ (_x_, _y_, _z_) is true.

For example, let _g_ (_A_, _B_, _C_) mean "_A_, _B_, _C_ are three points in a linear row." This must be construed to mean that whatever three objects _a_, _b_, _c_ we choose, members of _A_, _B_, _C_ respectively, we can always find three objects _x_, _y_, _z_, also members of _A_, _B_, _C_ respectively, and such that _a_ encloses _x_, _b_ encloses _y_, _c_ encloses _z_, and also such that _x_, _y_, _z_ are in a linear row.

Sometimes a double convergence is necessary, namely, a convergence of conditions as well as a convergence of objects. For example, consider the statement, "the points _A_ and _B_ are two feet apart." Now, the exact statement "two feet apart" does not apply to objects. For objects _x_ and _y_ we must substitute the statement, "the distance between _x_ and _y_ lies between the limits (2 ± _e_) feet." Here _e_ is some number, less than two, which we have chosen for this statement. Then the points _A_ and _B_ are two feet apart; if, _however we choose the number e_, whatever enclosure-objects _a_ and _b_, members of _A_ and _B_ respectively, we consider, we can always find enclosure-objects _x_ and _y_, members of _A_ and _B_ respectively, such that _a_ encloses _x_ and _b_ encloses _y_, and also such that the distance between _x_ and _y_ lies between the limits (2 ± _e_) feet. It is evident, since _e_ can be chosen as small as we please, that this statement exactly expresses the condition that _A_ and _B_ are two feet apart.

Straight Lines and Planes.--But the problem of the intellectual construction of straight lines and planes is not yet sufficiently analysed. We have interpreted the meaning of the statement that three or more points are collinear, and can similarly see how to interpret the meaning of the statement that four or more points are coplanar, in either case deriving the exact geometrical

statements from vaguer statements respecting extended objects.

This procedure only contemplates groups of finite numbers of points. But straight lines and planes are conceived as containing infinite numbers of points. This completion of lines and planes is obtained by a renewed application of the principle of aggregation, just as a set of first crude thought-objects of perception are aggregated into one complete thought-object of perception. In this way repeated judgments of the collinearity of sets of points are finally, when certain conditions of interlacing are fulfilled, aggregated in the single judgment of all the points of the groups as forming one whole collinear group. Similarly for judgments of coplanarity. This process of logical aggregation can be exhibited in its exact logical analysis. But it is unnecessary here to proceed to such details. Thus we conceive our points as sorted into planes and straight lines, concerning which the various axioms of geometry hold. These axioms, in so far as they essentially require the conception of points, are capable of being exhibited as the outcome of vaguer, less exact judgments respecting the relations of extended objects.

Empty Space.--It must be observed that the points, hitherto defined, necessarily involve thought-objects of perception, and lie within the space-extension occupied by such objects. It is true that such objects are largely hypothetical, and that we can bring into our hypotheses sufficient objects to complete our lines and planes. But every such hypothesis weakens the connection between our scientific concept of nature and the actual observed facts which are involved in the actual sense-presentations.

Occam's razor, _Entia non multiplicanda præter necessitatem_, is not an arbitrary rule based on mere logical elegancy. Nor is its application purely confined to metaphysical speculation. I am ignorant of the precise reason for its metaphysical validity, but its scientific validity is obvious, namely, every use of hypothetical entities diminishes the claim of scientific reasoning to be the necessary outcome of a harmony between thought and sense-presentation. As hypothesis increases, necessity diminishes.

Commonsense thought also supports this refusal to conceive of all space as essentially depending on hypothetical objects which fill it. We think of material objects as filling space, but we ask whether any objects exist between the Earth and the Sun, between the stars, or beyond the stars. For us, space is there; the only question is whether or not it be full. But this form of question presupposes the meaning of empty space, namely, of space not containing hypothetical objects.

This brings up a wider use of the concept of points, necessitating a wider definition. Hitherto we have conceived points as indicating relations of enclosure between objects. We thus arrive at what now we will term "material points." But the idea of points can now be transformed so as to indicate the possibilities of external relations not those of enclosure. This is effected by an enlargement of the concept of ideal points, already known to geometers.

Define "material lines" to be complete collinear classes of collinear points. Consider now the set of material lines which contain a certain material point. Call such a set of lines an ideal point. This set of lines indicates a possibility of position, which is in fact occupied by that material point common to all the material lines. So this ideal point is an occupied ideal point. Now consider a set of three material lines, such that any two are coplanar, but not the whole three, and further consider the complete set of material lines such that each is coplanar with each of the three material lines first chosen. The axioms which hold for the material lines will enable us to prove that any two lines of this set are coplanar. Then the whole set of lines, including the three original lines, forms an ideal point, according to the definition in its full generality. Such an ideal point may be occupied. In that case there is a material point common to all the lines of the set, but it may be unoccupied. Then the ideal point merely indicates a possibility of spatial relations which has not been realised. It is the point of empty space. Thus the ideal points, which may or may not be occupied, are the points of geometry viewed as an applied science. These points are distributed into straight lines and planes. But any further discussion of this question will lead us into the technical subject of the axioms of geometry and their immediate consequences. Enough has been said to show how geometry arises according to the relational theory of space.

Space as thus conceived is the thought-space of the material world.

IV. Fields of Force

The thought-objects of science are conceived as directly related to this thought-space. Their spatial relations are among those indicated by the points of the thought-space. Their emergence in science has been merely a further development of processes already inherent in commonsense thought.

Relations within the complete sense-presentation were represented in thought by the concept of thought-objects of perception. All sense-presentation could not be represented in this way; also the change and disappearance of thought-objects occasioned confusion of thought. A reduction to order of this confusion was attempted by the concepts of permanent matter with primary and

secondary qualities. Finally, this has issued in the secondary qualities being traced as perception of events generated by the objects, but--as perceived--entirely disconnected with them. Also the thought-objects of perception have been replaced by molecules and electrons and ether-waves, until at length it is never the thought-object of science which is perceived, but complicated series of events in which they are implicated. If science be right, nobody ever perceived a thing, but only an event. The result is, that the older language of philosophy which still survives in many quarters is now thoroughly confusing when brought into connection with the modern concepts of science. Philosophy--that is, the older philosophy--conceives the thing as directly perceived. According to scientific thought, the ultimate thing is never perceived, perception essentially issuing from a series of events. It is impossible to reconcile the two points of view.

The advantage of the modern scientific concept is that it is enabled to "explain" the fluid vague outlines of sense-presentation. The thought-object of perception is now conceived as a fairly stable state of motion of a huge group of molecules, constantly changing, but preserving a certain identity of characteristics. Also stray sense-objects, not immediately given as part of a thought-object of perception, are now explicable: the dancing light-reflection, the vaguely heard sound, the smell. In fact, the perceived events of the scientific world have the same general definition and lack of definition, and the same general stability and lack of stability, as the sense-objects of the complete sense-presentation or as the thought-objects of perception.

The thought-objects of science, namely, molecules, atoms, and electrons, have gained in permanence. The events are reduced to changes in space-configuration. The laws determining these changes are the ultimate laws of nature.

The laws of change in the physical universe proceed on the assumption that the preceding states of the universe determine the character of the change. Thus, to know the configurations and events of the universe up to and including any instant would involve sufficient data from which to determine the succession of events throughout all time.

But in tracing the antecedents of events, commonsense thought, dealing with the world of thought-objects of perception, habitually assumes that the greater number of antecedent events can be neglected as irrelevant. Consideration of causes is restricted to a few events during a short preceding interval. Finally, in scientific thought it has been assumed that the events in an arbitrarily small preceding duration are sufficient. Thus physical quantities and their successive differential co-efficients up to any order at the instant, but with their limiting values just before that instant, are on this theory sufficient to determine the state of the universe at all times after the instant. More particular laws are assumed. But the search for them is guided by this general principle. Also it is assumed that the greater number of events in the physical universe are irrelevant to the production of any particular effect, which is assumed to issue from relatively few antecedents. These assumptions have grown out of the experience of mankind. The first lesson of life is to concentrate attention on few factors of sense-presentations, and on still fewer of the universe of thought-objects of perception.

The principle by which--consciously or unconsciously--thought has been guided is that in searching for particular causes, remoteness in time and remoteness in space are evidences of comparative disconnection of influence. The extreme form of this principle is the denial of any action at a distance either in time or space. The difficulty in accepting this principle in its crude form is, that since there are no contiguous points, only coincident bodies can act on each other. I can see no answer to this difficulty--namely, either bodies have the same location and are thus coincident, or they have different locations and are thus at a distance and do not act on each other.

This difficulty is not evaded by the hypothesis of an ether, continuously distributed. For two reasons: in the first place, the continuity of the ether does not avoid the dilemma; and secondly, the difficulty applies to time as well as to space, and the dilemma would prove that causation producing change is impossible, namely, no changed condition could be the result of antecedent circumstances.

On the other hand, a direct interaction between two bodies separated in space undoubtedly offends the conception of distance as implying physical disconnection as well as spatial relation. There is no logical difficulty in the assumption of action at a distance as in the case of its denial, but it is contradictory to persistent assumptions of that apparatus of commonsense thought which it is the main business of science to harmonise with sense-presentation, employing only the minimum of modification.

Modern science is really unconcerned with this debate. Its (unacknowledged) conceptions are really quite different, though the verbal explanations retain the form of a previous epoch. The point of the change in conception is that the old thought-object of science was conceived as possessing a simplicity not belonging to the material universe as a whole. It was secluded within a finite region of space, and changes in its circumstances could only arise from forces which formed no essential part of its nature. An

ether was called into existence to explain the active relations between these passive thought-objects. The whole conception suffers from the logical difficulties noted above. Also no clear conception can be formed of the sense in which the ether is explanatory. It is to possess a type of activity denied to the original thought-object, namely, it carries potential energy, whereas the atom possessed only kinetic energy, the so-called potential energy of an atom belonging really to the surrounding ether. The truth is, that ether is really excepted from the axiom "no action at a distance," and the axiom thereby is robbed of all its force.

The modern thought-object of science--not yet explicitly acknowledged--has the complexity of the whole material universe. In physics, as elsewhere, the hopeless endeavour to derive complexity from simplicity has been tacitly abandoned. What is aimed at is not simplicity, but persistence and regularity. In a sense regularity is a sort of simplicity. But it is the simplicity of stable mutual relations, and not the simplicity of absence of types of internal structure or of type of relation. This thought-object fills all space. It is a "field"; that is to say, it is a certain distribution of scalar and vector quantities throughout space, these quantities having each its value for each point of space at each point of time, being continuously distributed throughout space and throughout time, possibly with some exceptional discontinuities. The various types of quantity which form the field have fixed relations to each other at each point of time and space. These relations are the ultimate laws of nature.

For example, consider an electron. There is a scalar distribution of electricity, which is what is ordinarily called the electron. This scalar distribution has a volume-density ρ at the time _t_ at any point (_x_, _y_, _z_). Thus ρ is a function of (_x_, _y_, _z_, _t_), which is zero except within a restricted region. Furthermore, at any time _t_, as an essential adjunct, there is a continuous space distribution at each point of the two vectors (_X_, _Y_, _Z_), which is the electric force, and (α, β, γ), which is the magnetic force. Lastly, individuality is ascribed to the scalar electric distribution, so that in addition to its conservation of quantity--involved in the assumed laws--it is also possible to assign the velocities with which the various individual parts of the distribution are moving. Let (_u_, _v_, _w_) be this velocity at (_x_, _y_, _z_, _t_).

This whole scheme of scalar and vector quantities, namely, ρ, (_X_, _Y_, _Z_), (α, β, γ), (_u_, _v_, _w_) is interconnected by the electromagnetic laws. It follows from these laws that the electron, in the sense of the scalar distribution ρ, is to be conceived as at each instant propagating from itself an emanation which travels outwards with the velocity of light _in vacuo_, and from which (_X_, _Y_, _Z_) and (α, β, γ) can be calculated, so far as they are due to that electron. Thus the field, at any time, due to the electron as a whole depends on the previous history of the electron, the nearer to the electron the more recent being the relevant history. The whole scheme of such a field is one single thought-object of science: the electron and its emanations form one essential whole, namely one thought-object of science, essentially complex and essentially filling all space. The electron proper, namely, the scalar distribution ρ, is the focus of the whole, the essential focal property being that the field at any instant is completely determined by the previous history of the focus and of its space relations through all previous time. But the field and the focus are not independent concepts, they are essentially correlated in one organised unity, namely, they are essentially correlated terms in the field of one relation in virtue of which the entities enter into our thoughts.

The fields of a group of electrons are superposed according to the linear law for aggregation, namely, pure addition for analogous scalar quantities and the parallelogram law for analogous vectors. The changes in motion of each electron depend entirely on the resultant field in the region it occupies. Thus a field can be viewed as a possibility of action, but a possibility which represents an actuality.

It is to be noted that the two alternative views of causation are here both included. The complete field within any region of space depends on the past histories of all the electrons, histories extending backwards in proportion to their distances. Also this dependence can be conceived as a transmission. But viewing the cause which effects changes on the electron within that region, it is solely that field within the region, which field is coincident with that electron both in time and in space.

This process of conceiving the actuality underlying a possibility is the uniform process by which regularity and permanence is introduced into scientific thought, namely, we proceed from the actuality of the fact to the actuality of possibility.

In conformity with this principle, propositions are the outgrowth from actual thought-expressions, thought-objects of perceptions from crude sense-objects, hypothetical thought-objects of perception from actual thought-objects of perception, material points from hypothetical infinite suites of hypothetical thought-objects of perception, ideal points from material points, thought-objects of science from thought-objects of perception, fields of electrons from actual mutual reactions of actual electrons.

The process is a research for permanence, uniformity, and simplicity of logical relation. But it does not issue in simplicity of internal structure. Each ultimate thought-object of science retains every quality attributed to the whole scientific universe, but retains them

in a form characterised by permanence and uniformity.

V. Conclusion

We commenced by excluding judgments of worth and ontological judgments. We conclude by recalling them. Judgments of worth are no part of the texture of physical science, but they are part of the motive of its production. Mankind have raised the edifice of science, because they have judged it worth while. In other words, the motives involve innumerable judgments of value. Again, there has been conscious selection of the parts of the scientific field to be cultivated, and this conscious selection involves judgments of value. These values may be æsthetic, or moral, or utilitarian, namely, judgments as to the beauty of the structure, or as to the duty of exploring the truth, or as to utility in the satisfaction of physical wants. But whatever the motive, without judgments of value there would have been no science.

Again, ontological judgments were not excluded by reason of any lack of interest. They are in fact presupposed in every act of life: in our affections, in our self-restraints, and in our constructive efforts. They are presupposed in moral judgments. The difficulty about them is the absence of agreement as to the method of harmonising the crude judgments of commonsense.

Science does not diminish the need of a metaphysic. Where this need is most insistent is in connection with what above has been termed "the actuality underlying a possibility." A few words of explanation may render the argument clearer, although they involve a rash approach to metaphysical heights which it is not the purpose of this paper to explore.

The conception of subject and object in careless discussion covers two distinct relations. There is the relation of the whole perceiving consciousness to part of its own content, for example, the relation of a perceiving consciousness to an object of redness apparent to it. There is also the relation of a perceiving consciousness to an entity which does not exist in virtue of being part of the content of that consciousness. Such a relation, so far as known to the perceiving consciousness, must be an inferred relation, the inference being derived from an analysis of the content of the perceiving consciousness.

The bases for such inferences must be elements in consciousness directly known as transcending their immediate presentation in consciousness. Such elements are universal logical truths, moral and æsthetic truths, and truths embodied in hypothetical propositions. These are the immediate objects of perception which are other than the mere affections of the perceiving subject. They have the property of being parts of the immediate presentations for individual subjects and yet more than such parts. All other existence is inferred existence.

In this chapter we are more directly concerned with truths embodied in hypothetical propositions. Such truths must not be confused with any doubtfulness which attaches to our judgments of the future course of natural phenomena. A hypothetical proposition, like a categorical judgment, may or may not be doubtful. Also like a categorial judgment, it expresses a fact. This fact is twofold: as a presentation in consciousness, it is just this hypothetical judgment; as expressing a categorical fact, it states a relation which lies beyond consciousness, holding between entities thereby inferred.

But this metaphysical analysis, short though it be, is probably wrong, and at the best will only command very partial assent. Certainly; and this admission brings out the very point which I wished to make. Physical science is based on elements of thought, such as judgments registering actual perceptions, and judgments registering hypothetical perceptions which under certain circumstances would be realised. These elements form the agreed content of the apparatus of commonsense thought. They require metaphysical analysis; but they are among the data from which metaphysics starts. A metaphysic which rejects them has failed, in the same way as physical science has failed when it is unable to harmonise them into its theory.

Science only renders the metaphysical need more urgent. In itself it contributes little directly to the solution of the metaphysical problem. But it does contribute something, namely, the exposition of the fact that our experience of sensible apparent things is capable of being analysed into a scientific theory, a theory not indeed complete, but giving every promise of indefinite expansion. This achievement emphasises the intimate relation between our logical thought and the facts of sensible apprehension. Also the special form of scientific theory is bound to have some influence. In the past false science has been the parent of bad metaphysics. After all, science embodies a rigorous scrutiny of one part of the whole evidence from which metaphysicians deduce their conclusions.

FOOTNOTES:

[Footnote 3: Cf. _Révue de Métaphysique et de Morale_, May 1916, where this question is dealt with by the author at the end of an article, "La théorie relationniste de l'espace."]

CHAPTER VIII

SPACE, TIME, AND RELATIVITY

(_Paper read to Section A at the Manchester Meeting of the British Association, 1915, and later before the Aristotelian Society_)

FUNDAMENTAL Problems concerning space and time have been considered from the standpoints created by many different sciences. The object of this paper is the humble one of bringing some of these standpoints into relation with each other. This necessitates a very cursory treatment of each point of view.

Mathematical physicists have evolved their theory of relativity to explain the negative results of the Morley-Michelson experiment and of the Trouton experiment. Experimental psychologists have considered the evolution of spatial ideas from the crude sense-data of experience. Metaphysicians have considered the majestic uniformity of space and time, without beginning and without end, without boundaries, and without exception in the truths concerning them; all these qualities the more arresting to our attention from the confused accidental nature of the empirical universe which is conditioned by them. Mathematicians have studied the axioms of geometry, and can now deduce all that is believed to be universally true of space and of time by the strictest logic from a limited number of assumptions.

These various lines of thought have been evolved with surprisingly little interconnection. Perhaps it is as well. The results of science are never quite true. By a healthy independence of thought perhaps we sometimes avoid adding other people's errors to our own. But there can be no doubt that the normal method of cross-fertilising thought is by considering the same, or allied problems to our own, in the form which they assume in other sciences.

Here I do not propose to enter into a systematic study of these various chapters of science. I have neither the knowledge nor the time.

First, let us take the ultimate basis of any theory of relativity. All space measurement is from stuff in space to stuff in space. The geometrical entities of empty space never appear. The only geometrical properties of which we have any direct knowledge are properties of those shifting, changeable appearances which we call things in space. It is the sun which is distant, and the ball which is round, and the lamp-posts which are in linear order. Wherever mankind may have got its idea of an infinite unchangeable space from, it is safe to say that it is not an immediate deliverance of direct observation.

There are two antagonistic philosophical ways of recognising this conclusion.

One is to affirm that space and time are conditions for sensible experience, that without projection into space and time sensible experience would not exist. Thus, although it may be true to say that our knowledge of space and time is given in experience, it is not true to say that it is deduced from experience in the same sense that the Law of Gravitation is so deduced. It is not deduced, because in the act of experiencing we are necessarily made aware of space as an infinite given whole, and of time as an unending uniform succession. This philosophical position is expressed by saying that space and time are _a priori_ forms of sensibility.

The opposed philosophical method of dealing with the question is to affirm that our concepts of time and space are deductions from experience, in exactly the same way as the Law of Gravitation is such a deduction. If we form exact concepts of points, lines and surfaces, and of successive instants of time, and assume them to be related as expressed by the axioms of geometry and the axioms for time, then we find that we have framed a concept which, with all the exactness of which our observations are capable, expresses the facts of experience.

These two philosophic positions are each designed to explain a certain difficulty. The _a priori_ theory explains the absolute universality ascribed to the laws of space and time, a universality not ascribed to any deduction from experience. The experiential theory explains the derivation of the space-time concepts without introducing any other factors beyond those which are admittedly present in framing the other concepts of physical science.

But we have not yet done with the distinctions which in any discussion of space or time must essentially be kept in mind. Put aside the above question as to how these space-time concepts are related to experience--What are they when they are formed?

We may conceive of the points of space as self-subsistent entities which have the indefinable relation of being occupied by the ultimate stuff (matter, I will call it) which is there. Thus, to say that the sun is _there_ (wherever it is) is to affirm the relation of occupation between the set of positive and negative electrons which we call the sun and a certain set of points, the points having an existence essentially independent of the sun. This is the absolute theory of space. The absolute theory is not popular just now, but it has very respectable authority on its side--Newton, for one--so treat it tenderly.

The other theory is associated with Leibniz. Our space concepts are concepts of relations between things in space. Thus there is no such entity as a self-subsistent point. A point is merely the name for some peculiarity of the relations between the matter which is, in common language, said to be in space.

It follows from the relative theory that a point should be definable in terms of the relations between material things. So far as I am aware, this outcome of the theory has escaped the notice of mathematicians, who have invariably assumed the point as the ultimate starting ground of their reasoning. Many years ago I explained some types of ways in which we might achieve such a definition, and more recently have added some others. Similar explanations apply to time. Before the theories of space and time have been carried to a satisfactory conclusion on the relational basis, a long and careful scrutiny of the definitions of points of space and instants of time will have to be undertaken, and many ways of effecting these definitions will have to be tried and compared. This is an unwritten chapter of mathematics, in much the same state as was the theory of parallels in the eighteenth century.

In this connection I should like to draw attention to the analogy between time and space. In analysing our experience we distinguish events, and we also distinguish things whose changing relations form the events. If I had time it would be interesting to consider more closely these concepts of events and of things. It must suffice now to point out that things have certain relations to each other which we consider as relations between the space extensions of the things; for example, one space can contain the other, or exclude it, or overlap it. A point in space is nothing else than a certain set of relations between spatial extensions.

Analogously, there are certain relations between events which we express by saying that they are relations between the temporal durations of these events, that is, between the temporal extensions of the events. [The durations of two events A and B may one precede the other, or may partially overlap, or may one contain the other, giving in all six possibilities.] The properties of the extension of an event in time are largely analogous to the extension of an object in space. Spatial extensions are expressed by relations between objects, temporal extensions by relations between events.

The point in time is a set of relations between temporal extensions. It needs very little reflection to convince us that a point in time is no direct deliverance of experience. We live in durations, and not in points. But what community, beyond the mere name, is there between extension in time and extension in space? In view of the intimate connection between time and space revealed by the modern theory of relativity, this question has taken on a new importance.

I have not thought out an answer to this question. I suggest, however, that time and space embody those relations between objects on which depends our judgment of their externality to ourselves. Namely, location in space and location in time both embody and perhaps necessitate a judgment of externality. This suggestion is very vague, and I must leave it in this crude form.

Diverse Euclidean Measure Systems

Turning now to the mathematical investigations on the axioms of geometry, the outcome, which is most important for us to remember, is the great separation which it discloses between non-metrical projective geometry, and metrical geometry. Non-metrical projective geometry is by far the more fundamental. Starting with the concepts of points, straight lines, and planes (of which not all three need be taken as indefinable), and with certain very simple non-metrical properties of these entities--such as, for instance, that two points uniquely determine a straight line--nearly the whole of geometry can be constructed. Even quantitative coordinates can be introduced, to facilitate the reasoning. But no mention of distance, area, or volume, need have been introduced. Points will have an order on the line, but order does not imply any settled distance.

When we now inquire what measurements of distance are possible, we find that there are different systems of measurement all equally possible. There are three main types of system: any system of one type gives Euclidean geometry, any system of another type gives Hyperbolic (or Lobatchewskian) geometry, any system of the third type gives Elliptic geometry. Also different beings, or the same being if he chooses, may reckon in different systems of the same type, or in systems of different types. Consider the example which will interest us later. Two beings, A and B, agree to use the same three intersecting lines as axes of _x_, _y_, _z_.

They both employ a system of measurement of the Euclidean type, and (what is not necessarily the case) agree as to the plane at infinity. That is, they agree as to the lines which are parallel. Then with the usual method of rectangular Cartesian axes, they agree that the coordinates of P are the lengths ON, NM, MP. So far all is harmony. A fixes on the segment OU_{1}, on O_x_, as being the unit length, and B on the segment OV_{1}, on O_x_. A calls his coordinates (_x_, _y_, _z_), and B calls them (X, Y, Z).

Then it is found [since both systems are Euclidean] that, whatever point P be taken,

$X = \beta_x_$, $Y = \gamma_y_$, $Z = \delta_z_$. [$\beta \neq \gamma \neq \delta$.]

They proceed to adjust their differences, and first take the _x_-coordinates. Obviously they have taken different units of length along O_x_. The length OU_{1}, which A calls one unit, B calls β units. B changes his unit length to OU_{1}, from its original length OV_{1}, and obtains X = _x_. But now, as he must use the same unit for all his measurements, his other coordinates are altered in the same ratio. Thus we now have

$X = _x_$, $Y = \gamma_y_/\beta$, $Z = \delta_z_/\beta$.

The fundamental divergence is now evident. A and B agree as to their units along O_x_. They settled that by taking along that axis a given segment OU_{1} as having the unit length. But they cannot agree as to what segment along O_y_ is equal to OU_{1}. A says it is OU_{2}, and B that it is OU_{2}′. Similarly for lengths along OZ.

The result is that A's spheres

$_x_^2 + _y_^2 + _z_^2 = _r_^2$,

are B's ellipsoids,

$X^2 + \beta^2Y^2/\gamma^2 + \beta^2Z^2/\delta^2 = _r_^2$, _i. e._ $X^2/\beta^2 + Y^2/\gamma^2 + Z^2/\delta^2 = _r_^2/\beta^2$.

Thus the measurement of angles by the two is hopelessly at variance.

If $\beta \neq \gamma \neq \delta$, there is one, and only one, set of common rectangular axes at O, namely that from which they started. If $\gamma = \delta$, but $\beta \neq \gamma$, then there are a singly infinite number of common rectangular axes found by rotating the axes round O_x_. This is, for us, the interesting case. The same phenomena are reproduced by transferring to any parallel axes.

The root of the difficulty is, that A's measuring rod, which for him is a rigid invariable body, appears to B as changing in length when turned in different directions. Similarly all measuring rods, satisfactory to A, violate B's immediate judgment of invariability, and change according to the same law. There is no way out of the difficulty. Two rods ρ and σ coincide whenever laid one on the other; ρ is held still, and both men agree that it does not change. But σ is turned round. A says it is invariable, B says it changes. To test the matter, ρ is turned round to measure it, and exactly fits it. But while A is satisfied, B declares that ρ has changed in exactly the same way as did σ. Meanwhile B has procured two material rods satisfactory to him as invariable, and A makes exactly the same objections.

We shall say that A and B employ diverse Euclidean metrical systems.

The most extraordinary fact of human life is that all beings seem to form their judgments of spatial quantity according to the same metrical system.

Relativity in Modern Physics

Owing to the fact that points of space are incapable of direct recognition, there is a difficulty--apart from any abstract question of the nature of space--in deciding on the motion to be ascribed to any body. Even if there be such a thing as absolute position, it is impossible in practice to decide directly whether a body's absolute position has changed. All spatial measurement is relative to matter.

Newton's laws of motion in their modern dress evade this difficulty by asserting that a framework of axes of coordinates can be defined by their relations to matter such that, assuming these axes to be at rest, and all velocities to be measured relatively to them, the laws hold. The same expedient has to be employed for time, namely, the laws hold when the measurement of the flow of time is made by the proper reference to periodic events. Thus the laws assert that the framework and the natural clock adapted for their use have been successfully found.

But, if one framework will do, an infinity of others serve equally well; namely, not only--as is of course the case--all those at rest relatively to the first framework, but also all those which move without relative rotation with uniform velocity relatively to the first. This whole set of frameworks is on a level in respect to Newton's laws. We will call them Dynamical frameworks.

Now, suppose there are two observers, A and B. They agree in their non-metrical projective geometry, _e.g._, what A calls a straight line so does B. They also both apply a Euclidean metrical system of measurement to this space. Their two metrical systems also agree in having the same plane at infinity, that is, lines which are parallel for A are also parallel for B. Furthermore, they have both successfully applied Newton's laws to the movement of matter, and agree in having the same sets of dynamical axes. But the framework (among these sets) which A chooses to regard as at rest is different from the frame (among the same sets) which B so regards.

Without alteration of their respective judgment of rest, they choose their co-ordinate axes so that the origins (O for A, and O′ for B) are in relative motion along OO′, which is the axis of _x_ for both.

Further, since OO′ is the line of symmetry of their diverse Euclidean systems, we assume that the two measure-systems agree for planes perpendicular to OO′, _i.e._, we assume a symmetry round OO′. Then if, for A at O, the distance OO′ be ξ, the relations at any instant between A's coordinates (_x_, _y_, _z_) and B's coordinates (_x′_, _y′_, _z′_) for the same point P are given by

$$_x′_ = \beta(_x_ - \xi), \quad _y′_ = _y_, \quad _z′_ = _z_.$$

Also, according to A's clock, O′ is moving forward with a uniform velocity _v_, and we measure A's time from the instant of the coincidence of O and O′.

Thus

$$\xi = _vt_,$$

and

$$_x′_ = \beta(_x_ - _vt_), \quad _y′_ = _y_, \quad _z′_ = _z_.$$

We now consider B's clock, and ask for the most general supposition which is consistent with the fact that their judgments as to the fact of uniform motion are in agreement.

We do not assume that events in various parts of space which A considers to be simultaneous are so considered by B. But we assume that at any point P, with coordinates (_x_, _y_, _z_) for A, there is a determinate relation between B's time T and _x_, _y_, _z_, _t_.

Put

$$T = f(_x_, _y_, _z_, _t_).$$

Write

$$P = \delta T/\delta _x_, \quad Q = \delta T/\delta _y_, \quad R = \delta T/\delta _z_, \quad S = \delta T/\delta _t_.$$

Now suppose that the point P is moving, and that (_u_{1}, _u_{2}, _u_{3}) is its set of component velocities along the axes according to A's "space and clock" system, and (U_{1}, U_{2}, U_{3}) is its set of component velocities according to B's "space and clock" system. Then by mere differentiation it follows after a short mathematical deduction that

$$U_{1} = \{(_d_\beta/_dt_)(_x_ - _vt_) + \beta(_u_{1} - _v_)\}/\{P_u_{1} + Q_u_{2} + R_u_{3} + S\}, \quad U_{2} = _u_{2}/\{P_u_{1} + Q_u_{2} + R_u_{3} + S\}, \quad U_{3} = _u_{3}/\{P_u_{1} + Q_u_{2} + R_u_{3} + S\}.$$

But we have assumed that, whatever the direction of the resultant velocity (_u_{1}, _u_{2}, _u_{3}), the velocities (U_{1}, U_{2}, U_{3}) and (_u_{1}, _u_{2}, _u_{3}) are both uniform when either is uniform.

Hence it is easily proved that β, P, Q, R, S are independent of the coordinates (_x_, _y_, _z_) and of the time _t_. In other words, they are constant.

Hence we obtain

$U_{1} = \beta(_u_{1} - _v_)/\{P_u_{1} + Q_u_{2} + R_u_{3} + S\}$,

and

$T = P_x_ + Q_y_ + R_z_ + S_t_$.

But we assumed that OO′, _i.e._, O_x_, is an axis of symmetry. It follows from this assumption that

$Q = R = 0$.

We thus obtain the simplified results

$T = P_x_ + S_t_$, } $U_{1} = \beta(_u_{1} - _v_)/(P_u_{1} + S)$, } (I) $U_{2} = _u_{2}/(P_u_{1} + S)$, } $U_{3} = _u_{3}/(P_u_{1} + S)$. }

Here we remember that ($_u_{1}$, $_u_{2}$, $_u_{3}$) are the velocities of any particle according to A's "space and clock" system, and that (U_{1}, U_{2}, U_{3}) are the velocities of the same point according to B's "space and clock" system. We have obtained the most general relations consistent with the facts that (1) they both employ Euclidean systems, related as described above, and (2) they agree in their judgments on the uniformity of velocity.

We now compare their judgments on the magnitudes of velocities.

Let the magnitude of the velocity of P be V according to A's judgment, and V′ according to B's' judgment.

Then

$V^2 = _u_{1}^2 + _u_{2}^2 + _u_{3}^2$, $V'^2 = U_{1}^2 + U_{2}^2 + U_{3}^2$.

Also we can put

$_u_{1} = _l_V$, $_u_{2} = _m_V$, $_u_{3} = _n_V$,

where (_l_, _m_, _n_) have nothing to do with the magnitude V, but simply depend on the direction of motion. In fact (_l_, _m_, _n_) are the "direction cosines" of the velocity according to A's judgment. By substituting in the above equation for V^2 we see that

$_l_^2 + _m_^2 + _n_^2 = 1$.

Now, substituting for ($_u_{1}$, $_u_{2}$, $_u_{3}$) in the equations (I) above, and squaring and adding, and eliminating $_m_^2 + _n_^2$ by the relation just found, we at once find

$V'^2 = ((\beta^2 - 1)V^2_l_^2 - 2\beta^2V_vl_ + \beta^2_v_^2 + V^2)/(PV_l_ + S)^2$.

It is thus seen that in general the relation of V′ to V depends on the direction cosine _l_. Now _l_ is the cosine of the angle which the direction of the velocity V makes with O_x_, according to A's judgment.

The meaning of this relation is, that if A discharges, from guns at the point P, shells with a given muzzle velocity V according to his judgment, B will consider that their muzzle velocities are different from each other, except in the case of pairs of guns equally inclined to the axis OO′. Instances of this type of diversity of judgment can be noted any day by any one who looks out of the window of a railway carriage, and forgets that he is travelling.

Now, suppose the velocity V′ bears a relation to the velocity V, which is independent of _l_. Then _l_ must disappear from the above formula. There are two conditions to be satisfied

One condition is

$V^2 = \beta^2_v_^2/(\beta^2 - 1)$,

or in a more convenient form

$\beta^2 = 1/(1 - _v_^2/V^2)$.

The meaning of this condition is, that there is one, and only one, muzzle velocity V (according to A's judgment), namely, the muzzle velocity given by the above formula, which can have the property that B will judge that all the guns are firing in their diverse directions with one common muzzle velocity.

Let us now suppose that V has this peculiar value: that is, if we look on this value V as known, we must suppose that β is given by the second of the above formulæ.

The other condition allows P and S to be put in the forms

P = -β_v_/λV^2, S = β/λ,

where

V′ = λV.

Thus we have the bundle of formulæ

β^2 = 1/(1 - _v_^2/V^2), T = β{_t_ - _vx_/V^2}/λ, V′ = λV.

The value which we give to λ is purely a matter for the adjustment of units. If we want A and B to agree in their judgments of the magnitude of this peculiar muzzle-velocity, we put λ = 1.

We then get the formulæ usually adopted, namely

β^2 = 1/(1 - _v_^2/V^2), } T = β{_t_ - _vx_/V^2}, } (II) V′ = V. }

But if we prefer that A and B should reckon (according to A's judgment) in the same units of time, we put λ = β, and obtain

β^2 = 1/(1 - _v_^2/V^2), T = (_t_ - _vx_)/V^2, V′ = βV.

But A and B are in any case in such hopeless difficulties over their comparisons of time-judgments that the detail of using the same units does not help them much. Accordingly the formulæ marked (II) are those used. Thus A and B agree in their judgments as to the magnitude of one special velocity V, whatever may be the direction in which the entity possessing it is moving.

In order to reach this measure of agreement, they have to disagree as to their space judgments and their time judgments. The root cause of their disagreement is their diverse judgment as to which axis system is to be taken at rest for the purpose of measuring velocities.

Before discussing the nature of the disagreement disclosed in formula (II), let us ask why we should bring these difficulties on our heads by supposing that two people in relative motion, who both (for the purpose of measuring velocities) assume that they are at rest, should agree in their judgments in respect to this special velocity V.

Such an agreement has no counterpart in any of our obvious judgments made from railway carriages. Surely we can wait till the contingency occurs before discussing the confusion which it creates.

But the contingency has occurred. It occurs when we consider the velocity of light. Perhaps I may venture to remind a philosophical society that light moves so very quickly that it is difficult to consider its velocity at all. So we need not be surprised that this peculiar fact concerning its velocity is not more obvious.

Now V being the velocity of light, unless _v_ is large, _v_/V (and still more _v_^2/V^2) will be quite inappreciable. The only velocity ready to hand which is big enough to give _v_/V an appreciable value is the velocity of the earth in its orbit.

Many diverse experiments have been made, and they all agree in concluding that a man who assumes the earth to be at rest will find by measurement that the velocity of light is the same in all directions. Furthermore, when the same man turns his attention to interstellar or interplanetary phenomena, and assumes the sun to be at rest, he will again find the velocity of light to be the same in all directions. These are well-attested experiments made at long intervals of time.

This is the exact contingency contemplated above.

Again the velocity of light _in vacuo_ has recently taken on a new dignity. It used to be one among other wave velocities such as the velocity of sound in air, or in water, or the velocity of surface waves in water. But Clerk Maxwell discovered that all electromagnetic influences are propagated with the velocity of light, and now modern physical science half suspects that electromagnetic influences are the only physical influences which relate the changes in the physical world. Accordingly the velocity of light becomes the fundamental natural velocity, and experiment shows that our judgment of its magnitude is not affected by our

choice of the framework at rest, so long as we keep to a set of dynamical axes. These experiments on light have been confirmed by other electromagnetic experiments not involving light.

Thus we are driven to equations (II), where V is the velocity of light.

The first conclusion to be drawn from equations (II) is that two people who make different choices of bodies at rest will disagree as to their measuring rods in the way described above. There is no peculiar difficulty about that. The only wonder is that all people agree so well in their judgments as to metrical systems. A mathematical angel would naturally expect incarnate men to be in violent disagreement on this subject.

But the case of time is different. For simplicity of statement we speak of A as at O, and B as at O′. We remember that O′ is moving relatively to O with velocity _v_ in direction OO′. Suppose A and B are looking in this direction; and they both measure their time from the instant when they met, as O′ passed over O. Then we have

T = ((_t_ - _vx_)/V^2)/((1 - _v_^2)/V^2).

Now, suppose we consider all the events all over space which A considers to have happened simultaneously at the time _t_. The events of this set which occurred anywhere on a plane perpendicular to OO′ at a distance _x_ in front of O (according to A's reckoning), will have occurred according to B's reckoning at the time T as given above. Let us fix our attention on the fact that B does not consider all these events to be simultaneous. For let T_{1}, and T_{2} be B's times for such events on planes _x__{1}, and _x__{2}. Then

T_{1} - T_{2} = _v_(_x__{2} - _x__{1})/(V^2 - _v_^2).

Thus if _x__{2} be greater than _x__{1}, T_{2} is less than T_{1}. Thus B judges the more distant events in front of him to have happened earlier than the nearer events in front of him, and _vice versa_ for the events behind. This disturbance of the judgment of simultaneity is the fundamental fact. Obviously the measurement of time intervals is a detail compared to simultaneity. A may think a sermon long, and B may think it short, but at least they should both agree that it stopped when the clock hand pointed at the hour. The worst of the matter is that so far as any test can be applied there is no method of discriminating between the validities of their judgments.

Thus we are confronted with two distinct concepts of the common world, A's space-time concept, and B's space-time concept. Who is right? It is no use staying for an answer. We must follow the example of the wise old Roman, and pass on to other things.

Thus estimates of quantity in space and time, and, to some extent, even estimates of order, depend on the individual observer. But what are the crude deliverances of sensible experience, apart from that world of imaginative reconstruction which for each of us has the best claim to be called our real world? Here the experimental psychologist steps in. We cannot get away from him. I wish we could, for he is frightfully difficult to understand. Also, sometimes his knowledge of the principles of mathematics is rather weak, and I sometimes suspect---- No, I will not say what I sometimes think: probably he, with equal reason, is thinking the same sort of thing of us.

I will, however, venture to summarise conclusions, which are, I believe, in harmony with the experimental evidence, both physical and psychological, and which are certainly suggested by the materials for that unwritten chapter in mathematical logic which I have already commended to your notice. The concepts of space and time and of quantity are capable of analysis into bundles of simpler concepts. In any given sensible experience it is not necessary, or even usual, that the whole complete bundle of such concepts apply. For example, the concept of externality may apply without that of linear order, and the concept of linear order may apply without that of linear distance.

Again, the abstract mathematical concept of a space-relation may confuse together distinct concepts which apply to the given perceptions. For example, linear order in the sense of a linear projection from the observer is distinct from linear order in the sense of a row of objects stretching across the line of sight.

Mathematical physics assumes a given world of definitely related objects, and the various space-time systems are alternative ways of expressing those relations as concepts in a form which also applies to the immediate experience of observers.

Yet there must be one way of expressing the relations between objects in a common external world. Alternative methods can only arise as the result of alternative standpoints; that is to say, as the result of leaving something added by the observer sticking (as it

were) in the universe.

But this way of conceiving the world of physical science, as composed of hypothetical objects, leaves it as a mere fairy tale. What is really actual are the immediate experiences. The task of deductive science is to consider the concepts which apply to these data of experience, and then to consider the concepts relating to these concepts, and so on to any necessary degree of refinement. As our concepts become more abstract, their logical relations become more general, and less liable to exception. By this logical construction we finally arrive at conceptions, (i) which have determinate exemplifications in the experience of the individuals, and (ii) whose logical relations have a peculiar smoothness. For example, conceptions of mathematical time, of mathematical space, are such smooth conceptions. No one lives in "an infinite given whole," but in a set of fragmentary experiences. The problem is to exhibit the concepts of mathematical space and time as the necessary outcome of these fragments by a process of logical building up. Similarly for the other physical concepts. This process builds a common world of conceptions out of fragmentary worlds of experience. The material pyramids of Egypt are a conception, what is actual are the fragmentary experiences of the races who have gazed on them.

So far as science seeks to rid itself of hypothesis, it cannot go beyond these general logical constructions. For science, as thus conceived, the divergent time orders considered above present no difficulty. The different time systems simply register the different relations of the mathematical construct to those individual experiences (actual or hypothetical) which could exist as the crude material from which the construct is elaborated.

But after all it should be possible so to elaborate the mathematical construct so as to eliminate specific reference to particular experiences. Whatever be the data of experience, there must be something which can be said of them as a whole, and that something is a statement of the general properties of the common world. It is hard to believe that with proper generalisation time and space will not be found among such properties.

Commentary added on reading the Paper before the Aristotelian Society

The first six pages of the paper consist of a summary of ideas which ought to be in our minds while considering problems of time and space. The ideas are mostly philosophical, and the summary has been made by an amateur in that science; so there is no reason to ascribe to it any importance except that of a modest reminder. There are only two points in this summary to which I would draw attention.

On pp. 192 and 193 there occurs--

"Wherever mankind ... unending uniform succession."

If I understand Kant rightly--which I admit to be very problematical--he holds that in the act of experience we are aware of space and time as ingredients necessary for the occurrence of experience. I would suggest--rather timidly--that this doctrine should be given a different twist, which in fact turns it in the opposite direction--namely, that in the act of experience we perceive a whole formed of related differentiated parts. The relations between these parts possess certain characteristics, and time and space are the expressions of some of the characteristics of these relations. Then the generality and uniformity which are ascribed to time and space express what may be termed the uniformity of the texture of experience.

The success of mankind--modest though it is--in deducing uniform laws of nature is, so far as it goes, a testimony that this uniformity of texture goes beyond those characteristics of the data of experience which are expressed as time and space. Time and space are necessary to experience in the sense that they are characteristics of our experience; and, of course, no one can have our experience without running into them. I cannot see that Kant's deduction amounts to much more than saying that "what is, is"--true enough, but not very helpful.

But I admit that what I have termed the "uniformity of the texture of experience" is a most curious and arresting fact. I am quite ready to believe that it is a mere illusion; and later on in the paper I suggest that this uniformity does not belong to the immediate relations of the crude data of experience, but is the result of substituting for them more refined logical entities, such as relations between relations, or classes of relations, or classes of classes of relations. By this means it can be demonstrated--I think--that the uniformity which must be ascribed to experience is of a much more abstract attenuated character than is usually allowed. This process of lifting the uniform time and space of the physical world into the status of logical abstractions has also the advantage of recognising another fact, namely, the extremely fragmentary nature of all direct individual experience.

My point in this respect is that fragmentary individual experiences are all that we know, and that all speculation must start from these _disjecta membra_ as its sole datum. It is not true that we are directly aware of a smooth running world, which in our speculations we are to conceive as given. In my view the creation of the world is the first unconscious act of speculative thought; and the first task of a self-conscious philosophy is to explain how it has been done.

There are roughly two rival explanations. One is to assert the world as a postulate. The other way is to obtain it as a deduction, not a deduction through a chain of reasoning, but a deduction through a chain of definitions which, in fact, lifts thought on to a more abstract level in which the logical ideas are more complex, and their relations are more universal. In this way the broken limited experiences sustain that connected infinite world in which in our thoughts we live. There are three more remarks while on this point I wish to make--

(i) The fact that immediate experience is capable of this deductive superstructive must mean that it itself has a certain uniformity of texture. So this great fact still remains.

(ii) I do not wish to deny the world as a postulate. Speaking without prejudice, I do not see how in our present elementary state of philosophical advance we can get on without middle axioms, which, in fact, we habitually assume.

My position is, that by careful scrutiny we should extrude such postulates from every part of our organised knowledge in which it is possible to do without them.

Now, physical science organises our knowledge of the relations between the deliverances of our various senses. I hold that in this department of knowledge such postulates, though not entirely to be extruded, can be reduced to a minimum in the way which I have described.

I have not the slightest knowledge of theories respecting our emotions, affections, and moral sentiments, and I can well believe that in dealing with them further postulates are required. And in practice I recognise that we all make such postulates, uncritically.

(iii) The next paragraphs on pp. 193 and 194 are as follows--

"The opposed philosophical method ... physical science."

It will be noted that, in the light of what has just been stated, the first of these paragraphs (which, I hope, faithfully expresses the experimental way of approaching the problem) really obscures the point which I have been endeavouring to make. The phrase, "If we form the exact concepts of points, etc.," is fatally ambiguous as between the method of postulating entities with assigned relations, and the method of forming logical constructions, and thus reaching points, etc., as the result of a chain of definitions.

Turning now to pp. 194-195, we come to the following paragraphs--

"The other theory ... eighteenth century."

We note again that the relational theory of space from another point of view brings us back to the idea of the fundamental space-entities as being logical constructs from the relations between things. The difference is, that this paragraph is written from a more developed point of view, as it implicitly assumes the things in space, and conceives space as an expression of certain of their relations. Combining this paragraph with what has gone before, we see that the suggested procedure is first to define "things" in terms of the data of experience, and then to define space in terms of the relations between things.

This procedure is explicitly assumed in the next short paragraph: "In this connection ... from the events."

The gist of the remaining paragraphs of this section is contained in the paragraph at the bottom of p. 196: "The point in time ... new importance."

The sentence, "We live in durations, and not in points," can be amplified by the addition, "We live in space-extensions and not in space-points."

It must be noted that "whole and part" as applied to extensions in space or time must be different from the "all and some" of logic, unless we admit points to be the fundamental entities. For "spatial whole and spatial part" can only mean "all and some" if they really mean "all the points and some of the points." But if extensions and their relations are more fundamental than points, this interpretation is precluded. I suggest that "spatial whole and spatial part" is intimately connected with the fundamental relation between things from which our space ideas spring.

The relation of space whole to space part has many formal properties which are identical with the properties of "all and some." Also when points have been defined, we can replace it by the conception of "all the points and some of the points." But the confusion between the two relations is fatal to sound views on the subject.

Diverse Euclidean Measure Systems

The next section deals with the measure systems applicable to space.

A measure system is a group of congruent transformations of space into itself. Consider a rigid body occupying all space. Let this body be moved in any way so that the particles of the body which occupied points P_{1}, P_{2}, P_{3}, etc., now occupy points Q_{1}, Q_{2}, Q_{3}, etc. Then any point P_{1} in space is uniquely related to the corresponding point Q_{1} in space by a one-to-one transformation with certain characteristics. By the aid of these transformations we can achieve the definition of distance in a way which definitely determines the distance between any two points, provided that we can define what we mean by a congruent transformation without introducing the idea of distance. If we introduced the idea of distance, we should simply say that a congruent transformation is one which leaves all distances unchanged, _i. e._, if P_{1}, P_{2} are transformed into Q_{1}, Q_{2} then the distance P_{1}P_{2} is equal to the distance Q_{1}Q_{2}.

But mathematicians have succeeded in defining congruent transformations without any reference to distance.

There are alternative groups of such congruent transformations, and each group gives a different measure system for space. The distance P_{1}P_{2} may equal the distance Q_{1}Q_{2} for one measure system, and will not equal it for another measure system. All these different measure systems are on the same level, equally applicable. A being with a strong enough head could think of them all at once as applying to space. The result so far as it interests us in respect to the theory of relativity is explained on pp. 197-200, ending with "The most extraordinary fact ... same metrical system." This final sentence bears on Poincaré's assertion that the measure system adopted is purely "conventional." I presume that by "conventional" a certain arbitrariness of choice is meant; and in that case, I must express entire dissent. It is true that within the circle of geometrical ideas there is no means of giving any preference to any one measure system, and any one is as good as any other. But it is not true that if we look at a normal carriage wheel, and at an oval curve one foot broad and ten feet long, we experience any arbitrariness of judgment in deciding which has approximately the form of a circle. Accordingly to Poincaré the choice between them, as representing a circle, is entirely conventional.

Again, we equally form immediate judgments as to whether a body is approximately rigid. We know that a paving stone is rigid, and that a concertina is not rigid. This again necessitates a determinate measure system, selected from among the others.

Accordingly we conclude that (i) each being does, in fact, employ a determinate measure system, which remains the same, except possibly for very small variations, and (ii) the measure systems of different human beings agree, to within the limits of our observations. These conclusions are not the less extraordinary because no plain man has ever doubted them.

It is an interesting subject to investigate exactly what are the fundamental uniformities of experience which necessitate this conclusion. It is not so easy as it looks, since we have to divest ourselves of all aid of scientific hypothesis if our conclusions are to be demonstrative.

Relativity in Modern Physics

Pp. 201-202, "Owing to the fact ... which B so regards."

The fundamental formulæ for the theory of relativity are the relations between diverse co-ordinate systems given on p. 203, and formulæ II at the bottom of p. 207. The general explanation of one method in which these formulæ arise--namely, Einstein's method--is given on pp. 201-211. Namely, we seek the condition that for all dynamical axes the velocity of light should be the same, and the same in all directions. It should be noted that the experiments which, so far as they go, confirm these formulæ, can also be explained in another way which makes the theory of relativity unnecessary. We need only ascribe to the ether a certain property of contraction in the direction of motion, and the thing is done. So no one need be bludgeoned into accepting the rather bizarre doctrine of relativity, nor indeed any other scientific generalisation. The good old homely ether, which we all know, can in this case serve the purpose. Just as an author of genius, if he lives long enough, survives the inevitable accusation of immorality, so the ether by dint of persistence has outlived all reputation of extravagance. But if we detach ourselves from the glib phraseology concerning it, the scientific ether is uncommonly like the primitive explanation of the soul, as a little man inside us, which can

sometimes be caught escaping in the form of a butterfly. As soon as the ether has to be patched up with special properties to explain special experiments, its scientific use is problematical, and its philosophic use is _nil_.

Philosophically the ether seems to me to be an ambitious attempt to give a complete explanation of the physical universe by making an elephant stand on a tortoise. Scientifically it has a perfectly adequate use by veiling the extremely abstract character of scientific generalisations under a myth, which enables our imaginations to work more freely. I am not advocating the extrusion of ether from our scientific phraseology, even though at special points we have to abandon it.

But the key to the reasons why it is worth while to consider seriously the doctrine of relativity is to be found on pp. 209, 210: "Again the velocity of light ... not involving light." Namely, we have begun to suspect that all physical influences require time for their propagation in space. This generalisation is a long way from being proved. Gravitation stands like a lion in the path. But if it be the case, then all idea of an immediate presentation to us of an aspect of the world as it in fact is, must necessarily be abandoned. What we perceive at any instant is already ancient history, with the dates of the various parts hopelessly mixed.

We must add to this the difficulty of determining what is at rest and what is in motion, and the further difficulty of determining a definite uniform flow of time. It is no use discussing this matter as though, but for the silly extravagant doctrine of relativity, everything would be plain sailing. It isn't. You may be quite sure that when, after prolonged study, you endeavour to give the simplest explanation of a grave difficulty, you will be accused of extravagance. I have no responsibility for the doctrine of relativity, and hold no brief for it, but it has some claim to be considered as a comparatively simple way out of a scientific maze.

In the first place, we use the Newtonian dynamical sets of axes, and the Newtonian clock to extricate ourselves partially from the difficulties of rest, motion, and time. These have proved capable of scientific determination within the limits of our experimental accuracy. Thus the only thing left over is the choice of the axes at rest, which is a completely indeterminate problem on Newtonian principles.

Again, so far as we can at present guess by adopting the theory that all metrical influence is electromagnetic, all influences are propagated with the velocity of light _in vacuo_. This electromagnetic hypothesis is by no means established, but it gives the simplest of all possible results in respect to the propagation of influence, which we therefore adopt.

But what dynamical axes are we taking as at rest? Now our practical choice gives a range of relative velocities small compared to that of light. So except for certain refined experiments it does not matter. There are two possibilities--

(i) We may assume that one set of axes are at rest, and that the others will show traces of motion in respect to the velocity of light; or--

(ii) That the velocity of light is the same in all directions whichever be the dynamical axes assumed.

The first supposition is negatived by experiment, and hence we are driven to the second supposition; which immediately lands us in the whole theory of relativity.

But if we will not have this theory we must reject the earlier supposition that the velocity of light _in vacuo_ is the same in all directions. This we do, in fact, by assuming an ether, and assuming a certain law for its modification. Then we, in fact, adopt the first supposition so far as to hold that there are dynamical axes specially at rest, namely, at rest relatively to the undisturbed ether. Then an assumed law for the modification of the ether so alters the velocity of light that we explain why no dynamical axes show traces of motion.

I wish now to go back to the point which I made a few minutes ago, that what we perceive at any instant is ancient history with its dates hopelessly mixed. In the earlier part of my comments I emphasised the point that our only data as to the physical world are our sensible perceptions. We must not slip into the fallacy of assuming that we are comparing a given world with given perceptions of it. The physical world is in some general sense of the term a deduced concept.

Our problem is, in fact, to fit the world to our perceptions, and not our perceptions to the world.

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[Illustration: THE FINEST SUBURBAN FARM PRODUCE.]

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With an Introduction by N. O. NELSON

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CONTENTS-INDEX.

PAGE

PREFACE 9-12 Becoming a gardener 9, 10, 11 Intensive Farm, the 9, 16 Some sorts of critics 10

INTRODUCTION 13-20 A practical offer 14 Co-operation 17-20 Farm for nothing, a 15 How much land is needed 15 Obstacles—how to overcome them 14 The only life 13 What intensive cultivation means 16

CHAPTER I.—THE GARDEN YARD 21-29 Brain value 24 Buildings you need 29 Choosing your farm 27 Fortunes, hidden 22-25 How to grow rich 28, 29 Land and crops 26 Location for field crops 21 Location for garden crops 21 Market importance 26 Mistakes and their cost 22 Money, in what 24 The value of ownership 28 Unknown capacity 21 Work not enough 25

CHAPTER II.—SOIL 30-41 An unusual use 31 Best soil, the 36 Failure your own fault 41 "Good" soil 33 Humus 40, 72, 73, 74, 86 Moisture, how to get and hold it 34, 36 Soil—How it was made 30, 31 " Its contents 31 " Texture 34 " What it is 30 Soils to avoid 37 Surface and subsoil 32 Tillage 37-40 Tilth 36, 37

CHAPTER III.—SOIL FERTILITY 42-48 Soil fertility—what it is 42 Agricultural Department's crop work 46, 48 Help it offers 48 Limited crops 46 Nature and the abandoned farm 42, 43 Seeds, Bob's solution 43, 45 Types of soil in the U. S. 46 Whitney's (Prof.) idea 45

CHAPTER IV.—LOCATION 49-50 How to buy, clear, build 49 Land you can't afford to use 49 Manure and watering 49, 50 Market 50 To find out where and how 49

CHAPTER V.—SEEDS 51-53 Houses, good seed 52 Ideal, the 51 Planting dates 53 Seed test 52 Use only the best 51

CHAPTER VI.—PLANT BREEDING 54-56 Plant breeding—what it is 54 Good farmers and breeding 54 How to improve 54 Professional breeders 54 Selection and variations 55 "Sports" 56

CHAPTER VII.—PLANT NEEDS 57-61 Plant needs—what they are 57 Foods, three sure 58 Light, degrees of 57, 58 Lime values 59 Medicines 59 Protectors 60, 61 Temperature 59 Under- and over-feeding 58 Water, effect of 57

CHAPTER VIII.—CROP ROTATION 62-65 Farming a business 62 Special crops 62 Value of rotation 63, 64, 65, 81

CHAPTER IX.—WEEDS 66-68 Weeds—how to know them 66 Common weeds 66 " " How to destroy them 67 " " Their use 68

CHAPTER X.—INSECTS AND DISEASES 69-71 Causes, some 69 How transmitted 70 Preventives 70 Preventing attacks 69 The little we know 69 Weeds as breeders 71

CHAPTER XI.—RE-SOILING 72-77 Best way to do it 73 Cleaning up 74 How to preserve it 76 Lawn, the 75 Misleading term 72 Prepared humus 74 Success, real 77 What we really do 72

CHAPTER XII.—HOW TO WORK 78-89 Grouping 80 How to plant 79 " " run rows 80 Keep soil busy 82 Manuring 79 Preparing the plot 78 Rotation 81 Test for acid 78 Transplanting 81 Companion cropping 82 Cellar growing 89 Drainage 82, 83 Drought, protection against 87 How we learn 88 Irrigation 82 Sewage 86, 87 Small area crops 88 Things that pay 88 Tools, keeping them clean 84, 85 Use brains 88 Waste water value 86

PART II.

CHAPTER XIII.—ROOT CROPS 90-105 Radishes 91 Culture 92 Enemies 93 Needs 93 Varieties 93 When to sow 92 Beets 94 As greens 95 Enemies 96 Fertilizers, special 96, 97 Marketing 97 Planting 95 Tillage 96 Where to grow 94 Yield 96 Carrots 97 How to sow 97 Soil preparation 97 Thinning 98 Types 98 Yield 99 Turnips 99 Easy to grow 99 Cowhorn turnip 44 How to plant 100 Root maggot 100 Soil 99 Thinning 100 Parsnips 100 Cultivation 101 Freedom from disease 102 Sowing 101 Thorough preparation 101 Yield 102 Salsify 102 Kitchen use only 102 Returns 103 Soil requirements 102 Types, modified 102, 103 Horse-radish 103 Grown from "sets" 103 How planted 104 Tillage 104 Yield 104

CHAPTER XIV.—TUBER CROPS 106-110 Potatoes 106 Early potatoes 108 Enemies and diseases 108 How to plant 107 Seed, potato 107 Soils, best 106 Spraying 108 Yield, average 106 " good 106 " phenomenal 218-225 " possible 106 Sweet Potatoes 109 Home of 109 Climate 109 Cultivation 109, 110 Enemies 110 Soil 109

CHAPTER XV.—BULB CROPS 111-118 How to propagate 111 Needs, their 111 Seed-bed crops 111 Leeks 111 How grown 111 Product 111 Storage 111 Ciboule 112 Cives 112 Garlic 111 Shallot 112 Onion, Welsh 112 Onions 112 Early crop 114 Enemies 118 Fertilizing 113 Growing 112 Handling and storing 116 "Multiplier" onions 115 New onion culture 115 Season, main 114 Selling onions 117 "Sets" 114 Sorting 117 "Top"-onions 114 Weeding 114 Yields 118

CHAPTER XVI.—COLE CROPS 119-133 Meaning of name 119 Why grown 119 Brussels Sprouts 127 Soil, food and tillage needs 127 Successful growing 128 Cabbage 119 Acre yield, an 121 Crops, two 120 Essentials for growing 119 Fertilizing 120 Field-grown 121 Hot-bed plants 121 Insects and diseases 122 Locality, effect of 122 Marketing 121 Planting 123, 124 Profits in cabbage 123 Protection from insects 125 Quick first crop 123 Second crop 125 Cauliflower 129 Good seed necessary 129 Growing seed 130 Tillage, right 130 Where it grows best 129 Kale 126 Better for frost 126 Collards 127 Cultivation 126 Enemies 127 How sown 126 Southern kale 127 Kohlrabi 131 Best varieties 131 How to thin 131 Insects, diseases and cures 131, 132, 133 Its family 131 " uses 131

CHAPTER XVII.—POT-HERB CROPS 134-140 Characteristics 134 Needs 134 What they are 134 Chard 137 Dandelion 138 Characteristics 138 Harvesting 139, 140 Tillage 139 Mustard 137 Where grown 137 Soil requirements 138 Purslane 140 Spinach

134 Forced spinach 136 How sown 137 How to sow 135 New Zealand spinach 136 Where and when grown 134

CHAPTER XVIII.—SALAD CROPS 141-160 What they are 141 What they need 141 Celeriac 159 How eaten 159 How to grow 159 Soil and tillage 159 Transplanting 159 Celery 150 Blanching 154, 155, 156 Care in tilling 153, 154 Diseases 158 Early and late crop 153 Fertilizing 153 How to sow 151 Loss in sprouting 152 Marketing 157 Seed-bed crop 150 Soil requirements 150 Storing 157 Thinning 152 Transplanting 152 Varieties 158 Where it grows best 150, 151 Chicory 145 How to grow 145 Salad plant 145 Use of chicory roots 146 Corn Salad 148 Cool-season crop 148 How and where to plant 148 Yield 149 Cress 146 How and where to grow 146, 147 How to plant 148 Varieties 146 Endive 144 Blanching 144 How to sow 144 Season, its 144 Soil and tillage 144 Use, its 145 Lettuce 142 Companion-crop 143 Culture 142 Growing in the open 143 " under glass 143 Nature 142 Sowing and thinning 143 Succession-crop 143 Yield 143 Parsley 149 Easy to grow 149 Nature 149 Uses 149 Salad Chervil 149 Culture 150 Ready for use 150 Varieties 150

CHAPTER XIX.—PULSE CROPS 161-172 What they are 161 What they need 161 Beans 166-172 Bush and pole beans 169 Enemies 171, 172 Lima beans 167, 170 Ornamental uses 170 Planting 170 Preparing the soil 167 String beans 166 Where they grow 171 Where and when to sow 166 Peas 161-166 Early crops 162 Enemies 163, 165 Pea values 162, 163 Planting 161 Soil requirements 161 Varieties 163

CHAPTER XX.—SOLANACEOUS CROPS 173-182 Crops included 173 Nature and requirements 173 Eggplants 179, 180 Enemies 181 Harvesting 180 Marketing 180 Planting 179 Tillage 180 Transplanting 179, 180 Treatment required 179 Husk Tomato 182 Peppers 181 Cultivation 181 Growth of demand 181 Starting 181 Transplanting 181 Uses 182 Varieties 182 Tomatoes 173 Cultivation 174 Fertilizing 174 Harvesting 178 Racks, cheap 166, 167 Sowing seed 173 Tillage 174 Training and its value 175 Varieties 179 Where grown 173 Yield 179

CHAPTER XXI.—VINE OR CUCURBITOUS CROPS 183-191 What they are 183 " " need 183 Why you fail 183 How to succeed 183 When and where to plant 184 Enemies 184 Cucumbers and Gherkin 185 Planting in hills 185 Uses 186 Varieties 186 Yield 186 Muskmelon 186 Enemies 187 Planting 187 Varieties 187 Where grown 187 Yield 187 Pumpkin and Squash 189 Differences 190 Enemies 191 Uses 190 Varieties 190-191 Watermelon 187 Cultivation 188 Enemies 189 Testing 189 Uncertain crop 187 Where and how grown 188

CHAPTER XXII.—UNCLASSIFIED ANNUALS 192-197 What they include 192 " " need 192 Martynia 197 Okra or Gumbo 196 Cultivation 197 Enemies 197 Nature 196 Uses 196 Where and why grown 196 Sweet Corn 192 Cultivation 193, 194, 195 Enemies 196 Important crop 192 Marketing 195 Preparation for planting 193 Where it thrives 192 Yield 196

CHAPTER XXIII.—HERBS, SWEET AND CONDIMENTAL 198-200 Varieties 198 Classes 198 Growing 198, 199 Annuals 199 Perennials 200

CHAPTER XXIV.—PERENNIAL CROPS 201-215 What they are 201 " " need 201 Asparagus 201 Cultivation 201 Enemies 206, 207 Growing from seed 203 Harvesting 204 Marketing 205 Planting 202 Soil requirements 201 Tillage 202 Winter protection 205 Yield 206 Rhubarb 208 Cellar plots 210 Forced growth 210, 211 Nature, hardy 208 New culture 209 Planting 208 Profitable growing 209 Soil needs 208 Yield 211 Docks and Sorrels 211 Varieties 211 Artichoke 212 Jerusalem and French Globe 212 Sowing 212 Stock feed 213 Uses 214 Ways of the artichoke 213, 214 Winter mulch 213 Yield 214 Sea-kale 214 Blanching 215 Care 215 How it grows 214

CHAPTER XXV.—SPECIALITIES 216-226 Asparagus 218 Celery 218 Chestnuts 217 Mushrooms 218 Onions and potatoes 218 300 bushels to the acre 218, 225 Other specialties 226 Specializing and profits 216, 217 Strawberries 225

CHAPTER XXVI.—WATCHING AND SPRAYING 227-236 Arsenical sprays 233 Bordeaux mixture, what it will do and how to make it 229, 230 Emulsions 235 Kerosene emulsions 234 Manufacture and use 234, 235 Need of watching 227 Paris green 232 Spraying as a remedy 228 Spraying mixture 228, 235 Uses 232 Value of spraying, the 235

CHAPTER XXVII.—FERTILIZERS 237-249 Best are cheapest 241, 242, 243 Care of manure, the 240 Natural and chemical 237, 238 What each contains 238, 239 What fertilizer is 237 Wire basket, soil needs test 244, 249

CHAPTER XXVIII.—MORE ABOUT FERTILIZERS 250-257 Experiments show, what 250, 251 Growing crops and fertilizers 255 Manure contains, what 257 Potassium, kainit, wood ashes and lime 252, 253 Value of "check plats," the 253, 254 Valuable elements 250

CHAPTER XXIX.—ROOT HOUSES AND VEGETABLE PITS 258-259 How to build one 258, 259 Uses, their 258 Varieties of pits 259

CHAPTER XXX.—SMALL FRUITS 260-266 Cultivation 262 Currants and gooseberries 264 How to grow them 264 Enemies and their remedy 264, 265 Grapes 265 How to grow them 265, 266 Growing new plants 263 Labor and yield 260 Marketing 262 Planting 261 Preparing the soil 261 Raspberries and blackberries 263 How to grow them 264 Strawberry patch, the 260

CHAPTER XXXI.—THE POULTRY RUN 267-279 Branches of the business 272 Care and feed 269 Central hatching 273 Cleanliness 269 Colony plan versus yarded 274, 275 Effort and profit 278 How to succeed 279 Importance of incubation 273 Incubator hatching 271 Indian Runner ducks 277 Intensive hen, the 267 Location of house 270 Modern hen-house, a 270-271 Outdoor brooding 271 Profitable poultry 268 Small companies 269

CHAPTER XXXII.—ORGANIZATION 280-291 Agricultural colleges and books 281 New methods 280 Work of the months 282-291

CHAPTER XXXIII.—A FEW PRACTICAL "DON'TS" 292-298 Deep plowing 292 Department of Agriculture 294 Farmer's life, the 292 Feed the soil 295 Making seeds comfortable 292, 293 Successful farmers 296, 297 Tools and their care 295

APPENDIX I. 299-300 Island of Guernsey products 299

APPENDIX II. 301-306 French Gardening, etc. 301

APPENDIX III. 307-317 Maylands Gardening Customs 307

APPENDIX IV. 318-321 Agricultural Courses 318

PREFACE.

An intensive farm is only an enlarged garden patch.

This book is not intended as a scientific book on agriculture; there are many such books which are out of the depths of everyone except professors and professionals. In a nice experiment station, nice experiments and scientific calculations are excellent; but I want to give the plain man or woman who has a back yard or back lot, out of which he might make part of a living or more than a living, a book that will show how to do it.

I want to help the man or woman who has to do the cultivation at odd times and who finds it hard to get the time for the work, even though this work enables him to do far more work of other kinds. I have had all sorts of experience with gardening, in spite of telegrams and people who want "just five minutes for some important business." So if you have the same trouble getting the time, do not let that discourage you. We can get health, happiness and some profit in spite of the interruptions.

It won't be enough simply to read this book; that won't make you a gardener; but if you study it while you are working on the land and use your judgment and common sense, in one season you will be able to teach most of those whom you now have to hire as expert Gardeners at Three Dollars a Day.

If anybody sneers at your gardening as being "book farming," let him sneer; a fool never understands what a wise man is doing: if he did, he would do it himself. You have here the plain, simple, practical facts without scientific terms—just the ordinary garden talk. There are plenty of things you will not find in this book. You won't find analyses of fertilizers, nor how to grow "pomatoes," or anything else that won't sell when you have grown it. Nor will you find fairy stories of poultry profits that make the goose's golden eggs look like thirty cents. There is a use for all that sort of thing—it arouses interest and stimulates the imagination. But you will probably be content to be a good, practical, every-day gardener who can make things grow and knows what to do with them after they have grown.

Some critics, who will not read this book, will sagely remark that such books as Mr. Hall's are dangerous, because they induce inexperienced persons to sell out and lose their money trying to get Liberty on Three Acres or a Living from a Little Land. To repeat for such people my cautions and advice to learn navigation before buying your ship, is to blow against the North wind.

If you have skipped the foregoing, just skip again, back to it. You will see that I have promised to use no scientific terms. This book will be read by more plain people than by scientists, and so I have aimed to talk just as I would if I were trying to teach you how to raise lettuce—or rather trying to teach you to learn for yourself how to raise lettuce. For we cannot teach anyone anything, we can

only give him the opportunity of learning. So if the experimental agriculturist thinks that a good deal has been left out that might have been put in, I hope he will remember that I have had to pick from a measureless field, and by trying to crowd in too much I might easily confuse the less experienced and make it hard for him to learn.

And yet no one need think that by reading a book or any number of books he can be made a gardener. That is done by work of head and hands on the soil; and the best preparation for a really scientific use of your own land, is to hire yourself out for a while to a market gardener and get the practical, every-day experience.

You might as well expect to learn writing without using a pen as gardening without using a bit of land. You will make some mistakes and lose some crops, but I can show you how to profit by mistakes and to lose very little by losses.

If you don't understand the directions, that is my fault: I should be able to make it clear to everyone. So just write me (a pencil and a postal card will do) and I will tell you what you want to know, if I know it myself or can find out.

BOLTON HALL.

56 PINE ST., NEW YORK CITY.

INTRODUCTION.

A farm is the only proper home. Working for yourself is the only true independence. Labor on the land in the open gives health and long life. Raise a living and sell the surplus. Work all the time, but don't overwork. Make faces at the cynic who says the farmer and his wife and children work fifteen hours a day and then starve. It isn't so. Work alone is not farming; you must manage. Farming needs intelligence and care, nothing more so. Everywhere you see good farm-homes and poor ones; the difference is in the farmer. What the good farmers do, all can do.

In this book, the author tells how to lay out the land, how to prepare and plant and harvest, and how to make life joyous. He has boiled down the experience of himself and his friends and the information contained in bulletins and books and catalogs. A cobbler or clerk or typo, can take this book and with his tennis-made muscle and his trade accuracy can make a bare living the first year, a good living the second, and start a bank account the third. I know it because I helped do it in my youth and I have seen it done all my life.

One of the obstacles in the way of town families going to the country is separation from friends and going among strangers. Another is the conscious ignorance of the work and a sense of helplessness. These are real and valid difficulties. They are equivalent to the difficulties besetting a German or Norwegian farmer coming alone into an American community in a new state. The hundreds of thousands of European farmers who came to the states every year from the forties to the end of the eighties overcame this difficulty by organizing colonies of friends and neighbors and settling in one spot. They thus had society and they had the benefit of their best leaders. Then their old friends kept coming in smaller squads. This is the way for town people to do. Find six or ten or a dozen and go together. Even if all are not relatives or friends they may be of the same class or trade.

To any such colony I will furnish the money to pay for all the land they need and let them begin paying the cost price of it at the end of five years and finish in ten, with 4 per cent. interest. They may pick the tract and bargain for the price. Upon their showing that the agreed number are ready to go and are able to make the improvements and provide the working equipment, I will advance the money to pay for the land. They can divide it up to suit themselves.

I have furnished farms already plowed, fenced and housed, and horse and cow free of charge. But these empty-handed folk, who have saved nothing out of their former occupation, lack the qualities to manage for themselves and to succeed at farming. They are too helpless and dependent. Their best plan is to hire out in the country until they learn farm work and life, then rent a piece of land, and then buy.

How much land shall each one have, how much can he properly cultivate? That depends on what he raises, and this governs his location and the price of the land. With present methods, he will need 20 acres if he keeps a dairy of ten cows; or, 10 acres if he raises vegetables, small fruit, poultry and milk; or, four acres is enough for truck and a horse and cow, while one acre is enough if he raises only celery, asparagus or tomatoes. The price of land is influenced by social conditions, speculation, proximity to and quality of market and agricultural adaptability, all the way from $5.00 an acre to $250.00. There is plenty of it not above the value of the public and private improvements. It is useless to buy a farm of 160 acres for one family. They cannot work it, it is a dead

expense, they would be lonesome, would starve and quit. But a colony, settling as neighbors on well-chosen land for which they pay only when they have had time to earn it, will have every opportunity to succeed.

Only in rare cases would I advise town dwellers to go singly to the country; they are disqualified by their social and industrial habits. A colony of friends or Co-operative Associations overcome the difficulties and do in fact assure success to any one possessed of industry and frugality.

By intensive cultivation is meant, not any particular kind of product, but farming the land thoroughly, getting the best yield and the best quality out of every acre, the best seeds and the best breeds and the best way of disposing of the crop when you get it. The farm or garden may be in the vegetable or small fruit or corn and hay or dairying section. In either case, you can cultivate it intensively, which is thoroughly.

The book will tell you in A, B, C style how to farm. I am asked to tell what to do with the crop after you have raised it, how to buy what you don't raise, and how to make social substitutes for the city crowds and sights.

Associate! _Co-operate!_

You may not know it, but the world is turning from private trade to co-operation at a fast rate. In some countries most of the farmers do all their business by co-operation.

Co-operation is simple and sure and safe, when enough people want it and are shown how.

I have practiced co-operation in my business for twenty-three years. I have been intimate with it the world over for twenty-five years. I have seen it grow and grow until it numbers its millions of workers in some countries, and is doubling every five years in many countries and states. Though I am a manufacturer, my chief occupation is to preach and teach co-operation to farmers—at my own expense.

Co-operative creameries have changed Minnesota from a declining wheat state to a rich dairy state. Co-operation has saved the California orange grower from bankruptcy and made him prosperous; it has raised Denmark's exports of butter, eggs and bacon from eighteen to eighty millions a year, and it has almost cut off our supply of policemen and politicians from Ireland, because over a thousand co-operative associations have grown up there in twenty years.

After you have undertaken what this book tells you all about, you want to count on forming co-operative associations with your neighbors to do all the business that you have. You raise your own crop; but pack it, ship it and sell it through your association. You use bought goods, but buy them all through the association. That gives you a saving in expenses, a saving in price, and a better quality. What is still more, it makes better neighbors of you, and rids you entirely of the demoralizing tricks of the trade, and prevents you figuring how to get the best trade out of the other fellow. You are yourself "the other fellow." In the co-operative way, your interest lies in producing the best stuff, which will gradually improve your motives. Co-operation fits any sort of business, if there is enough of it.

One hundred and fifty cows are needed to start a cheese factory, 250 for a milk shipping association, 500 for a butter creamery; fewer than these do not pay.

For co-operation in raising vegetables and small fruits, no fixed quantity of product is required; two or more persons working together is better than each for himself.

Talk it up as neighbors and then hold a meeting. Let all who want to join, sign an agreement to deliver all their truck to the association and pay a membership fee of $5.00 or over. Each member should have an equal voice regardless of his acreage. Organize, either as a corporation or a limited partnership. Elect the best qualified men to be officers, and then give them unqualified support. Select a manager and see to the marketing arrangements. If the quantity raised is large enough, it is best to have your own receiving and selling agent in the principal market. Every member must make a legal contract with the association to submit to its rules about condition, packing and delivering, to apply to his entire crop. Good quality, reliable packing and regular supply are essential to good prices.

The manager or inspector must have full authority. Each member's delivery is graded, weighed, measured or counted and accurately recorded. Once a month the account from each grade is made up, and the proceeds, after paying expenses, are paid over.

The manager should be an experienced trucker, competent to instruct and advise about the work of planting, growing and gathering. The growers meet each other at the station, and compare notes. They all learn what is known by the most expert among them. They can arrange to have one man gather up the crops from several places and make one load to the packing-house, taking turn about in this service. Small or poor growers may be admitted with a nominal payment, even as low as 25 cents, the remainder to be paid by a 5 per cent. deduction from his proceeds.

The association and management can also fill the assembled orders of members for fertilizer, seed, implements and packing material, at wholesale prices. In time you will make your own boxes, erect a cannery for the surplus and even buy your own groceries co-operatively.

You can form a credit society with unlimited liability, to receive on deposit the members' surplus and borrow from the city. That money is lent, for productive uses only, to members of known ability and honesty, who give two similar members as security.

When you get safely started in one kind of co-operative association, you will easily go to the next, as the Danes and the Irish have done.

ST. LOUIS, MO.

N. O. NELSON.

CHAPTER I.

THE GARDEN YARD

No man knows, nor can know, the capacity of a yard of earth, for it is unlimited, just as the speed of the engine is unlimited. Just as with the engine, the only question is whether it would pay to make it do any more—it may cost too much. Where land is cheap, labor is high; there intelligent cultivation will pay, but intensive cultivation will not. That is the place where the field crops should be raised.

But the garden crops should be raised right round the towns and cities and it is foolish to get to a distance from them. Stay right where you are and get the piece of land that is best for your purpose; buy it, if you can without paying too much for it; if not, rent it for as long a term as you can; or get permission to use the bit of land, the vacant lots—there are plenty even in the most crowded cities—and raise your truck and your income on those lots. Without separating yourself from your acquaintances or exiling your wife and children, learn to get your living out of the earth.

Suppose that a man owns his house, even if it be but a bit of a bungalow, and suppose he has a little bit of land on which he can raise the most of what the family eats; he may have to work hard, especially if his family cannot help in the work, but at least he is independent; at least panics, lock-outs, change of circumstances or even loss of health will not reduce him to starvation.

If you have a farm, Intensive Cultivation should interest you all the more. Every farm is full of opportunities to make good money; but you must not make the usual mistake of half working a big piece of land; that means that you will always be overworked, always have a lot of things that you know ought to be done, but cannot find time to do; always have common grade crops that bring common prices. Everyone that is overworked is underpaid, for he cannot do his best work.

Use the big fields for pasture, or for raising fine horses, or for pigs or Angora goats or even for sheep; you had better let the fields run wild rather than half cultivate them.

Keep accounts and watch your chance to sell all the land that does not pay well. It may be that you are missing a fortune in the old neglected orchard, or in the chestnut or hickory grove. The black walnuts or butternuts, that are usually left for the neighbors' boys, may be the most profitable part of the farm.

The wood-lot may have possibilities for barrel hoops, which may be sold to the improvement of the timber. It may need only thinning to bring you a steady income while it increases in value.

Fine apples grafted on the old trees that now bear only cider apples, if properly sprayed and thinned so as to give first-class fruit, may sell for more than all the corn you can raise.[1]

The “pesky briers” that the farmer struggles with year by year, may be the raspberries and blackberries that will sell readily for good prices, when they are cultivated, to the summer residents or boarding-houses. Your exposure and soil may be just the place for the fine strawberries with which, when nicely separated from the second and third grades, no market is ever overstocked.

But if you are always behind with the work and always short of cash or worried to pull through, you have no time to think of these things and no means to hire labor nor to develop them.

That pond may be needed, if it were cleared out, for a profitable ice supply, furnishing paying work in the winter. The stream may be a valuable water-power or at least may bring a high-priced crop of water-cress; or it may be the very water needed, when properly distributed, to make yours the most fertile land in the county. The bit of swamp land, that raises nothing but mosquitoes, may need only a few dollars’ worth of cranberry sets to be the best paying acre in the country side.

There may be a veritable gold mine in a neglected quarry, or brick-clay pit, or kaolin clay deposit, or in a sand bank, or a vein of marl.

Possibly you could rent the farm house or let camping sites for the summer to people who would pay city prices for much of your stuff; so that you could afford to keep help enough to leave only the easy work of superintendence for you. Brains save more work than machines.

If you are raising the same crops that your neighbors do, harvesting at the same time, and getting the same prices that everyone else does, you may be sure that you are neglecting your chances.

The money is in finding things to raise that will sell, and that do not have to compete with all the others.

Says the _Farm Journal_: “Farmers need more time to plan their work and look after the business and economic end of their calling. The employer who makes a full hand in barn and field from 5 A. M. till 8 P. M., has no other time to devote to the real business of the farm than the hours in which Nature imperatively calls upon him to rest, and a man with aching muscles and tired limbs is not in condition to think clearly or plan intelligently. It is poor economy for a farmer to take the place of a dollar-a-day man in the field, when in so doing he has left no leisure in which to work out the details of his operations.”

Think—think—it is true that we ourselves must work with the men if we are to get the best work out of them; there is a big difference between saying “Go, do that,” and “Come and let us do this.” But it is not enough to work; any jackass can do that.

You know the old fable: “A farmer got his wheels stuck fast in a miry road. The man knelt down in the mud crying to Hercules to come and help him. Said Hercules, “Get up and put your shoulder to the wheel, I help only those who help themselves!”

(There is a new part to that fable)—Now the mire was very deep and even Hercules’ help was not enough; so he called on Pallas, the Goddess of Wisdom. Said she, “Put this lever under the wheel.” Then the wagon was easily lifted out.

Since then, some one else suggested using wide tires, so that the wheels would not sink at all, and another invented a split-log road-drag to keep the roads hard. But we are still waiting for the farmers to learn to use them.

Maybe the roses in the bit of garden would bring you bigger money, if they were made to bloom at the right time, than the potatoes that take twice as much outlay and ten times as much work.

Pick out as much land as you can attend to without walking your legs off, and raise on it the best crops that bring the best prices and let the rest take care of itself.

The market is more important than the crop. Consult the editors of your agricultural papers about where to sell. Require bank reference from any commission merchant that you do not know, and write to the bank for its report on him before you ship to him. Make his acquaintance, if possible, and talk to him about what he can sell the best; naturally, he will take more interest in the affairs of a man that he knows than in a stranger. Don’t go to town or to the boat or railroad with half a load or with a load of poor stuff. Arrange with your neighbors to take enough for them to make your trip pay.

If a trolley or a carrier can be brought into use to make regular shipments, see some merchant or hotel man and arrange to supply him constantly. Then lay out your plantings so as to have a constant supply of what he needs.

If you are choosing a farm or have a chance to sell yours, inquire and look to see if you can find one near a good market where you will earn your own commissions. The way to find out what you want is to talk about it to everyone you meet. A good local map will

help you, but of course the real estate agents know more about what is for sale and the prices and values than you could learn in a year's travel. No men, except editors and hotel clerks, are so ready to give information as the real estate agents. Remember, however, than even when they are honest (most of them are, like the rest of us, as honest as circumstances allow), the successful real estate agent must see the rosy side of the peach and may not point out the worm-hole on the other side. You will have to look for that yourself.

When you have found what you want, point out that you are buying to improve, so that the security will be better every day, and fight for easy terms and for a long mortgage. You can get the privilege to pay off any time that you cannot use the capital to better advantage.

Let some good lawyer examine the records and see that the papers are all straight, and guarantee the title. If there is a local title insurance company its policy is worth all it costs, and will help you greatly should you want to sell or to raise another mortgage.

Buy your land—don't rent it; it does not pay to put your work into another man's land.

Every improvement in the condition of the earth—agricultural, mechanical, ethical, educational, political or even religious must go eventually and mainly to the benefit of the owners of the earth; therefore get hold of a bit of the earth, so that everyone who does good will do that good for you.

Get a small bit of land near the market rather than a big bit away from it, because the more people there are near you the better you can live and the more money you can make. Besides it is much pleasanter and better for the wife and children, as well as for yourself, to be near schools, libraries, proper company, stores, than to be away out among stumps. A growing town will make you rich when it grows out your way, because you are in the way and when the land is wanted you must be paid to get out. Meanwhile, you can get manure and help much easier and cheaper than if you were at a distance.

Don't put your labor or your money into expensive buildings: they only invite the tax assessor; but get proper buildings—they may be only shacks, but they should be well planned shacks, for you must have room enough to shelter your tools, wagons and farm machines, to house your stock, to store your crops, to sprout your seeds, to save your manure and to do indoor work during bad weather.

FOOTNOTES:

[1] There is only one good way to do this: cut back all the old wood and work out a new top on which to graft the fine apple scions.

CHAPTER II.

THE SOIL.

If this book is to be of real service, we must be clear about the terms and expressions, so that, though you may know nothing about gardening when you begin to read it, you may know enough to earn a living from the soil when you finish it—and practice a little.

Many talk glibly enough about the soil, though few could tell exactly what it means. But market-gardeners must understand it, if they are to live by it. So it will be well to begin with the soil itself. Soil is that thin layer of earth that covers our globe like a blanket, and in which all that plants, beasts and men live upon, grows. If it were washed off, starvation would follow. The scientific explanation of the origin of this blanket, is, that it was formed by the action of heat, cold, water, frost, ice, low forms of vegetable life and tiny animals; sometimes working singly and sometimes all together. It is now established that the most of the face of the earth was once rock which was rubbed, crushed and ground by these forces until this surface layer was made. Then higher forms of life became possible. Not centuries only, but aeons of time, were necessary to accomplish this. Layer upon layer of finely crushed particles were exposed to the action of the air which completed the work the grinding of Nature's forces had begun.

To follow out the story of the development of the soil is a most fascinating study, and if you have time from your other interests, you will be glad that you took it up; for though you may be a good farmer without this knowledge, you will be a better one with it, because you will be more intelligent and sympathetic. The soil-blanket holds within its warm folds all that is necessary for life, and the wonder of it all increases the more we learn about the millions of years and numberless forces employed to bring it to this state of perfection. If Nature has not wearied in her great work, there is poor excuse for the gardener to shirk or neglect the labor necessary to get the best possible results from any given piece of soil.

Nobody yet knows what are the best possible results from any given piece of soil; for since new discoveries are being made every year, we can show only what has so far been done with the best knowledge and skill at our disposal. One man in Pennsylvania is selling his soil; not his crop, at $1.50 per bushel to inoculate other ground.

The fine, fertile layer of earth that is called soil does not go very deep. It covers another layer which is harder, coarser, colder than itself, and this second layer is known as the subsoil, or that soil which is under the surface layer. In all temperate climes the difference is strongly marked, but in rainless, sun-dried regions there is often no difference to be noted. The intelligent farmer or gardener has the opportunity to decide just how much of that subsoil he will convert into surface soil, and the means of doing this will be disclosed later under the head of "Tillage." The more of it he brings into use the greater his own profit, so that it pays to know how. In the early days of farming no effort was made to bring the subsoil into use, and consequently the returns from agriculture were small. Now we know better than that, and we also know how to get more out of the soil, whether surface or subsoil.

No soil, no garden; so the new gardener must get acquainted with the ground he intends to cultivate. It is not to be denied that soil which is in good tilth will be a great help to the beginner, but that is only to be had in well-cultivated gardens, which usually bring a good price when found in the market. Besides, with proper care and attention, any well situated soil can be made to yield good returns, and the gardener who is not disposed to give proper care and attention will find nothing in this book, or in any other, that will teach him how to succeed. The German idea is that a good soil is merely a place to put fertilizers (and German ideas on gardening are not to be despised). This is simply another way of repeating that, with brains and work any soil can be made to yield good returns. It is not safe, however, to trust to the "Light of Nature" as to what "proper care and attention" is, so here are the details.

If you are already settled and are planning to use your back yard for a garden, you will have to take the soil as it is, and by your own effort make it what it should be. There is no cause for despair no matter what it may be. A back yard that was trodden almost as compact as asphalt, and whose clods when dug had to be broken up with an axe, was made to yield a large variety of flowers the first season it was planted. So go ahead and do what you can with what you have. But, if you are hunting for a garden plot, bear in mind the importance of soil texture. You may thereby save yourself both time and labor.

The first thing is to examine the soil to determine whether it is sandy or clayey, dry or moist, light or heavy, well drained or wet; whether it is warm and live, or cold and dead. You will then learn what sort of cultivation is best for your particular plot of ground.

Because in your neighbor's garden a certain treatment has been successful, is not saying that it will give the same results in yours, unless all the conditions are the same. For instance, his light, sandy loam needs little cultivation, and your soil may be hard and clayey. In that case you would have to make up the difference by careful work.

There are "gardeners" who think it is sufficient barely to break up the ground, add a little manure or other fertilizer, and scatter seeds. That they get any sort of results only shows how willing Nature is to give a return on the slightest labor. But Nature is wise as well as willing, and therefore gives lavishly to him only, who, by intelligent labor, deserves the best returns.

Therefore, learn the needs of your soil and supply them, and you will have no cause to complain of the niggardliness of Mother Nature to those of her children who feed at her bosom.

Plants often die for lack of moisture in the soil, and this condition cannot be satisfactorily remedied by the watering-can. The trouble lies back of such surface treatment and can only be cured by getting at the cause. The soil should be so prepared by tillage that it will catch and hold enough water to supply the plants with the moisture they need even through hot, dry spells. Plants draw their nourishment through their roots to their stems and leaves, and you need only examine the fine roots and rootlets of any plant to realize for yourself that such nourishment could not be taken in in a solid form. Plants are constantly drawing this moisture from the soil and as constantly giving it off into the air through their leaves. If you will watch any plant during a drought, you will see the leaves begin to shrivel before the stems or branches show signs of suffering. This is Nature's effort to sustain the life of the plant as long as possible. The shrivelling of the leaves prevents the escape of the little moisture the plant can draw, and retains it longer within the plant's system.

Deep plowing, the breaking up of the subsoil, the addition of decaying vegetable matter or humus, fertilizing with stable manure, and the raising of crops that can be frequently tilled, all help to add moisture to the soil. If you do these and the dry spell does strike you hard, so that it seems necessary to bring water, the soil will suck it and hold it, instead of letting it pass off quickly through the action of sun and air. Frequent stirring of the surface soil, to the depth of one inch, will make a little dry layer or top-coat through

which the moisture does not readily escape. This is what is called a "mulch." A mulch may also be an added coat of leaf-mould or stable-litter or any little dry covering which will prevent the moisture from escaping.

For early crops a light, sandy loam is best. A sandy loam is a loose, sandy soil made productive by good tillage, by mixing in humus and plant food or fertilizer. But when you haven't the best, it is for you to counterfeit it as nearly as possible. The advantages of sandy loam are that it is early, easy to work, responds quickly to fertilizers and is readily kept in good tilth.

"Tilth" is really the planting condition of the soil, and good tilth means the best possible conditions for planting seeds; where the plow and the harrow have done their work; where the sun has warmed and the rain moistened; where the fertilizer has sweetened and quickened; where stones and weeds are unknown, so that the new life finds the best conditions for sprouting and developing. You will understand why such soil is not often in the market. It is Nature's materials plus man's intelligent labor; and he who has it, is usually found working it to his own profit.

Some soils are easily put into condition: others require much time and labor, but all always repay. It is well, however, to avoid a hard, cold, clayey soil if possible; it takes so long to warm up, that the seeds make little progress. Of course, steady persistent effort will greatly improve even this soil, and if that is the sort you have, you must do your best with it, but the average gardener cannot afford to wait.

Compared with agriculture, which has been known in some form ever since there have been any records, tillage is very new. Like many another important thing, it was discovered quite accidentally by an English farmer, named Jethro Tull. He found that by stirring up the soil about his plants, he got better returns; and gave his discovery to the world. But he could not explain why it was so; he merely knew the fact itself. Science has since discovered that it is due to the action of the air in helping to break up the many compounds found in the earth containing plant food. It was a simple thing, yet it has really revolutionized gardening. Before tillage was known the returns from the sort of cultivation in use were very scanty, and this book had never been written had Tull's discovery never been made. So you may be able to do the world a great favor if you cultivate intelligently, not fearing to experiment or to make known the results of your experiments. It may be reserved for you, in your little garden patch, to discover some new truth that will prove a blessing to the whole world, for no science today offers so wide a field for discovery as the science of Agriculture, nor so sure a return for labor expended.

There is a story that illustrates the value of tillage. A man lay dying and as his four sons gathered about his bed he whispered feebly, "My sons, there is a great treasure hidden in the garden." Scarcely had they laid the body of their father away, when the sons went to the garden and began digging it up. They dug every inch carefully, and found nothing for their pains. Then the eldest son, being of a practical turn of mind, suggested to his brothers that they plant the garden and thus secure some return for their labor. This they did, and when harvest-time came the returns were so wonderfully increased that they said, "Now we know what our father meant. Let us seek like treasure in all our fields." And in every garden and field lies hidden the same treasure that can be revealed only by the expenditure of intelligent labor.

Tillage is an art in itself, and very important to success. There are two kinds—the tillage of preparation and the tillage of maintenance. They are widely different in their purpose and effect. The average farmer thinks that both may be carried on at the same time, and this belief may be in part the cause of his failures.

The tillage of preparation includes not merely the breaking up of the soil by the plow, but pulverizing it for as great a depth as the roots of the plants will reach. How deep that may be, depends upon the character of the soil and of the crops. For example, a hard soil with a subsoil near the surface, must be plowed deep; so that the root crops, which run deep, may find sustenance. On the other hand, sandy soil, or one which leaches away, can stand only shallow plowing, as we must hold the subsoil firm to prevent leaching. So that, even in the tillage of preparation it comes back to the same point, to learn the needs of your particular soil and supply them.

The tillage of maintenance should be given as often as once a week or ten days, and is merely that surface loosening which enables the soil to drink in the rain and withstand the heat of the sun. The loosened surface will not cake about the plants, and it makes a layer of mulch for the protection of the under soil.

By the addition of humus, or vegetable matter, a clayey soil may be put in condition so that it will respond to further tillage as satisfactorily as the lighter, sandy loam. This is the way to "counterfeit the best soil."

Humus is added by plowing into the land vegetable matter which is in condition to rot quickly and become thoroughly mixed with the soil. Rye, clover, cornstalks, vines or other garden waste, and manure, are commonly used. Manure that contains a large proportion of stable litter and sweepings, and street sweepings, are especially rich in humus, and are much sought after by experienced gardeners. By adding them, the texture of the soil is lightened and improved, made loose and mellow so as to hold moisture, and is at the same time prevented from caking. Moreover, humus contains plant food and heat that make seed sprouting easy.

The amateur gardener seldom recognizes the importance of the physical texture of the soil, but the best results demand the best conditions. Unless you want to grow pears and plums—which thrive in clayey soil—break up the clayey earth and improve its texture in every way. Your garden will repay you, and you won't go about denouncing those who have written books about the possibilities of small areas as wilful deceivers of the guileless and unwary. Get it firmly fixed in your mind to start with, that, if your garden does not yield adequate returns upon your labor, the fault is yours. You are working unintelligently, and deserve no more than you are getting. To know your soil is to be able to give it the treatment it needs to make it fruitful.

CHAPTER III.

SOIL FERTILITY.

Soil fertility is the power in the soil itself to produce a good crop under proper conditions. Man can neither make nor destroy the land. All that man can do is to make it more or less efficient, according to how he uses it. Two men may take two pieces of soil of equal fertility and get vastly different results; by careful study and experiment we may learn how to take advantage of this fertility; but the real secret of it, Nature has wisely locked up in the soil itself, so that one generation of men cannot really rob the next. It has been said that old-time farmers, of New England particularly, robbed the soil of its fertility, so that their sons have been compelled to abandon the old farms and seek new land in the west, or new occupations in the cities of the country. The real truth is, not that the soil has been robbed of its fertility by the fathers, but that the sons have continued the unenlightened methods of the fathers even after their ineffectualness has been proved.

Since that land was abandoned it has not really been idle. Nature has been improving it all these years by placing leaves and trees back upon it, thus providing humus; and also by the action of heat and cold. Some of this land, overgrown with briers and brush, has been cleared and found to be better and stronger than ever before. Much of the soil is sour, but that is easily remedied, and wherever a patch is burned over, the grass works in well. On some of these abandoned farms there is an excellent opportunity to combine intensive culture on the lowlands with orcharding on the hills, for the fertility is still there. If man could destroy this quality, that clings to all soil, he would have spoiled it centuries ago, and the race would have starved. But we are a long time learning how best to use it.

Robert S. Seeds, of Birmingham, Pa., thinks he has solved the secret of unlocking that soil fertility, and he offers the astounding results of his operations on an abandoned farm, as proof of his claims. He not only raises enormous crops, but he sells his soil by the bushel, to his less enlightened neighbors to inoculate their farms. He tells the story of his experiments in a lecture called "How God made the Soil Fertile," which is published in pamphlet form and sells for 25 cents.

He says "The Lord made all the acres of the land fertile, from the Atlantic to the Pacific, and gave it to man to live upon, to prosper and be happy. In doing so He never hauled a wagon-load of manure or a load of lime, nor bought a ton of fertilizer—and how did He do it? He did it with vegetable matter; and I thought if the Lord could do it, I could do it. This sounds a little conceity, but I mean it."

As a result of this belief, Mr. Seeds took to experimenting, beginning with the crops that store nitrogen in their roots, such as crimson clover, and with purple-top strap-leaf turnip. But the results were not sufficiently great to please this man, who was after all there was in the soil. He needed some plant with longer roots, and finally hit upon the cowhorn turnip, which will grow roots from 9 inches to 2 feet long, thus making available the plant food locked up in the subsoil. Finally he combined cowhorn turnip and rape, and now his soil is the most fertile in his district, and is so profitable as an inoculator of other soils that he keeps fields free from harvest crops so as to have the soil for sale.

"Bob Seeds" further says that a field filled with the decayed vegetable matter and humus from one crop of crimson clover plowed down, will hold fifty tons more water to the acre than soil that is not. If you figure how much water you must have to raise a crop of corn, oats, potatoes, hay, etc., you will see the value of land that has the power to hold water. There was a farmer in Pennsylvania

who got his farm in such a water preserving condition that he said the spring rains were a nuisance. Watch the soil and you will see, that soil that is filled with decayed vegetable matter and humus is warmer in the winter-time, cooler in the summer-time, wetter in dry weather and dryer in wet weather.

A mulch which preserves the moisture in hot or cold weather also unlocks this fertility of the soil.

All of this is of immense importance, not only to the farmer on a large scale, but also to you, with the limited area of your garden yard; for in it lies the secret of heavier and earlier crops than your less instructed neighbors. Professor Whitney, Chief of the Bureau of Soils, Department of Agriculture, Wash., says that deep plowing and shallow cultivation are the best means of retaining moisture in the soil, and he adds, "Strange as it may seem, while we suffer if we do not get rains, we should actually be better off, as they are in the arid regions of the west, if we did not have any rain during the growing season and had a means of providing water when we wanted it. The trouble with us is that we cannot maintain the dry mulch, because we have rain on the average every three days. If you knew what was coming, you could save your crop through any ordinary period of drought, provided you had the skill, the judgment and the chance which would lead you to begin your operations at just the right time."

According to Professor Whitney there are about 400 distinct types of soil so far encountered in the United States, with varying degrees of known fertility, and only eight or ten staple crops growing. This, of course, does not include the special crops like celery; it is the regular, staple field or garden crops that are unnecessarily limited. These are grown on all kinds of soil in all parts of the country without regard to the suitability of the soil to the crop.

The Government, through the Department of Agriculture, has given a great impetus to plant introduction, and you cannot of course expect to rival or approach it, with its enormous funds and staff of experts, but you can experiment with the new crops it introduces. Hitherto, in this country, where the soil was too dry for corn or wheat, or too moist for potatoes, it has been neglected altogether; but the present movement includes finding crops suitable for these lands. The Government has introduced the durum wheat which yields crops in regions suffering from drought, and in 1905 the United States exported 6,000,000 bushels of it; Japanese Kiushu rice is doing well in Louisiana and Texas rice fields; the Japanese salad plant, the udo, is being tested from Maine to California and giving good results; Kafir corns from Abyssinia, India and East Africa are being grown in Kansas and other western sections; while the English broad bean, Hungarian paprika, and fruits from all parts of the world, are being tested in all sections of this country. Those 400 different types of soil should mean limitless diversifications of crops, and it is fair to assume that the real day of agriculture, in this country at least, is only just dawning.

The Government is now testing profitable crops for the farms of New England which have been abandoned to the mortgagees. Areas there are too small to grow corn[2] and wheat in successful competition with the great farms of the west, but there are other crops which will yield even better results and command the market. You, who are now coming into the great calling of earning your living from the soil, could not have chosen a better moment for entrance. Keep in touch with the Department of Agriculture. It is your department, a sort of college or training school which you maintain, and anything you want to know the Department will gladly try to tell you. If you want to know what is best for you to plant on your patch, send a sample of your soil, tell where your farm is located, what are your means and experience, and the suggestions made will fit your particular case. If you send any of your requests, whether for advice or for bulletins, addressed simply to the Department of Agriculture, Washington, D. C., you will get a reply, and will find out who is the head of the special department your request was referred to. The Department is doing needed work, and by corresponding with them and getting advice, you can give proof of your interest.

FOOTNOTES:

[2] NOTE.—But corn growing is on the increase in New England and at the great Omaha Corn Show a Connecticut farmer won three first prizes. The Flint varieties are especially adapted for the New England climate and soil and open up new possibilities for the New England farmer.

CHAPTER IV.

LOCATION.

How to buy land and why; how to help the poor to keep themselves on the land and what plain people have actually done; the record yields and how they have been raised; how much capital can be used by one man, are considered in "A Little Land and a Living."

How much of a crop you may be able to get; how much or rather how little capital it takes; how much labor is needed; where cheap lands are to be found and how to clear wild land and how to build, are all treated fully in "Three Acres and Liberty," now published in fine shape at fifty cents. So this "hand book" need only show what other things are included in the term "location."

If you are thinking of the character of the soil when hunting for a garden plot, you will more than ever think also about the importance of location. Any soil, even the best sandy loam, needs some fertilizing and watering, and you cannot afford to use land where manure can not be had easily, or where there is not a good water supply. To pay high for fertilizer cuts the profit from your small area, and this is more especially true if your soil is clayey and needs much preparation-tillage. In most cities you will find stable-keepers and others who will give you manure or street sweepings in the winter in return for hauling it away. That is a great advantage to you, but if you locate your garden where truckage amounts to two or three dollars a load, you have offset the advantage you derived from the free manure. Also, if your water supply is poor, you will find it difficult to carry your crops through the hot weather.

MARKET.

You can raise a good crop from good soil properly fertilized, but if you cannot market it to advantage, you can't sell it at a profit. A long railway haul not only injures the garden truck, but it also eats up the profits. Therefore, get your plot near a town or city where the expense of selling is reduced to a minimum and where the demand for garden products will at least equal the supply.

So the good-garden-plot tests are three: first, the character of the soil, second, the location as regards the market, and third, the demands of that market. He who must of necessity use the land where he is, will, if he uses his brains as well as his hands, find his reward satisfactory, even though it fall below the returns from a plot with all advantages.

CHAPTER V.

SEEDS.

The expense and labor of preparing and tilling soil is too great to allow you to plant poor seed. The stock-breeder does not take his sickliest, poorest specimens for breeding purposes, but rather selects the best and most nearly perfect specimens; you should be careful to do the same with your plants. The farmer's work is just as important as the stock-breeder's. It should be the aim of each to improve the strain and produce the best possible result. Therefore, if you are growing corn, plant seed only from the stalk that produced the most and the best ears of corn. It is good to send fine ears to market and get the best price for them, but if you save only your scrubby ears for seed, next year you will not have fine, perfect ears of corn to send. So select of your very best for seed purposes, and if your best is not good enough, then buy from a better grower who has the best. Aim to produce an ideal ear of corn. It can be done, and you might as well do it. Only in this way will you find your corn crop paying you for your time and labor. If you carefully follow this every year, you will find your acre annually producing more and more corn without any additional labor or expense. That is one trick in making farming pay. It is a trick that holds good with every garden crop as well as with corn. It won't do to wait until harvest time to find out if the seed you have planted is any good, if you have to buy your seed and want to make a profit from your garden the first season. This simple method of testing seeds may save you time and money. Get your seed early in the season, select about one hundred and put them between two moist pieces of flannel, which in turn are placed between two soup plates. Keep the flannel moist (not soaking wet with water standing in the dishes), and as soon as the seeds have sprouted, count the proportion of live ones. If only a few of them have sprouted, you will know that you cannot afford to give ground up to the use of such poor seed. The larger the proportion of your test seeds that sprout, or "germinate," as this process is called, the better for your profit, if you plant from this same stock or assortment.

Be sure you deal with a seed house that has a reputation at stake; and if possible go there yourself and see the man who really knows about seed: generally there is only about one man in a concern who does know his business.

If you answer attractive advertisements and buy at "big bargains" you may lose your money, or, what is worse, you may be kept waiting from day to day till your planting days are over, or worst of all, you may plant poor seed. The dates of planting given throughout this book are for the latitude of New York. In Northern New England planting should be about three weeks later. All the middle western states can be figured the same as New York: but all states south of Pennsylvania may be figured twelve days in advance for every one hundred miles southward.

This holds good for sowing out of doors or for transplanting out of doors. For starting seeds in your home, these times will do for the entire eastern states.

CHAPTER VI.

PLANT-BREEDING.

Plant-breeding is producing plants adapted to particular conditions or requirements; but the mere production of something new or different, is not true plant-breeding. The plant breeder has a definite purpose or aim in mind, and this comes only from a clear idea of his business. The professional breeders produce the races or groups, but the intelligent individual farmer adapts them to his own conditions, and may make modifications of inestimable value to other farmers.

Good farmers have always been plant-breeders, even though they did not know it. They have always kept the best ear of corn and the best potato for seed. They have followed the stock-breeder's plan—only the best stock for sires and dams. So no common plants should be used for seed; only the finest is worth planting. Improvement is made by selection, as Darwin taught us many years ago, but we are slow to learn new lessons. We know that we do not look to the children of physically, mentally or morally deformed persons for our specimens of physical, mental and moral manhood; nor to the cur's litter for the best type of pup. Now we are learning that the same holds good with plants, and that the farmer who keeps the small potatoes for seed will produce poorer potatoes than he ought to have.

The other day I found a farmer harvesting a measly lot of corn. "Where did you get that seed?" I asked. "Oh," he said, "I picked it up 'most anywhere." I could have told him that myself without asking.

Selection and breeding are not the work of experts alone, for any one who gains the simple knowledge that enables him to recognize the plant or crop that resists prevailing diseases and flourishes best under his conditions, needs only to preserve the seed of such plants for propagating. Cross-breeding, on the contrary, is expert work, but new strains may be secured by straight selection of individual plants, and this gives enormous results. If one persistently saves the seeds of those plants that best serve his purpose, he will soon have crops that are superior to any that he had before. The process is so simple that anybody can do it. We have talked for years of the "survival of the fittest," and this is but helping the best to beat the poorer ones.

What causes the variations that make selection possible nobody yet knows; but we do know that changes in soil, climate, methods of growing and in other things have an effect. Some variations come from "crossing," and some from no cause that we can see: in those cases they are called "sports" of nature; learn to look out for them and when the new variety is better than anything you have before produced, save it for seed and see what comes of it. You may thereby be doing all mankind a service.

CHAPTER VII.

PLANT NEEDS.

Plants need water, air, food, light and warmth just as animals do, and it is wonderful to study the shifts and contrivances to which they resort to get these, and also to protect themselves against too much of any of them. If the plant were not able to change itself to suit the conditions, it would often die where now it fights successfully.

Nothing affects the plant like the water supply; the size of every part of the plant is increased by plenty of water. It not only helps the growth of flowers and fruits, but it even changes the character of the plant. In a moist air, cactus will put out leaf-like organs, gorse will grow leaves instead of thorns; while where the water supply is very scanty, the potato will put forth no leaves, but will become like a cactus.

Yet plants do not grow in soil that is too wet, because they need air, and too much water suffocates the roots. By proper irrigation—which means giving just the right supply of water—both the quantity and quality of the crop can be improved.

While plants need light, all varieties do not need the same amount of it. You will find that those which need much light can turn towards it, and this of itself will show you where such plants should be sown. Plants have various ways to resist the supply of light when they are getting too much. They droop their heads or close their leaves, which prevents evaporation.

Different plants need different food and the same soil conditions will not suit all. Some require rich soil if they are to flourish, while some do better in poor soil. On the whole, plants, like people, are better for under-feeding than for over-feeding. In general, starving a plant makes it flower and fruit more quickly, but less abundantly; while over-feeding helps to make much stem and leaf instead of fruit, and also produces monstrosities. Too much nitrogen, especially, makes too much stem and leaf, though nitrogen is one of the most important plant foods. (Bailey says too much nitrogen can be corrected to a certain extent, by potassium put in the soil.[3])

We are sure of only three plant foods—potash, phosphoric acid, and nitrogen. Then there are lime, stable manure, green manure, clover and cowpeas to doctor the soil with, when it is suffering from chemical ills. This gives some idea of the vast unexplored regions of agriculture which afford you and every other worker in the soil an opportunity to make some great discovery for the benefit of the world. No other calling offers such limitless opportunities.

Lime is especially valuable for plant food and also to make other kinds of plant food available. Crops often fail in soil where there is plenty of plant food, because it is not in the form that the plants can use. Lime hastens the decay of vegetable matter, sweetens sour soil, and greatly improves the texture of clay soils. Besides this it counteracts magnesium in the soil and destroys its bad effects. But lime may not be applied carelessly, because, although some plants cannot live without it, some require a very small quantity. (It is, therefore, wise to send a sample of the soil, to write what we want to grow, to the nearest Government experiment station, who will probably suggest what could be done with it, to make it productive.)

The right degree of warmth is another plant necessity. The best temperature for plants generally is 86° of the ordinary thermometer (30° Centigrade). This, however, depends upon the plant. The "best temperature" varies with the species and variety. Usually, if the soil is hotter than that, growth stops, and if the greater heat is kept up, the plant dies. When the temperature is lowered, growth ceases before freezing point is reached. Some few plants may be frozen without injury if they are allowed to thaw slowly, but most of them are easily killed by the frost. Too great heat or too much cold acts the same as lack of water; the heat causes too great evaporation, the cold prevents the roots taking in the water.

Shingles stuck in the ground on the sunny side will serve to protect young plants from sun and rain, while cool soil may be had by using the shady places, or by sheltering the ground with flat sheds the roof boards of which have open spaces between them as wide as the boards. This is done in some southern tobacco fields.

It is the law of nature that living cells must have a constant supply of oxygen, that is why a tar wash sometimes kills plants by cutting off the air supply. In the same way, too wet soil or too hard a crust smothers the roots and the plants die. The surface soil should be kept loose and sufficiently dry, so that the air can circulate. If this be prevented, the soil becomes hard and sour and unfit to feed plants.

It is of the greatest importance to keep the soil open and loose by proper tillage, so as to make plants healthy and vigorous.

Though plants need air they should be protected from draughts and sudden blasts of air, whether hot or cold. For this reason, the intelligent gardener will consider the effect of wind upon his crops and where necessary will plant windbreaks. If you look about you, you cannot fail to see the ill effects of strong winds in the odd shapes of forest trees; and in badly arranged gardens you will find the same effects in the fruit trees and small fruit bushes and in the stunted crops. Plants shape themselves to their surroundings, and the way they shape themselves is determined by inherited qualities; so it may be said that the success of the plant depends upon its surroundings and upon the seed it came from.

FOOTNOTES:

[3] NOTE.—In regard to muck soils, it is not a case of excess of nitrogen but lack of potash which makes potash valuable for such. Samuel Fraser.

CHAPTER VIII.

CROP ROTATION.

In agriculture on a large scale the difficulty is how to arrange the farm business so as to make it pay. It is only of late that we are beginning to understand that agriculture is a business, and that to make it pay one must apply business principles. The best farmer is not necessarily the one who knows the most "Science," but the one who is able to fit his science, his facts and his business in together.

The market value of special crops is so high that the grower can afford to provide the extra manure and other expensive materials to keep the land in good condition. This is the chief reason for the use of great quantities of stable manure in market-gardening, far greater quantities than are needed for mere food of the crops. So if you find that you are advised to use more manure on your small plot than some farmer you know uses on his big field, do not feel that you are being imposed upon. He could not afford to use so much and you cannot afford to use less. The farmer on a large scale has to let part of his low priced land rest in clover once in a while. You cannot afford to let any of your small area rest, so you must make up to the land by giving it plant food enough.

In these days machinery has made so many wonderful changes in the management of crops that the farmer who sticks to the old farming customs has no chance of making more than a living. When the country was new, it was the practice to farm one section until it was exhausted, and then to move to fresh soil. The farmer was saved the bother of cultivating, as virgin soil needed practically only to be planted to bring forth a good harvest. But conditions have changed and the virgin soil left today is not important in the farming possibilities. Therefore, we have had to look for other means of getting crops and making every inch of land do its share. We no longer allow land to lie fallow that it may rest and renew itself. We renew it by fertilizing and by rotation of crops. Crop rotation is very valuable because it is a saving of fertilizer and labor, and keeps the soil in good condition. This has been proved by experiments made without manure, depending entirely upon rotation for fertilizing, which gave excellent results.

There are probably a dozen or more good reasons for the value of crop rotation which have not yet been discovered and formulated, but the following are well known:

Some crops tend to correct the faults of others. It has been proved that the continuous growing of one crop injures the soil in some respect, and the crop falls off both in quantity and quality. Rotation tends to overcome this difficulty. Then, too, this rotation works out and evens up the inequalities of the soil, partly through the different treatment required by the different crops.

Different plants draw different portions of food from the soil and at different times. By rotation these heavy drafts on the plant food do not come at the same times, and the seasons get a chance to even up the inequalities.

Different plant food gets mixed into the soil, so that the roots can feed on it, by the decay of the parts left in the ground or which are plowed under. But the greatest benefit comes from the nitrogen compounds through growing plants, such as cowpeas, crimson clover, etc.; these “leguminous” plants have little knots or tubers on their roots with the mysterious power of gathering the free nitrogen out of the soil or air, and turning it back again to the soil in condition to be used by other plants. Now nitrogen is the hardest to keep and the most expensive of all the plant foods that the farmer has to buy, and to get this nitrogen is sometimes the only reason he has for buying chemical fertilizers.

This shows the importance of leguminous crops to the farm. They supply this nitrogen at almost no cost, or at a profit.

Some plants have more power than others to use the contents of the subsoil, and may draw less on the upper soil, and further, by their decay may add richness to the earth. Most legumes have this power to take nourishment from the subsoil.

Well-planned rotation helps to maintain the supply of decayed stuff in the soil, on which the plants feed. It also improves the soil’s texture. Moreover, it not only lessens the necessity for much chemical fertilizer, but it puts those fertilizers to better use. Where live stock is kept, crops should be raised to feed the stock to make manure.

Rotation is, also, a plan for cleaning the soil. Different weeds and insects grow after different crops and the succession or “rotation” as we call it, prevents any kind getting a secure hold.

It enables the farmer to meet the demands of the market, by continuous crops.

CHAPTER IX.

WEEDS.

It is not enough to know what to grow, you must also know what not to grow for profit, in a garden patch; and first in this class come weeds. Study them until you know even their seeds. You cannot expect to get rid of weeds until you know the nature of them and the best way to attack them, so that they may be readily destroyed. If you run across any common ones that you cannot place, send sample to the Department of Agriculture. They will tell you all about them. Get from the Department Farmer’s Bulletin 28 on “Weeds and How to Kill Them.” All this will pay.

One of the most common of the weeds of the north is the pigweed. This is the growth of one year and can be destroyed by simply preventing it from running to seed. A year or two will clear out even the most obstinate growth of pigweed.

Mustard, plantain, chess, dodder, cockle, crab-grass and Jimsonweed are the most disagreeable of the common weeds. The best time to kill them is when they are small; therefore, you should keep the ground constantly stirred up that the young weeds may not have a chance to get a firm hold of the soil. If they do get a start on you, don't let them ripen. Cut them down before they run to seed at all. Never let up in your war upon them. That advice holds good for all weeds, whether they be annuals, which die every year, biennials that last for two years, or perennials that can stand the winters. The biennials commonly found are wild carrot, thistle, moth mullein, wild parsnip and burdock. These are best destroyed by cutting the roots below the leaves with a grubbing hoe or spud. Be sure they are cut low enough, else they will branch out and make new seeds.

Some weeds live more than two years and are called perennials, such as many grasses, dock, Canada thistle, poison ivy, passion-flower, horse-nettle, etc. The best thing to do with them is to dig them out and take them away. Crude sulphuric acid applied to the soil kills them, or they may be starved by covering them with boards or with layers of straw. If they come up through the straw, lift it up a bit and let it fall again. There is yet another method, and if you have the time and land to spare, you will find it a good one. Smother them out by a dense growth of useful plants. Some use buckwheat and others cowpeas. The cowpeas are to be preferred as they enrich the soil by the nitrogen their roots gather. And that is another story that has its own time and place. Just now we are considering weeds, and you will find that they will keep you considering most of the time, for the only good thing so far known about them is, that they make even lazy farmers till their crops, if they have any. Left to themselves, weeds shade the crops, steal their nourishment, waste moisture, and probably poison the soil. Not even a mortgage can eat up a farmer's profits like weeds.

CHAPTER X.

INSECTS AND DISEASES.

The wise gardener uses the spray to prevent disease and the attacks of insects, instead of waiting to fight them after they have arrived. But if they attack your garden you must fight them intelligently and without ceasing.

The destruction by insects, is, generally speaking, easily seen, but diseases of plants are not so plain, and have only been carefully studied even by experts during the past fifty years. At present, all we know is how to fight insects and diseases by different substances, put on or about the plants. As fresh discoveries are constantly being made, we will some day get rid of all these difficulties. It is always better to get the advice of an expert when insects or diseases become troublesome.

Anything in the soil or surroundings of your garden which interferes with the plants during the growing season, weakens the crop and lays it open to attacks. Plants are like children. If they are badly fed, poorly clothed, ill housed or neglected, they are far more likely to become diseased than if they are kept in a good state. So look after your drainage, the character of the soil and the sort of cultivation you give it. All these help the crop to withstand disease. On the big western wheat fields, it has been found that drainage has a most marked effect upon blights, wilts and rust. Undrained wheat sections suffer greatly from rust.

Just how diseases are caught by one plant or section of a garden from another, is not fully known, but we know that insects often carry infection from one to another, as in fruit trees to which bees go for honey. The bee, coming from an infected tree to a perfectly healthy tree, may bring with it the germs of the disease or the eggs of the pest. Many scientific men now hold that plant diseases are transmitted by germs, which are carried not by insects only but also by the wind and the water in the soil.

The wrong use of fertilizers or barnyard manure may often induce disease, simply because the unbalanced food supply causes irregularity in growth, which weakens the plant's resisting power. What is called a "balanced ration," is of the utmost importance to plants. It is not enough that the soil contain an abundance of some of the elements of plant food, but that it contain all of them in nice proportion, so that the plant can draw all it needs, and not be overfed in some ways and underfed in others. That is why we add humus, why we fertilize, why we cultivate, and why we take note of our plants while growing. Only in this way can we supply their wants.

Weeds spread diseases and we should be ashamed of them. Not only are they usually favorable to the growth of insects, scales and blights, but some kinds of weeds actually breed these parasites. Moreover, they rob the soil of nourishment during the dry, hot spells, thus bringing about various kinds of rots and mildews. And now it is supposed that they give out a kind of poison, or

excrement, which renders the soil unfit for crops. All this shows the necessity of clean cultivation if we would help our crops to resist both insects and diseases.

CHAPTER XI.

RE-SOILING.

There is a good deal of talk these days about re-soiling, but the word is misleading. We cannot re-soil this earth or any part of it. The soil is there for keeps. It was here before us, and will remain after we are gone. All we can do is to put back into the soil some of the vegetable matter of which we have robbed it; and this is really what we have in mind when we speak of re-soiling. People have the habit of coining almost meaningless words, and then wondering why everybody does not know at once what they meant to say.

What we are after is, to put humus, which is really decayed vegetable matter, back into the soil. Then that natural fertility, of which we have been talking, will have a chance to get to work.

[Illustration: WINTER RESIDENTS IN A SUMMER CAMP.]

Now, decayed vegetable matter is part of what makes up stable and barnyard manure, street and stable sweepings; but, in practice, this does not afford enough humus: that is one reason why crops of clover, cowpeas, velvet-bean, buckwheat, etc., are often grown only to be plowed into the ground in the fall. These are the green manures which decay and become a part of the soil before the next planting season. Soil fertilized in this way will be richer, moister, darker, than soil fertilized solely by stable manure or commercial fertilizer. Soils that contain enough plant food to supply crops for a thousand years to come, are often barren or yield but a niggardly crop. This may be because they lack humus, which is the key that unlocks the store of plant food in the soil, and makes it available for the seeds and tender rootlets. How much more humus may do, we do not yet know, but every year fresh discoveries are made, and if we are to be benefited by them, we must get ourselves ready for the new truths by using those already known.

On his famous farm in Birmingham, Pa., “Bob” Seeds plows his cowhorn turnips, tops and all, into the earth in the fall, and by spring they have decayed. He says wherever a turnip has rotted, you can see the difference in the color of the soil even some distance away, and the abundance of the next season’s crop shows how quickly Nature responds when we work with her.

All vines and garden waste may be used for humus if plowed into the ground in the fall, unless they have been infested with insects or troubled by diseases. It is well established, that insects and their eggs manage to live over the winter by the aid of vines and refuse left lying about, as well as by weeds that the careless farmer has failed to destroy. It is well to cut all weeds, not only those that bother you in your garden, but also those that grow along the road, as often their seeds are carried by the wind or the birds into your garden patch. Gather them into a heap and burn them, adding to your bonfire all the sickly, dead, diseased, or insect-ridden vines and plants, and completely destroy them. You may be sure that the bugs on those particular plants will not bother you next year. What you lose in possible humus by this practice, you can make up by growing green manure, or even by buying some of the prepared humus materials now on the market.

The _Long Island Agronomist_, in a recent issue, tells of one of these materials which comes from New Jersey, and consists of innumerable rootlets, leaf-fibres and vegetable matter of all descriptions. It is gathered from the peatbogs of New Jersey and is really the wash from mountains and hills carried down by streams in freshet times, until some level was reached where this deposit was made. When spread on the land or mixed with the earth, it is found to hold much moisture, for each particle swells up as if it were a sponge, and the crops planted on soil treated with this preparation do remarkably well. It was so very expensive at first as to be almost prohibitive except for very valuable crops, but the price is now such that many a man can afford to use it, especially if he cannot afford the time or space to grow his own green manure.

Nothing looks nicer about a house than a green lawn, with smooth-cropped, velvety surface, but nothing is harder to maintain after a few years of cropping. This is because a well-kept lawn is carefully raked after each clipping, and is kept free from falling leaves or other vegetable waste matter. It must be admitted that the general effect is better, particularly when the lawn stretches from the front of the house to the roadside. But the lawn is, nevertheless, being starved, and though watered every day it cannot keep up its velvety surface indefinitely, unless supplied with the food it needs. This is Nature’s own secret for replenishing the earth with good crops, and all you need do is to observe what is going on around you, to find daily proof of it.

To quote Mr. Seeds again: "Every two years, we ought to sow clean blue grass or lawn grass seed over the lawn. I prefer to mow often and leave the clippings on the lawn. It is the blanket and vegetable matter that will do the lawn good. Every few years I cover the lawn with barnyard manure, in the fall; let it lie there all winter and that which we rake off in the spring we put on the garden. This is a little trouble, but I want to say that I made more money creating my lawn than I ever did in taking a fat ox from the stall, or a bushel of potatoes from my cellar.

"A man will stand on the public road in front of my place, and give me more for my property on account of my lawn; but money is not the only thing in the world. The lawn makes the boys and girls want to stay on the farm. It is on our lawn that we spend our spare moments on Sundays, entertaining our friends, in the summer; and there, beneath the shade of 'the old apple-tree,' the smoke curls more beautifully from my chimney than from any other I ever saw."

So there is no reason why you should not have a good lawn, as well as a good garden, if you will supply what the grass roots want. And it is true that the lawn is a genuine asset. The man who is too busy to bother with making a lawn, or to sit on it with his family in spare moments, even though it takes a good deal of contriving to spare those moments, is the man who, by and by, is going to complain that his boys and girls have left the old place, and that "farming is mighty expensive with all hired help." Unless you have made yourself and your family happy, you will not have achieved success, no matter how much wealth you may get. Give your crops and your children what they need for their best development, and you will find nothing to complain of either in parenthood or in farming.

CHAPTER XII.

HOW TO WORK.

If you are only just beginning to experiment with gardening, and feel that a fresh supply of fruits and vegetables from May until Christmas would satisfy you for the first year or so, you will find a plot 100 × 200 feet quite large enough to feed your family and a little more besides. If your plot has not been used for a long time, you will have to do your plowing, if you can, the fall before you plant it. This will give the frost a chance to sweeten the soil, and it is very likely to need a good deal of sweetening. Most yard soils have become acid, and in an acid soil little will grow. It comes from the earth having been so long packed down that the air has had no chance to circulate, and fresh air sweetens your soil just as it does your house.

It is not good to put stable manure on an acid soil. What it wants is a little slaked lime or plaster, to help the sweetening process. Some scientists claim that we can find out whether or not soil is acid by the use of blue litmus paper, which you can get at any druggist's. Open the soil to a depth of six inches and put in the litmus paper, drawing the earth close up to it. Examine it in 20 minutes, and if there is any acid present, the paper will have turned red. This test is still being experimented on.[4]

If your land is in proper condition to manure, use about twenty-five heaping wagon-loads to the acre before plowing in the early spring, and then use a disc or cutaway harrow until you have made the soil as fine as dust. Then you have good planting conditions.

How much of the discontent with farming and gardening may have arisen from the old method of planting in beds, it is hard to say. But that cause for dissatisfaction no longer exists. We now plant in long rows far enough apart to allow the use of the wheel-hoe in cultivating the large and small plants alike, without having to readjust the blades. The wheel-hoe is one of the most useful of farm tools, and has done away with most of the back-breaking work of hand-weeding.

We cannot use the wheel-hoe on beds; that is why we now plant in rows. If your plot allows rows one hundred feet long, you will find one row of any vegetable enough for family use. Let them run crosswise of the slope of the ground if your patch is not level, else the rain may make channels of your seed rows. If possible, choose a southern exposure for your garden; because this gets all the sun, it will be earlier than less favored exposures. Lay out a plan of your land and work with a definite purpose. The "rule of thumb" is no more satisfactory in gardening than in carpentering.

If the slope of your land allows it, run your rows north and south, so that each row may get the sun from the east in the morning, and from the west in the afternoon. Put asparagus, rhubarb, sweet herbs and other permanent vegetables in a row at one side, so they may not interfere with the plowing of the rest of the garden.

Plant vegetables of the same height together, so far as the tillage required will allow. Put the tall ones at the back, so as not to shade the others. If you have a hedge, a building or a strip of woods as a windbreak on the side where the wind blows worst in

winter, you will get vegetables a fortnight earlier in the spring, and probably a month later in the fall. The more protected the garden, the warmer the soil, and warm soil means quick and abundant returns. That is one reason why we use so much manure. It warms and quickens the soil.

Plant vegetables that ripen at the same time as near together as their size, habits and tillage requirements will permit.

Practice rotation; for instance, lima beans should not immediately follow string beans or peas. As far as possible, keep the plants subject to the same insects and diseases together. It is easier to treat them, and besides, it leaves the other portions of the plot uninfested, if they get so bad that you have to change the position of the plants.

If you are growing fruits, you could plant a row of apple trees about fifteen feet apart on the northern border, plums and pears on the west, and cherries and peaches on the east side. Then if you could put a grape-trellis next the apples, and a row of gooseberry, currant, raspberry and blackberry bushes in front of the grapevines, you will have a windbreak as a protection against the north winds, which will prove profitable in itself as well as in its service to the vegetables.

Transplant freely; nearly all vegetables are the better for it, especially lettuce and other salad plants. Sow seed thickly in the first place. You can easily thin out or transplant, but you cannot increase the number of plants if you have sown thinly. Even a small proportion of weak seed that would not sprout would seriously affect your crop. Besides, where you sow thickly, you can afford to weed out all but the best and stockiest, and you are thus doing something to improve the strain.

Keep your soil busy all the time. Dr. Watts said, “Satan finds some mischief still, for idle hands to do,” and that might be paraphrased to read that “Nature has great store of weeds in idle lands to grow.” “Weeds are the farmer’s best friend, they force him to cultivate.” But that friendship is only true where it has that effect. The farmer who lets the weeds grow either in the garden rows or in the walks and hedges, is going to find them his worst enemy. They poison and suffocate his crop, and are also regular incubators of insects and diseases. The best way to fight them is to starve them out with paying crops. Therefore, as soon as one crop begins to ripen, plant another, and then another, and so on. To grow but one crop is risky, unless you are specializing and have prepared the best possible conditions for that one crop. For a special market this is very profitable. But usually companion-cropping is best. That gives two crops in the ground at the same time, one maturing before the other needs the space. Thus late celery may be planted between the rows of early celery; lettuce with early cabbage; radishes with beets or carrots; corn with squash, pumpkins or beans, and horse-radish with early onions or cauliflower.

Irrigation for arid soils and drainage for wet or clayey soils, are the two opposite methods which bring astounding results. Any sort of drainage is better than no drainage, but the best form so far discovered is the tile drain laid about two and a half to four feet below the surface. This carries away the surplus water and prevents the roots of the crops being suffocated. On the other hand, irrigation supplies to the dry lands the moisture they need. The tremendous irrigation works carried on by the Government in the sandy, hitherto barren, reaches of the west, are bringing results even more tremendous than the works.

Hard, wet soil will not grow crops and here is where the advantage of draining comes in. Drainage deepens the subsoil and removes the water; it deepens the surface also and makes more of the plant food in the soil available. Wet soil is sticky and hard for the seeds to push their way through; but drainage will improve its texture and make it crumble and fall apart easily, or as the experts say, it will make it “friable.” At the same time it will prevent it washing or “leaching” away. But even this does not tell all of the advantages of drainage. It warms the soil and by making the ground more porous allows the roots to go deeper in search of their food and moisture. This in turn enables plants to withstand drought and hot weather better and makes returns more sure. It also permits working the ground earlier in the spring and after rains, because, the more porous the soil, the quicker it absorbs and stores moisture that comes in rain.

There are germs in the soil which change the nitrogen into nitrates, the form in which nitrogen becomes the real plant food, and drainage favors the development of these germs. You see how important good drainage is.

Get the tools you need. You cannot afford to be without implements if you are cultivating intensively. That does not mean that you must get all the advertised garden tools, or even all that your neighbor has. Although a tool may be the best of its kind, that is not reason enough for buying it. You must have a use for it on your plot. Get whatever you have a use for, and get only the best. It pays in the long run.

A list of tools and costs is given in “Three Acres,” and in “A Little Land,” so it is necessary only to note here that the spading fork is a far better tool than the spade; some gardeners never use a spade. The spading-fork is easier to use and breaks the soil much

better.

The seeder, attached to the wheel-hoe, is also a saver of labor and of seed: it makes the rows quite straight, so that they are easy to keep free from weeds; it drops the seeds at even distances and if your soil is as fine as it should be, it covers them all just deep enough—provided you have learned to fix the gauges right to start on.

Combination tools, those that do several different things, sometimes work well, but they usually get out of repair quickly, and are apt to puzzle the beginner. Get the best and simplest form of the tool you want, and keep it always in condition for use. Tools that are not cleaned after use are spreaders of disease. Cleanliness prevents and cures. See to it that your cultivating tools, your harvesting baskets and bags, and your storage bins are thoroughly cleaned, and you will soon discourage the bugs. They will regard you as cold and unsympathetic, and your garden as a place to be avoided.

Don't be afraid to use manure, both stable and green, and when you must, use commercial fertilizer. But this is expensive and is only profitable under particular crops. You won't need it, if you keep the soil supplied with humus.

Don't waste kitchen slops or any other waste water. It all has fertilizing qualities that will help your garden. Even in the winter it is a good plan to pour your slops on the ground, choosing a different spot each day so that no one place may get too wet and leave surface pools. Mankind in the lump is stupid, so stupid that we drain our fertilizing matter into our harbors and then dig it out again at the cost of four dollars the yard.

But you need not be so stupid as that. Even some of our cities are now learning the value of sewage, notably San Antonio, Texas. This city, with its 85,000 inhabitants, has solved the problem of what to do with its sewage, although the city fathers leased the rights to a private corporation, instead of providing for the city's own disposal of it. This company carries the sewage six miles out of town, and has built five miles of canal, through which the surplus sewage not used in irrigating, flows upon a filter-bed where all solids are removed, and the water runs into a big basin which covers about 1000 acres. This basin being very shallow, the sun's rays reach the bottom of it, and purify the water, so that, though it enters one end of this basin as sewage, it flows out of the other as pure water. Chemical analyses and tests have proved this many times over, and we might take a hint from this at home to "raise our darkened windows and open wide our doors, to let the blessed sunshine in." It is the best destroyer of disease and impurity yet discovered.

The company's acres along the line of the canal profited so much from this irrigation, that farmers soon began to purchase the irrigating sewage water for use on their forage crop fields, and for root crops particularly. The solids are spread on the surface of the lands upon which the clear, purified water is to be used, and the results have been most satisfactory. San Antonio really makes a profit out of that which is costing other cities millions every year, and in doing this has shown us another way to work, in bringing into use all lands that are available in any way for intensive cultivation.

Plenty of manure and thorough cultivation are almost a complete protection against drought. If you have plowed deep, manured thoroughly, added humus and maintained tillage, you can laugh at the drought that would once have spelled ruin for the farmer in any part of the country. You have been told this before in this very book, but that is no reason why it should not be repeated. It is of such great importance, that the average farmer would make no mistake if he had it made into a motto printed in large and striking type, and hung it where he could see it a dozen times a day. It is part of the "How to Work," and a mighty big part, as you will learn, whether you practice it or neglect it.

Use your brains; that's what they are for. After you get your farm started, you can get cheap and unintelligent labor, to keep it going, if you wish; but you can only reap a profit from intelligent labor, and you must furnish the intelligence yourself. Plan your work, and make the most of your soil, your climate and your market. Things that everybody grows bring low prices, but things that you alone grow, or that you grow better than your neighbors, bring good returns all the year round.

We have to learn, you know, and if we won't learn by doing right and profiting by it, then we shall have to learn by doing wrong and suffering for it—"the way of transgressors is hard."

If you have very little time or very little land, you will probably get the best return for your time and money by growing radishes early in the season with lettuce, followed by bush-beans or tomatoes and then sweet corn.

Put some nasturtiums in any odd space and climbing nasturtiums and morning-glories on your fence, and you will have a very creditable looking garden—big returns for little expenditures.

If you haven't got any land, don't let that discourage you: grow some things in a window box and learn how, so that you have learned something when you do get some land.

You can grow mushrooms in half a barrel in the cellar. The thing to do is to get started growing something.

FOOTNOTES:

[4] NOTE.—Another way is to mix a little soil with rain water, stir it well, and put the litmus paper in it. Pure rain water is the only water that can be successfully used in this test.

Part II.

CHAPTER XIII.

ROOT CROPS.

Root crops are usually grown in drills and are not ordinarily transplanted. They are hardy and require little skill in the gardener, but they need a cool season and deep soil so as to grow long, firm and well shaped. The quicker they grow the better the quality, so that in the north it is necessary to warm the soil with stable manure and have it in good condition. Good tilth helps quick growth and therefore improves the quality; so that it rests with the gardener to make his root crops among the first and the best in the market. The price of a root crop depends almost entirely upon its looks, so have as few side roots as possible, and cut off those that may develop in spite of care. Forked or branched roots should not be mixed in when we market, for even a few such specimens lessen the price of all.

Early crops, such as radishes, beets, carrots and turnips, are sold in bunches of 6 to 12. All in the bunch should be of the same size and shape and tied neatly around the leaf-stalks with a cord. The leaves are left on these early vegetables, so they should be kept cool and moist, as wilted leaves also spoil the sale price. Beauty may be only "skin deep," but it commands the market.

Late root crops sell in bulk, and harvesting them is the hardest work connected with root crops. It is well to plow them out, cut off the tops, and allow the roots to lie in the sun only until the soil is dry enough to shake off. They are then ready for storing in pit or cellar, and are easy to keep.

RADISHES.

The radish is the earliest root crop, and the quickest growing. It is ready for market in three to six weeks after planting the seed; so it is a great financial help to one who is just starting a garden. It is a hardy crop requiring rather cool weather or shade. The radish responds well to hot-bed culture and the earliest spring varieties are usually grown that way. But even for planting in the open garden you need not wait long. Soaking the seeds will save several days. As soon as you can work the ground, even before all the frosts are over, radishes may be sown, provided there has been good preparation-tillage. To secure crisp, edible radishes, the growth must be continuous. Any interruption in development, or an overgrowth, makes the root stringy, bitter and often hollow. See that those in each of your bunches are even-sized and bright and clean, so that they will look like the delicacy that they are. A prime bunch of radishes is as pretty as a bouquet.

The radish is a partial season crop, and is, therefore, suited for all sorts of double-cropping. It is often sown shallow in the same drills with the other vegetables of later growth, because it matures so early that it breaks the earth crust for the slower seeds. Radishes may also be sown between rows of cabbages, beans, peas, etc., or broadcast in beds by themselves. One ounce of seed will sow about 100 feet of drill or eight to ten pounds to the acre.

Sow the seeds one-half inch deep (better sow too shallow than too deep) in rows 6 to 12 inches apart, if you have only a little plot; or in long rows a little farther apart if you use a wheel-hoe. Drop two or three seeds to the inch; this can be done only with a seeder attached to the wheel-hoe frame: later, thin out the seedlings to about two inches apart. Only large seeds should be used, the small ones being too slow maturing. They may be sown at regular intervals of seven to ten days all through the spring. It is usually difficult to grow good radishes in summer, unless you can select a cool spot and keep the soil cool, but some sorts of radishes do well in the hot weather. Although in America the radish is best known as an early spring crop, it may also be grown for winter use if planted in July or August, and stored like turnips or other root crops. The tops make good greens for boiling.

The radish is the easiest of crops to grow, and has only one serious enemy, the root maggot. This insect is one of the cabbage enemies also, and can be destroyed by injecting bisulphide of carbon in the soil, but that treatment is too expensive for the returns from radishes. The most effective way is to sow the radishes where the maggot has not been breeding, and thus starve the pest out.

The most popular varieties of radish are the French Breakfast, Olive-shaped, Scarlet Short-top, Chartier, Wood Early Frame, and White Box. Those that grow well in summer are White Naples, White Vienna, Strasburg and Stuttgart, while for use in winter Scarlet Chinese, Black Spanish and White Spanish are best.

BEETS.

Beets, like radishes, are a hardy crop requiring a loose, rich soil and continuous growth to reach their best and quickest development. They are easy to raise and respond readily to good tillage. The early or garden beet is usually a succession or companion crop, because it may be planted early and matures quickly. Although most kinds require two or three months for maturing, yet with some of the early varieties roots large enough for bunching may be had in six weeks to two months. The quickest sorts are the round or nearly round varieties, which may almost be called surface feeders. For this reason they require soil in excellent tilth and the richest, well-rotted barnyard manure. Indeed, the wise gardener will plow his land in the fall, and plow it deeply, too; then as soon as it can be worked in the spring run the cultivator and harrow over it, and plant the seed about 1½ inches deep in rows from 12 to 18 inches apart. The land must be kept well tilled and free from weeds, especially during the early part of the season. The long field-crop beet is now very little grown, as the early varieties may be sown late in the season for fall and winter use, and the Southern grown beets cost less in the late winter than it does to grow and store them. Even in feeding cattle, the beet has been largely superseded by the mangel, so that few are grown except the short round sorts for table use. The sugar beet is a field crop.

The seeds (which are really fruits, containing within a hard shell four or five seeds each) require a great deal of moisture to germinate. Some gardeners advocate throwing them into hot water and allowing them to soak for six or eight hours before planting. This makes them sprout more quickly. Beets come up in clumps and must be carefully thinned, until they stand 6 to 8 inches apart, although this is not done until the tops are sufficiently grown to sell for "greens." In this way there is no waste, since top and root alike are used as a pot-herb. The contrast of the green leaves with clean roots attracts customers.

If you plant beets early in the season, say as soon as the ground can be worked, they may be followed by celery, late potatoes, cabbage or cauliflower; or they may be grown at the same time between the rows of some main season crop like cabbage. If planted in hot-beds or cold-frames it will not pay to transplant them, as they mature very early under such conditions, and may be bunched and sold without that labor. In July or August, and in some places even in September, the turnip-rooted variety may be sown for fall and early winter use, but special attention must be given to tilling them so that the soil may not be too dry. The best and firmest of the roots may be stored for winter use, and for better prices.

Early beets are sold in bunches of six, but late crops are sold in baskets or barrels. Five to eight pounds of seed are needed for each acre; one ounce will sow from 75 to 100 feet of drill. The average crop is from 300 to 400 bushels to the acre.

Beets have three serious diseases: root-rot, for which apply lime to the soil; leaf-spot, kept in check by spraying with Bordeaux mixture; scab, for which the only cure now used is not to plant where the land is infested.

Beets respond to special fertilizers, which may be used if the soil is already rich in plant food, and the market will afford enough profit to pay for the extra expense. At the New Jersey Experiment Station from 400 to 700 pounds of nitrate of soda well-worked into the soil before the plants were set out, increased the yield from 10 to 23 per cent.; and the earliness all the way from 17½ to 135 per cent. In the "Farmer's Cyclopedia of Agriculture," Messrs. Wilcox and Smith of the Department of Agriculture, say that "where earliness is of primary importance, nitrate of soda can be used with profit with this crop even on the richest of soils."

If you can't get your root crops early, get them late. When the mercury goes away down, the prices go away up.

CARROTS.

Besides being a hardy crop that may be planted in the early spring as soon as the ground can be worked, carrots have the advantage of having no serious insects or diseases. They require a clean, mellow soil, that will not "bake" over the seeds, and the best of surface tillage. Carrot seeds are so small and so slow in sprouting, that it is good practice to plant radishes or turnips or

other quick seeds in the same row, to help break the crust for the tender seedlings. The young carrots have such a slight hold upon the soil, that they need petting, only the shallowest, surface tillage being possible, yet scarcely any of the garden crops need tillage more. But once let the carrots get established in the soil, and they are easy to grow and give good returns. They are sown thickly about one inch deep in rows from 12 to 18 inches apart. When they are well up, they should be carefully thinned so as to stand two to three inches apart in the row. The early varieties will bear forcing and respond to hot-bed culture, but they are slower of growth than radishes or beets, requiring from two to two and a half months to be ready for market. They are tied in bunches of six with the tops left on, and are in great demand in the early season when small and bright and tender.

Carrots are of two main types, the early, small variety and the large sort grown in the field for winter use. The large kind is not much grown, because the smaller varieties may be planted late for winter use, and as feed for stock, carrots are no better than the larger root crops. If you grow the early variety for winter use, you will need to be sure that the soil is in good tilth, as dry or weedy soil would be fatal to carrots. Maybe you are tired of reading that all these crops need good tillage; but you will be much more tired if you neglect it. This crop may be sown as late as the middle of June in the Northern States, and the ground should be sown with some early crop, like radishes, to keep it in good condition until needed for the late carrots.

Carrot seed is sown thickly, about two pounds of seed being required for an acre, or one ounce to about 300 feet of drilled row, if the seed is fresh. A good crop of carrots is from 200 to 300 bushels per acre.

The best varieties are the Early Forcing, which may be grown in hot-beds, cold-frames, open garden in the spring, and also in the fall for home use; the half-long Danvers for a good, reliable mid-season crop and the Long Scarlet for a good late crop.

These root crops are among the prettiest “fancy goods”—where they can be sold directly to well-to-do people they bring fancy prices.

TURNIPS.

The turnip is such an easy crop to grow that the gardener would have a snap with it if it were not for the snap that the root maggot has. It is a hardy, quick-growing crop, requiring a cool, short season and a moist soil. The turnip is so hardy that the herbage can bear considerable cold without real injury, so that when grown for winter use it is left standing in the field until the black frosts; but the roots will not stand such hard freezing as parsnips or salsify.

Turnips should be planted in moist, rich soil to insure quick sprouting, because their chief value as food is the result of rapid growth. Like the radish, the turnip, if it grows slowly, is likely to be tough, woody and stringy. True turnip has soft, white flesh (sometimes the boys eat it raw) and the roots are flatly rounded, while the leaves are rough and hairy. The seed is sown as soon as the soil can be got ready in the spring for the early crop, and as late as the last week in July in the Northern States, or the middle of August in the Middle States, for a fall crop. They are ready for the table in six to ten weeks. Turnips are planted from 1 to 1½ inches deep in drills from 10 to 18 inches apart; one ounce of seed for every 200 to 300 feet, or one pound to the acre. Plants should be thinned until they stand three or four inches apart, and later, as the roots are pulled, a foot of space will allow of full development.

Turnips suffer so from root maggot, that where the land has become infested with this pest, it is better not to try to grow them until the insects are starved out, because the only effective treatment that we have found so far is to inject bisulphide of carbon into the soil, which costs too much for turnip crops.

PARSNIPS.

Unless your preparation-tillage has been thorough, there will be no good parsnips for you. They require cool, very deep soil in excellent tilth to make good roots a foot long, straight, clean and tapering. A lumpy or shallow soil makes the roots branchy, and of little market value. Parsnips are usually sown in drills, far enough apart to let the wheel-hoe in; sow thickly and then thin out the rows, leaving plants about six to eight inches apart. We have to sow thickly because some seeds may be bad, for parsnip seed does not retain its life for more than two seasons. An ounce of fresh seed will do for 200 to 250 feet of drill, or about four pounds to six pounds to the acre.

The seeds sprout so slowly that it is well to plant some quick-growing seed with them to break the soil, else it may have to be broken by hand. The parsnip is hardy and the seeds may be sown as soon as the ground can be put in condition, but it must be the main crop, for it takes the whole season to grow the long roots. The roots may be left in the ground until the next spring, as the hard winter freezes do not injure them. In that case you must store a large part of the crop in cool pits or cellars, because the best price

is obtained in the late winter or very early spring when the ground is often frozen so hard that you can't pull the roots up. It would not pay to blast them out, you know. There need be no waste where stock is kept, because the ragged roots make excellent feed. The Hollow Crown and the Student varieties are the standards. A good crop is 500 to 600 bushels to the acre, but under good conditions, this can be bettered. No serious pests or diseases consume the parsnips, so men and stock get all that grow.

SALSIFY.

The salsify plant tastes so like an oyster that it is called the oyster plant. It is grown for kitchen use only, not for stock. Like its cousin, the parsnip, it must be sown in deep, rich soil and given the whole season to mature. Salsify can be left in the ground all winter, unless it is needed for the late winter or early spring market. The seeds sprout quickly and may be sown as early as the soil is ready. Like beet seed, the salsify seed is really a fruit, long and hard like a stick, and it is somewhat difficult to use a seed drill in sowing them. An ounce of seed sows only about 70 feet of drill; an acre requires eight to ten pounds and a good yield is from 200 to 300 bushels per acre. There are no serious insects or diseases.

There are two important modifications of salsify known as Black Salsify and Spanish Salsify. The regular type is a biennial, though cultivated as an annual, becoming wild and losing its fleshy root if left in the ground longer; but the Black, which is grown just the same as the main type, is perennial, and the roots continue to enlarge, yet to remain edible, though left in the ground more than one year. It has broader leaves than the regular salsify and a long black root, yellow flowers and light seeds.

Spanish salsify is not generally known in this country. Its root is much lighter in color and not so strong in flavor, but with careful cooking it develops other qualities of its own that are most agreeable. Moreover, it is easily cultivated and yields larger returns than the regular salsify and the average person would not know the difference. It is sown and cultivated just as salsify is, and when bleached the young leaves are eaten like cardoons, that is, as a pot-herb.

HORSE-RADISH.

Although horse-radish is a perennial, it gets woody the second year, so that the market gardeners grow it from fresh cuttings, called "Sets," every year. These cuttings are taken off the side roots, from three to seven inches long, and from the thickness of a lead-pencil to that of a little finger. The cuttings are made when the roots are dug in the fall and may be stored all winter. Horse-radish grows very easily, but as it is a late season crop, and needs cool soil, there is nothing gained by planting it early. It requires very deep soil if the roots are to grow straight, long and tender. Only long, large, even shaped and uniform roots bring any price in the market. It may be planted with early cabbage or beets, and when they are harvested, the horse-radish takes the land. It will grow until freezing weather and is the better for being left in the ground as late as possible. Sets are planted either upright or slanting, three to five inches below the surface and from twelve to eighteen inches apart in rows. If they grow too fast they may be cut down two or three times, as horse-radish stands considerable ill-usage, if it is planted deep and in good soil. Before sending to market, wash the roots and trim them of all side shoots; tie them in bunches of six or eight; or they may be sold in bulk or by the barrel. The price ranges from ten to fifty dollars a ton, and in good rich soil four tons can be raised to the acre. The usual yield is only two tons. The extra two come from knowing how.

But horse-radish can easily become a bad weed, for weeds are only plants misplaced. So plow the roots out as soon as you have dug your crop and have them removed. Although it is next to impossible to get them all out, they cannot do much harm if the ground is kept thoroughly busy with some other crop. There is a good deal of the Old Nick in Nature, and wherever she finds idle land she sets to work to grow weeds. She would just as readily help your crops; so it is for you to profit by her willingness.

CHAPTER XIV.

TUBER CROPS.

POTATOES.

A heavy yield of potatoes may be simply a matter of moisture and frequent tillage. The potato likes Scotland[5] and Nova Scotia because it thrives best in deep, cool, moist soil, finely pulverized and containing much potash. Knowing the conditions under which any crop grows well, is equivalent to growing a big crop, to the careful farmer, so if you want some potatoes, you may as well get the most possible. The average farmer raises 75 bushels to the acre, but it pays to be above the average. You ought to be ashamed to grow less than 200 or 300 bushels even taking 75 as a starting point, for, when you consider that by the exercise of

brains and labor, all the way from 600 to 1300 bushels per acre have been produced, you may well decide to prove what you can do. You have a chance to beat the record.

Potatoes should be planted deep and early. If they are planted too near the surface they will ripen before they are fully grown or maybe get sunburned and unfit for eating. Choose your best potatoes for seed, if you plant from your own crop; or buy only the best varieties, if you must buy. But it is well to remember that there is always danger in potato seed raised elsewhere than on your own patch where you can watch conditions. Don't use a potato for seed if it has a black thread running through it; a roughened or irregular circle on the skin, or a hollow center. Burn all such; else you will have diseased crops and give yourself no end of trouble and expense. Plant the seeds at least four inches deep and plow them in. The surface should be harrowed two or three times before the plants come up, and the crop should have light, surface tillings five to eight other times during the season.

Potatoes are planted in "drills" or continuous furrows, 27 to 42 inches apart, at intervals of 9 to 18 inches, and it requires from 8 to 18 bushels of potatoes to plant an acre. Most farmers plant too sparingly. There has been much book discussion as to the size of seed cuttings, but the most economical size is one weighing about three ounces or the size of a large hen's egg, with at least one good eye. The potato cutting is food; therefore the larger the cutting the more food, and the more food the better early growth, and the better the early growth the better the yield. Bailey claims that a piece containing too many eyes means too many sprouts contending for that food and each weakening the other in the struggle for its own existence.

For early potatoes, the only ones that can pay in a small plot, remember five different things: (1) good site and an early soil; (2) land prepared either by special plowing the fall before, or by growing late-tilled crops, that the soil may be in good tilth; (3) free use of concentrated, quick-acting fertilizers; (4) early varieties of potatoes; (5) sprouting the sets, so that the short, thick, firm, colored shoots are secured. To secure these, light and a moderate degree of warmth, 40°-50°, is needed. Nothing pays better than sprouting.

No crop needs spraying more. Unless it is frequently sprayed, it is almost certain to be attacked by the potato bug, the flea-beetle and blight, and the yield cut down. Dry Paris green puffed on while the leaves are damp with dew, ends the troubles of the bug, and Bordeaux mixture can be sprayed for blight. No specific has yet been discovered for the flea-beetle, but it does far less damage where Bordeaux mixture is freely used. I have heard of letting the chickens loose on the flea-beetles.

SWEET POTATOES.

The common or Irish potato does badly in the South, except as an early crop, because the climate is too warm, but where the common potato suffers, the sweet potato thrives. It requires a warm, sunny climate, a long season, and warm, loose soil, with plenty of moisture during growing time, and less during ripening. It is very tender and cannot stand frost. It is grown extensively as far north as the sandy lands of New Jersey.

The soil must be rich, loose, and well drained and liberally fertilized with well-rotted manure. Wood ashes will help the growth of the tuber most satisfactorily.

Only one variety of sweet potato, the Spanish, is cut and planted like the common potato. All other varieties are grown from "slips," or, as they are sometimes called, "draws." A whole potato is laid on a hot-bed and covered with a couple of inches of loose soil or leaf-mould. Very soon it begins to sprout and when the shoots are from three to five inches high, they are broken off next the tuber, and planted. Their roots have already begun to form and these are the "slips." The same potato or tuber, will give another set of slips if allowed to remain in the ground. In the extreme south no hot-bed is necessary to start the sprouting.

Another method of obtaining slips is from cuttings from the ends of the vines. Take cuttings from 10 to 12 inches long, from the earliest planted or the most vigorous vines. Having removed all the leaves except those at the very tip, plant the cutting lying down with only an inch or two of the tip showing. The rows should be about three feet apart and the slips in the row 18 inches apart. The average yield is from 200 to 400 bushels per acre.

Sweet potatoes suffer from several fungous diseases which are discussed in New Jersey Experiment Station bulletins on Sweet Potato Culture. Leaf blight may be checked by the use of Bordeaux mixture, but rotation is the cure for tuber crop diseases.

FOOTNOTES:

[5] Ireland is not really the land of the "praties"; the average yield of Great Britain is higher than of Ireland.

CHAPTER XV.

BULB CROPS.

All bulb crops are hardy, liking cool seasons and moist rich soil with a loose top. As a rule they are seed-bed crops, but are sown early in the open field. They grow from seeds or bulbs and may be raised as main or secondary crops and treated like onions. Their tops are often used for seasoning.

LEEKS.

To the average American, there is but one important bulb crop, the onion, but the foreign-born use garlic, leek and others also. Of these the leek is the mildest flavored and the best worth knowing. It is grown from seed sown in the early spring, and requires the whole season to reach full development. It produces soft bulbs and thick leaves, both being used for seasoning. The leek is stored green, as celery is, being set in earth in a pit or cellar.

GARLIC.

The garlic is the strongest of all the bulb family in flavor. It is grown from "cloves," as the separate sections of the bulb are called, and is planted early. It does not fully mature until the end of the summer or early fall.

SHALLOT.

Shallot is much like garlic, only it is milder, and is grown in the same way. There is one interesting difference, however, between the two. The "cloves" of the garlic are all encased in one outer skin, those of the shallot grow separately.

CIBOULE AND CIVES.

The Ciboule or Welsh onion, and Cives, are grown for their leaves which are used for seasoning. The Ciboule is the most like the common onion and grows the same way and requires the same cultivation. Cives grow in dense tufts and are propagated by separating the tufts and planting a section. They are perennial, and make a good border for the garden walk, combining grace and toothsomeness.

ONIONS.

It pays to grow onions intelligently. They take lots of care, but they repay the time and trouble.

You cannot get the best results from onions by beginning now, at the moment you start your garden, to sow your seed. Onions require that you should begin last year, so to speak. The ground should be well plowed in the fall, after having been in use with good tillage all the previous season, and the surface soil must be in super-excellent condition. The onion is practically a surface feeder, and as the seed sprouts slowly, and the baby plants are delicate and slender-rooted, conditions must be absolutely right for a good growth. In fact, no other vegetable crop, grown on a large scale, requires such fine surface soil. Hard or baked soil is sure to give a poor crop. The surface must be kept loose and in good tilth, and low, level land is the best place for your onion patch.

When the ground has been plowed, go over it carefully and break up all the clods or lumps, and remove all stones and weeds. Do not use coarse, fresh stable manures, as that leaves the ground too coarse in texture, and moreover increases the probability of weeds, and weeds are death to onions. Only fine, old, well-rotted stable manure may be used, and this must not be plowed under, as it is the surface soil which must be rich. Commercial fertilizers, especially the sorts rich in potash, are of great value in growing onions, and, because of their potash, wood ashes make an excellent top dressing for the onion patch. Keep the soil finely pulverized and you will then have ideal conditions for planting your crop. Next get good seed. Good onions often give poor seed, but cheap seed always means poor onions, so buy the best seed always.

Reclaimed marshes, freed from roots and peat, and thoroughly fertilized, are ideal places for growing onions. The rows or drills, which must be 14 inches apart, must also be perfectly straight, else the necessary cultivation cannot be given. The crop often needs two weedings by hand when the plants are very young, and frequent cultivation by the wheel-hoe. Now the wheel-hoe cannot do good work on rough or uneven ground, and its best work is none too good for onions, so you see where you are at.

The onion crop is divided into two classes, the early crop and the main season crop. Early crop onions are immature, green, and are tied in bunches for market; main season crops are dry and are a staple product.

Early onions may be grown from seed, but are usually grown from bulbs. There are three kinds of bulbs for planting: "top" onions, potato or "multiplier" onions and "sets"; the first two are distinct types, but "sets" are only partly grown onions. "Top" onions are really small bulbs which grow on the top of the plant instead of fruit; "multipliers" are onions with several hearts or cores, each of which may be planted and will give rise to another bulb, which, in its turn, will develop two or three more cores. The process is continued indefinitely.

"Top" onions start quickly and soon give edible onions. If the bulb is planted out the following year it will send up a stalk and produce a new crop of tops.

To raise "sets," seeds are sown thickly on dry, light ground, where they soon crowd each other, and by midsummer anyway, the tops die for lack of room, food and moisture. The bulbs, which should then be from one-half to three-quarters inch in diameter, are picked, cured and stored as ordinary onions are. When planted in the spring they start to grow again and soon produce eatable bulbs.

The new early onion culture is growing onions from seedlings raised in the hot-bed or forcing house, and transplanted as soon as the weather permits. By this method the large, quick-growing Southern varieties, Gibraltar and Prize-taker, come to perfection in the North. Our season is too short for this by the ordinary open planting. This "New Onion Culture," which is not so new, after all, except in the middle East, is fully described by T. Greiner, in his book published by the Orange Judd Company, N. Y.

In the main season crop, earliness is not so necessary, and less fertilizer will do, so long as it is the right kind. Seed is sown as early as possible, as the onion likes a cool season. In the garden, it is sown thickly because the onion often fails to sprout, but in the field, it is sown more carefully, waste of seed and the thinning in the big field being expensive.

On some land the onion runs to tops, particularly where there is too much moisture, or the ground is too new, or coarse manures have been used. If the tops are still rank and green in late August or early September, it is a good thing to break them by rolling a barrel over the rows, that the growth may go to the bulbs.

The trouble with onions does not end with growing them. They are a difficult crop to handle and store, unless the fall is warm. After they are pulled they must dry a day or two, either in the field or under cover—cover is more expensive but the bulbs have a better, brighter color. The bulbs must be free from dirt and the tops cut off about a half-inch above the bulb, neither more nor less, else the bulb will suffer in marketable value. It must be a clean cut without ragged ends, and the outer skin or covering must not be broken. If the crop is uneven in size, as is quite apt to be the case, sort them over, because one misshapen or under-sized onion in a dozen, will materially lessen the price received for the crop. There are so many good vegetables on the market today, that the consumer is growing finicky, and wants only the best looking as well as the best tasting. Be careful to give him what he wants, and he will give you what you want—good prices—in return. The sorter may be a very simple contrivance, consisting of a rack or trough with a slat bottom through which small onions will drop. When raised to a convenient height on a slant it is easy to work the bigger onions over the end of the rack into boxes or baskets below.

Most farmers prefer to sell their onion crop in the fall, because it is difficult to house it. Mature onions will not stand freezing, unless they can be kept frozen all winter and allowed to thaw gradually in the spring. But this is a risky process and often results in heavy loss. They need a steady warm temperature, and many store houses are heated to ensure safety from frost.

It takes an ounce of onion seed for 150 feet of drill, or from 3½ to 5 pounds to the acre. A good crop for an average farmer is from 300 to 400 bushels per acre, but an average crop for a good farmer is 600 to 800 bushels per acre; and some have grown as high as 1100 bushels to the acre. You can choose your own class.

The root maggot is the worst enemy the onion has, and there is no really successful method of fighting it. Infested land should be used for other crops that the root maggot will not feed upon, until he is starved out. Rust and smut which also affect onions, may be practically cut out, or at least held in check, by the use of Bordeaux mixture, but rotation is the best remedy for smut.

CHAPTER XVI.

COLE CROPS.

Cole crops are among the hardy plants of the garden and field, requiring plenty of moisture at the roots, a cool season and cool soil. Hence their name, Cole meaning cool. They are mostly seed-bed crops and need considerable space in which to spread. They are grown for their tops, rather than for their roots or fruits.

CABBAGE.

Cabbage culture needs a cool deep soil that will hold moisture, and continuous growth from start to finish. Its other essentials are: extra care in the selection of the seed; frequent and thorough surface tillage; avoiding the root maggot, club-root, and rot, by proper rotation of crops, and by destroying the cabbage worm as soon as it appears. "A cabbage head" may mean a stupid man, for "a cabbage head" can't take care of cabbages.

The demand for cabbage has increased more rapidly during the past ten years than for any other vegetable in the market. For sauer kraut alone the demand is enormous. Where a few hundred barrels would supply all the demand twenty years ago, tens of thousands of barrels are now needed annually. Its use was at one time largely confined to the German in this country, but that is no longer true. So there is always a market for cabbage, and if you are willing to take the pains necessary to grow good cabbage, you will find it a paying crop. Cabbage is also largely grown for stock-feeding, and all the animals, from the horses to the fowls, are glad to get it.

There are, of course, the two sorts of crops now so usual in market-gardening, the early and the main season crops. The early crop is started under glass either in the hot-bed or forcing house, while the main season crop is sown in seed-beds or in the open.

The best soil preparation begins the fall before, with deep plowing and from 10 to 20 tons of manure to the acre. Then, if the land is at all acid or has not recently been limed, it is well to apply lime at the rate of 1000 pounds to the acre, and plow that in along with 50 pounds of nitrate of soda. This will supply the food for the cabbage, which is a gross feeder, and won't thrive without plenty of food. Farmers who raise it in large quantities, give it three applications of nitrate of soda after it is quite well grown. They use about 50 pounds to the acre each time, about ten days apart.

If sown in hot-beds, care must be taken to harden the cabbage sprouts by gradual exposure to the air before transplanting, so as not to cause any serious delay in growth. In field-grown cabbage, likely to be used in part at least for stock feeding, the plants should stand from 24 to 30 inches apart, in rows not less than 30 inches apart. This gives room for the heads to increase in size and weight. Under these conditions an acre will produce from 7500 to 9000 plants. But on small areas, where the crop is intended for market, the plants may be crowded somewhat, to keep down the size and to secure an average weight of four to six pounds each. In this way an acre will bear 10,000 plants. Cabbage should be cultivated once in a week or ten days until the heads touch in the rows. If your cabbage is uniform in size, has few outside leaves, very little stump or core when cut open, closely packed leaves lapping in the centre, freedom from disease or insect injury, and is true to name and type, you should secure the uniform price of five cents a head in good markets.

Cabbage suffers from many diseases and insects, and the gardener needs to be on the watch constantly if he is not to lose his crop after all his labor. The cabbage worm makes its appearance early, and should be destroyed at once; while for club-root, black rot, etc., rotation is our only usual remedy.[6]

Different varieties thrive better in different localities. You must experiment in a small way, or find out what your neighbors have done, keeping a record of the sort that does best under your conditions, and then plant only that. Near New York City the Bergen Drumhead does wonderfully well, but in some western parts of the country it has less success. The Newark Flat Dutch, on the other hand, for an early cabbage, does well both east and west. For a late season variety the Premium Flat Dutch is excellent.

To show the possibilities of profit in cabbage, Professor Bailey, in his "Vegetable Gardening," quotes from an expert cabbage grower in Green Bay, Wis., as follows:—Assume that you have first-class land worth $200 per acre:

Interest and taxes per year will cost, say $15.00 Forty loads manure at $1.00 per load. 40.00 Plowing and fitting the ground 3.00 10,000 plants at $4.00 per thousand 40.00 Setting and watering 5.00 After-cultivation 10.00 Harvesting and marketing 50.00 -------- Total $163.00 8000 heads sold at $3.50 per hundred 280.00 -------- Net profit $117.00

If you get only 8000 plants out of 10,000 set, it is a little below the average return, and as the market price is estimated at only 3½ cents per head, there is no trace of exaggeration in these figures. The estimate was made ten years ago.

A crop of cabbages can be grown and harvested in 100 to 110 days, which makes possible two crops from the same piece of ground in the one season. There are two ways of planting the first crop. One is to use a good rich seed-bed and sow the seed in November, the favorite variety being the Jersey Wakefield. When the plants are three or four inches high, transplant them to cold-frames in a protected spot and let them winter there. In the spring they will soon start growing and be ready for transplanting to the field early. The only drawback to this method is, that the plants being really old when spring comes, you are apt to lose a good many by their running to seed. For this reason, another method is rather to be preferred. Use the same variety of seed, but sow in hot-beds in February, and as soon as the plants are three or four inches high, transplant to cold-frames. If they are not too crowded, they will be ready for planting in rows in the field by April 1. But you must remember that the cabbage is a heavy feeder and that your soil must be rich and full of humus.

One noted cabbage grower in New Jersey says he plants his cabbage with a potato planter, which makes the rows 3 feet apart, distributes the fertilizer, and makes the ridges for the plants all at one time. He levels down the ridges with a plank drag which covers two rows at a time. The fertilizer is of high grade, applied at the rate of 1000 pounds to the acre. If plants are set 20 inches apart, it will require 10,000 for an acre. He cultivates thoroughly until the cabbages begin to head; then while cultivating once more, he applies nitrate of soda at the rate of 150 pounds to the acre, putting it on the row close to the plants, but not on the plants. This makes the cabbage head up quickly and uniformly, and makes the heads crisp and tender, besides increasing the yield enormously. This crop should all be marketed by July 4, and the yield should be from 8000 to 9000 heads per acre.

For the second crop, sow the seed in a good bed in the open, about the last of May and by July 15 at latest, the plants can be transplanted to the field. Between marketing the first crop and transplanting the second, the ground should be again thoroughly prepared by the addition of 1000 pounds of fertilizer to the acre and 150 pounds of nitrate of soda. Plant the same as in first crop. The variety most used is the large, early Dwarf Flat Dutch.

In growing late cabbage there is much more danger of maggots and other insects destroying your crop. The New York Experiment Station has tried a simple device which has given satisfaction so far as tested. This consists of screening the bed completely with cheesecloth which protected the plants from maggots. From 1800 square feet of screened bed 50,000 plants were transplanted to the field, while from an unscreened check plat intended to plant 40 acres, only enough plants for four acres were secured. The plants were "hardened" by removing the screen one week before transplanting. There was no more wilting than with plants grown in the open. This is cheaper than any form of insecticides.

KALE.

Kale requires much less care than cabbage, and is usually sown where it stands. It is probably nearer the original type of cole plant than any other, and even in cultivation produces no heads, but very large, heavy foliage. It is a very hardy plant, and is grown especially for spring and fall crops, and is much used as greens at seasons when other greens are not to be had. In the Northern States the seeds are sown in the spring and the plants are ready for use in the fall. When the crop has been thinned, the plants that are to reach maturity should be from 10 to 20 inches apart, and the distance between rows may depend upon the sort of cultivation to be given. In large areas of kale, horse-cultivation is best, but in a small plot the usual 12 to 18 inches will allow of wheel-hoe work.

Kale is such a hardy plant that frost will not hurt it, and the crop is often allowed to stand in the field until very late in the season, or even all winter. The large outer leaves are improved by frost. In the South and Middle South, kale seed is sown in the late summer and the young plants allowed to stand in the field unprotected all winter, but this cannot be done in the North. There the young plants need cold-frame protection. For this reason there is little winter-grown kale in the North, and the extensive supply that comes from Virginia from January until late spring makes it unprofitable to force it for early spring in the North.

There is a form of kale called collards, which is much grown in the South, especially where the climate is too hot for successful cabbage-growing. The seed is sown very early in the spring in protected seed-beds, so that the crop may get its growth before the hot weather sets in. It is much like cabbage, and sometimes young cabbage plants are raised for greens, and are called collards. Kale is subject to the same enemies as cabbage (which see), and requires the same sort of cultivation.

BRUSSELS SPROUTS.

Brussels sprouts are closer kin to kale than to cabbage, although not exactly like either. All cole crops have similar needs in soil, food and tillage, so what holds for one may be taken as true for all, except that kale and Brussels Sprouts do not exact so much

care as the others. In the Northern States, the seeds are generally sown quite late in the season that the crop may not come to perfection too early, as the plants are most prized in late autumn and early winter. A large part of the crop's growth is made in the cool weather of early fall. If the seed is sown in seed-beds in June, the plants will be ready to set out late in July or early in August. Where the winters are mild the crop is often left in the field until used, but in the North it is usually dug and placed in pits, like leek or celery.

The stalk of the Brussels sprouts may be from two to three feet high, although where the season is short, the dwarf or half-dwarf varieties give surer crops. All along this stalk, from the root to the crown of leaves at the top, grow tiny baby cabbages, each of which is called a "sprout," and averaging from an inch to two inches in diameter. When the sprouts are small and tender they are the most delicately flavored of any of the cabbage family. In many places, however, the demand is very limited.

Success in raising a good crop depends chiefly upon careful selection of seed. There is no crop which runs down so quickly, and in which greater care is necessary in choosing only the best for seed. It is subject to the same diseases as other cole crops.

CAULIFLOWER.

The cauliflower is more particular than cabbage, both as to climate and cultivation. It won't head up in the heat and must have a cool, moist climate to reach perfection. It also needs a constant water supply and therefore demands the best of tillage. It will grow only from the best of seed, and as it is easily sunburned, it is grown chiefly for early and late crops. For early crops the seeds are sown in hot-beds or forcing houses, and transplanted as soon as the weather is settled, so that the crop is off in late June or early July. The best varieties for this early cropping are the Snowball and Paris, variations of the Early Dwarf Erfurt. The fall crop is started in seed-beds in the summer and transplanted to the garden. For this crop some of the larger and later growing varieties may be planted.

Cauliflower is grown to best advantage along the northern sea-coast States, Long Island, the shores of the Great Lakes, and in the Puget Sound region, and wherever irrigation is practiced. Where the climate is at all inclined to be sunny it is well to tie leaves over the young heads to blanch them, otherwise they will brown in the strong light and bring a lower market price. It is necessary, too, to save all the moisture there is in the soil by the most careful tillage. Tillage should be shallow but frequent all through the growing period. "Buttoning" or the throwing up of irregular growths which spoil the evenness of the head, comes from poor seed, or dry soil, or too great heat; and also from allowing the plants to be checked in their growth and then started again by renewed cultivation. The crop requires steady and persistent care, rather than occasional energetic care, and will repay you for all your effort.

The best cauliflower seed—and that is the only sort worth using—is expensive, often running as high as $3 to $5 an ounce, and you may be tempted to choose the cheaper sorts. But the best seed is of vital importance in growing cauliflower, the cheaper kind being given to "buttoning," which lessens the price you can get in the market. The best seed in the market has so far come from Denmark, but the Puget Sound growers are beginning to rival the Danes. There is a family of long-season, late-growing cauliflowers, called broccoli, but they are little known in this country. Things that are little known are all right to eat and to show, but they are usually hard to sell.

KOHLRABI.

Although of the cabbage family, kohlrabi looks and tastes more like turnips and is cultivated like turnips. It is grown for the thickened stem or tuber which grows above the ground, and if eaten when young is very tender and more delicate in flavor for early spring use than turnips. It is also excellent for stock feed and is grown extensively for that. The best variety for garden use is the White Vienna, and the tubers should be eaten when from two to three inches in diameter. Like all cole crops they need continuous growth, otherwise they become bitter and stringy. Successive sowings of the crop may be made and when thinned the plants should stand from six to ten inches apart. They require from two and one-half to three months to mature and may be planted and tilled just as turnips are.

Cole crops all suffer from the same insects and diseases and it is well to get the latest advice upon how to deal with them. For root maggot, a most troublesome pest, read Cornell Bulletin 78 (published at Ithaca, New York), though the only really effective remedy is well-planned rotation. In this bulletin, Slingerland recommends placing tarred paper cards close to the young plants to protect them against the maggot; rubbing the eggs of the maggot off the base of the young plants, and injecting bisulphide of carbon or carbolic acid emulsion into the soil about the plants. It is necessary to use a syringe made specially for this purpose.

The Cornell Bulletin 104, deals with cut-worms, and New York Bulletins 83 (p. 657) and No. 144, tell about the cabbage worm or butterfly, the common yellow butterfly. Better look them up. They recommend persistent use of Paris green on the first crop, and a mixture made of five pounds pulverized resin; one pound concentrated lye; one pint fish oil or any cheap oil except tallow; five gallons water. The same treatment does for the cabbage looper.

For aphids, or lice, read the New York Bulletin 83 (p. 657) and Florida Bulletin 34 (p. 270). The injection of bisulphide of carbon in the ground, or the application of kerosene emulsion to both sides of leaves when young and small; tobacco; pyrethrum; Persian insect powder—any of these will prove more or less effective.

New York Bulletin 83 (p. 683) will tell you about methods of dealing with the Harlequin Cabbage Bug. Hand-picking is effective, and with clean culture, should eradicate this pest.

Club-root is really cured only by a thoroughly planned system of rotation, although air-slaked stone lime, applied in the proportion of 75 bushels to the acre, does good work. Read New Jersey Bulletin 98.

FOOTNOTES:

[6] NOTE.—Some experts think that lime is the one great soil doctor, especially in a garden where crops are plowed under, lots of manure is used and there is not much chance for crop rotation. Heavy doses of lime will destroy many fungous diseases and also kill off a good many insects, especially the soft-skinned kind which gather as crops are grown in the same place year after year. It would scarcely be possible to grow good cabbage in the same spot for a series of years without heavily liming the soil. It prevents club-root.

CHAPTER XVII.

POT-HERB CROPS.

Pot-herb crops are “greens,” grown for their leaves. Unless the growth be quick and continuous, the leaves will not be crisp and tender. Quick and continuous growth can be secured only by having the soil in good condition and giving the crop careful tillage. Furthermore, greens are mostly surface feeders, so that the surface soil must be in excellent tilth, and contain much plant food. They demand cool weather and are usually grown as succession- or companion-crops, because they do not require the whole season to mature.

SPINACH.

Spinach is a spring crop and a fall crop, because spring and fall give the cool, moist temperature it needs to come to perfection. Spinach belongs to the pigweed family and is a cousin to the beet. There are two varieties, the prickly seeded and the round seeded. The prickly seeded is the hardiest, and is most commonly used for fall sowing.

Farmers in the North used to grow spinach extensively under glass, but of late years the large out-door crops grown around Norfolk, Va., have spoiled the profit in that, and the Southern product takes its place. The spinach for early spring is sown in the field or garden in September and should be thoroughly established before winter, with a spread of leaves at least three or four inches.

As far north as New York State it is left out uncovered all winter and does not suffer unless the frost causes the ground to “heave.” If straw or litter can be had without trouble or expense, the spinach can be covered lightly as that often prevents “heaving.” If all goes well, the plants resume growth early in the spring, and may even continue growing during the winter if the season is mild. It is ready for market in April or May and should be off the ground in June to make room for the main crop. Southern spinach is marketed from late November until April or May.

Although spinach is a comparatively easy crop to grow, it needs certain conditions for perfection. The land must be rich and well drained, and liquid fertilizer must be applied after the crop gets started. Some put manure on the plot in the fall, and, as it leaches during the winter, it fertilizes the plants and starts them growing in the spring. Hen manure may be used. But the best way is to apply nitrate of soda or sulphate of ammonia in a weak solution so that 50 to 75 pounds will be sufficient for an acre. This is generally used in a sprinkler and is applied two or three times at intervals of a week or ten days, using each time, 50 to 75 pounds of fertilizer.

Spinach is sometimes sown in the spring in the place where it is to grow. But in that case, the position chosen must be a warm one, and even then, although a better stand is often obtained, the crop does not mature quickly. It is still occasionally started under glass and transplanted to the garden, and sometimes it is grown in frames all the way through to maturity. Gardeners who want to hasten their crop frequently cover it with glass during February and March, and it responds well to this treatment.

A variety known as New Zealand spinach, which is hardly a true spinach, thrives in summer, but as greens are not greatly in demand in summer, it has not become very popular in this country.

An ounce of spinach seed will sow 150 feet of drill, or 10 to 12 pounds to the acre. It is so necessary to have excellent drainage for spinach, that the land is usually plowed into low ridges or beds six to nine feet wide. The spinach is sown lengthwise of the beds 12 to 18 inches apart, according to the sort of tillage to be used.

CHARD.

One of the best of the pot-herbs, though not so generally known, is the chard or leaf-beet, which usually requires the whole season to mature, although it will give a succession of leaves from early summer until fall. The leaf-blades and midribs of the chard are very broad, and are usually white or slightly tinted, instead of green. Gardeners often blanch them further by tying the leaves together while growing. The seeds are sown in the spring as thickly as the ordinary beet is sown, and the plants are thinned until they stand six to twelve inches apart in the row.

MUSTARD.

Mustard is cultivated more extensively in the South than in the North, as it will grow where the climate is too hot for other greens. In the North it is usually grown only in home gardens for family use; the plants run to seed in midsummer, so seed must be sown very early in the spring. They are ready for use in May or June. Some of the new improved varieties of curly-leaved mustard are among the best of pot-herbs. In the South, the Southern Giant Curled Mustard is much used, taking the place that lettuce and spinach fill in the northerly sections. The Chinese Broad Leaved is a vigorous variety which gives a large amount of foliage. It is easy to grow, and even in the North, if the soil is warm and sandy, seed may be sown in the fall and the plants will be ready for use early in the spring, even though the seeds do not start sprouting in the fall. The seed escapes easily and sows itself in unoccupied areas and spreads rapidly. So, if it is not carefully watched to prevent too general seeding, it can readily become a troublesome weed.

DANDELION.

Everybody knows the wild dandelion, and almost everybody likes it as a pot-herb, but only those who have eaten the improved garden varieties, know its real possibilities. Although the dandelion is perennial, it is treated as an annual for the best results in cultivation, and the seed is sown in early spring and the crop either harvested that fall or allowed to remain in the ground until the next spring. It will grow anywhere, and often persists in growing in its wild type where you don't want it; but if you want plants with large, cut or frilled leaves, you will see that the soil is rich and deep, and that the plants have good tillage all the season through. The leaves of these varieties are not only good to eat, but they are extensively used for garnishing. If they have been properly cared for, the plants will often measure 12 to 20 inches across, with a crown or rosette of dense foliage.

Dandelion seeds are usually sown where the plants are to stand, although occasionally they are sown in seed-beds and transplanted. As soon as they have made a fair growth they are thinned to about one foot apart: the distance between the rows will depend upon the sort of cultivation the plants are to receive. Hand tools require less space than horse tools, and hand-hoeing less than wheel-hoeing, with more labor and less returns. If the plants are allowed to stand through the winter, they are ready for the market very early in the spring when the demand is briskest and the prices best. In harvesting, the plant is cut off just below the rosette and the roots must then be plowed out so that there is no danger of the herb becoming a weed. It is not worth while to try to sell the small plants, but they should be cut off, to prevent them going to seed and becoming a nuisance. Some growers take the roots up and put them in forcing house or hot-bed for growing greens; or, they may be forced in the dark, which gives white or blanched leaves. This same effect may be obtained in the field by tying up the leaves, thus securing a blanched crown just as is done with endive. We owe much of the improvement of the dandelion to the French.

PURSLANE.

Purslane, or, as it is more generally called, "pusley," is another herb that the French growers have greatly improved. The common pusley weed is a weak, trailing plant, but the French, cultivated variety stands up stiff with large leaves and juicy stems. It grows easily in any good garden soil, matures quickly and is not hurt by warm weather. The seeds are sown early in the spring and there is little danger of the cultivated sort sowing itself and becoming a pest.

There are some other varieties of greens; but this book aims only to treat of those which are generally grown and for which there is a sure market each year.

CHAPTER XVIII.

SALAD CROPS.

Salad crops are close kin to pot-herbs. But a salad is eaten uncooked, while pot-herbs are boiled. Some plants are used both ways, but they are then classed according to their most general use. Salad crops need a cool, moist soil and quick continuous growth. As has been frequently said before, (but not too frequently,) this can only be obtained by having the soil in good condition and plenty of plant food in a shape that the crop can eat. Salad crops need plenty of water, clean, thorough culture, and a good deal of prompt attention, but they mature so rapidly, that the demands are not really excessive. Having supplied their needs, you must, thereafter, depend upon the weather to help you perfect your crop. If you get dry, tough, wilted salad crops, you need not take the trouble to harvest them, for nobody wants that sort; and that is the only kind you can raise if you neglect them.

There is no pleasure like the ever-new exultation and joy of seeing the things we ourselves have planted come up; and these lovely colored shoots, springing from the brown earth, serve to renew our faith in the bounty of Nature and the loving order of the world—as well as to fill our pockets.

LETTUCE.

The most popular salad crop is lettuce, a hardy, short-season, companion- or succession-crop requiring moist, rich, mellow soil, and plant food in quickly available form. It is easy of culture and is chiefly grown in the open, though the demand for it has increased to such an extent that it is started in hot-beds or forcing houses that it may be earlier on the market. You can get it in about five weeks. Coolness and continuous growth are necessary to prevent toughness and bitterness. It is little grown in the summer, though the Cos variety can stand the hot weather very well, if the soil is moist and cool. Lettuce does better if transplanted and for that reason it is usually sown in seed-beds; in transplanting, it is usual to cut off the top third of the leaves, unless the seedlings are very stocky; but the mid-season and later crops may be sown where the plants are to stand. Fall lettuce should be sown in late August or early September, and, as it is easier to control soil conditions and to get quick sprouting in a seed-bed than in the field at that dry time of year, it is better to use the seed-bed. At any time lettuce does best in a soil that is loose and "warm," that is known to gardeners as "quick." Heavy, clayey soils are not adapted to lettuce, so see that your soil is pulverized and well fertilized before the seeds are sown. It has been found to pay well to treat the soil with nitrate of soda after the plants are set, because of the more rapid growth. The soda is applied dry, at the rate of two or three hundred pounds to the acre, and then raked or tilled in. Lettuce seed is sown thickly and the plants thinned, as they become edible, to about a foot apart. The thinnings make excellent "greens." The rows are usually 8 to 12 inches apart.

When grown as a succession-crop, lettuce may be followed by cabbage, early cauliflower, celery and other things. Or, it may be grown between the cabbages and cauliflower as a companion-crop, since it matures before either, and leaves the land to those plants when they need all the space. Seed may be sown successionally until warm weather, and you may count upon 1000 plants for each ounce of seed. There are three well-known tribes: head lettuce, cut or curly-leaved, and Cos, and a fourth variety little known, called narrow-leaved lettuce. There are about 100 varieties. Field-grown lettuce has few enemies.

ENDIVE.

Endive is a summer and fall crop, thriving at a time when it is not easy to grow lettuce to perfection.[7] It is, therefore, a good addition to lettuce, and its culture is largely the same, though endive takes longer to mature than lettuce does. Endive matures under proper care about fifty days after the seeds are sown. If seeds are sown in June the plants will be fit for table use in August or September.

Endive requires about the same sort of soil as lettuce, the same tillage and the same general treatment. The plants should stand about a foot apart each way to make cultivation easier. It is sometimes sown in cold-frames, but just as often in the open field, and successive sowings will give successive crops, but that which gets its start during hot weather is not satisfactory. The inside leaves of the crown are usually blanched by tying them together near the tops for two or three weeks before the plants are ready for market. The blanched sort brings a better price. The disadvantages of blanching are that the plants fade and decay quickly unless used at once, and if rain or damp weather follows the tying-up, there is great danger of decay while in the ground. So the plants must be examined occasionally to see that they are doing well. When endive is used as a pot-herb, as it sometimes is, it is better to pick the new young plants before they have time to head or can be blanched. The coarse, outer leaves of the plant are apt to be bitter and tough, so that only the leaves of the crown are used for salads.

With all these crops you can see why nearness to market is so important—even though the land is higher priced.

CHICORY.

Chicory has various uses and is now quite largely grown in gardens. As a salad plant only the tender, blanched leaves of the crown are used. The outer, green leaves are often used for "greens," like dandelion. Chicory is not a surface feeder like most salad plants, but is grown as a root crop the same as carrots or parsnips. The soil must be deep, that the roots may come to perfection by fall; cuttings of leaves may be made during the season. The roots may be left in the ground over the winter. Chicory is really a perennial, but under cultivation it is better to grow a new lot of plants each year. When wanted for winter use, the strong roots are taken up in the fall, and buried in a sloping direction in a pit or cellar, with the crown of the plant showing an inch or so above the sand or earth. The growing-place must be kept dark, and in a few weeks the small, prized leaves begin to show. When chicory plants are covered, crowns and all, with about two feet of manure, they develop heads resembling lettuce heads. The young, tender roots of chicory are eaten as beets or carrots are, while the dried root is extensively used in place of coffee. This accounts for the increased area devoted to chicory in this country of recent years; it is less injurious to the nerves than coffee.

CRESS.

There is a delicate "bite" and piquant flavor to cress, that makes it a favorite for salads and for garnishings. Of the three kinds in general use, the water-cress is probably the best liked, but to bring it to perfection it is necessary to have a running brook of clean, cool water. To grow it in a drain is a good way to get typhoid fever. It is a perennial, and readily propagates itself when once it has got a start, while the grower can increase its spread by scattering seeds along the brookside, or by planting bits of stems in the mud. When once established it will care for itself, and gives the grower no trouble. Although it does best along the sides of running streams, water-cress will grow anywhere if it can get moisture enough, even though not covered with water. Any moist, shady garden spot will do, if it is frequently watered, and gardeners often use abandoned hot-bed pits, where the hose can be turned on the plants daily.

Two women made a nice profit by sending fine water-cress, packed in oiled paper and cardboard boxes, to select customers by mail.

Common garden cress is a cool-weather, short-season annual, whose seeds may be sown early in the spring in a cool, rich soil, as its whole value as a salad plant depends upon its quick, vigorous growth. The plant runs quickly to seed in hot weather, or if left in the ground until late in the season. It is easily grown in pots or boxes in the house in winter; or, if wanted for fall use, the seeds may be sown in late summer and in early fall. Under ordinary conditions, the leaves are ready for use about six to eight weeks after seed is sown. There are a number of varieties of the garden cress; the sort with curled leaves being most in demand. It is not so well known here as in Europe. The third variety, known as the upland or upright cress, is perfectly hardy and common to all parts of the United States. In cultivation it is usually treated as an annual or as a winter perennial. Seeds may be sown late in the season, when the young plants will be ready for use early in the spring; or, they may be sown in the earliest spring and will be ready for use about fifty-two days after sowing. If grown through the summer they are apt to be bitter and tough, unless grown in a shady place. The upland cress resembles water-cress in flavor.

CORN SALAD.

Corn salad is not so well known here as in Europe, where it is highly prized as a fall and winter salad and as a pot-herb. It is a cool-season crop, grown as lettuce is. It is hardy and may be sown as early in spring as the soil can be worked. It comes to maturity in six or eight weeks, producing a bunch of leaves something like spinach. It may also be sown in the fall and protected in winter the

same as spinach, so as to have very early plants in the spring, or, if sown late in the summer, it will give edible leaves in the fall, and in a mild, open season, will nourish all through the winter. In warm weather or dry places, it soon runs to seed. It is very easy to raise corn salad in any cool soil, and an ounce of seed will give from 2000 to 3000 plants, which should stand about six inches apart in the rows.

PARSLEY.

Parsley is the most popular of all the garnishing herbs, and requires no special care from the gardener, so long as it is planted in a cool, moist soil. The leaves are used for salads and for flavoring as well as for garnishing. Parsley seed is slow growing, and unless the garden soil is in excellent tilth and moist to the very surface, it is better to start the plants in a seed-bed. Although the plant is biennial, the foliage is usually gathered the first year and the plant destroyed, unless seed is wanted. In all these green things, it has been found better to adopt the annual treatment rather than let them develop into biennials or perennials, though that may be their natural habit: we can improve the nature of plants, animals and men.

SALAD CHERVIL.

Although salad chervil closely resembles parsley and may be used the same way, it is very little known in this country. It requires about the same culture as parsley, and is easy to grow in cool, moist soil in spring or fall. It does not thrive well in our hot summers, but with very little protection from cold-frames or even from brush, it can be carried safely through the winter, if the weather is not very severe. The curly-leaved variety is the most popular, whether used as garnishing or seasoning. The salad chervil grows nearly two feet high when it reaches full maturity, but the young foliage is the most prized. It will give leaves for cutting in six or eight weeks after the seed is sown.

CELERY.

All garden or field crops are divided into two classes, those whose seeds are sown where the crop is to grow; and those whose seeds must be planted in special conditions, such as seed-beds, hot-beds or forcing houses. Celery is always a seed-bed crop, and occasionally a hot-bed or forcing-house crop, according to the time when the grower wishes it to mature. It requires a cool, rich, very moist soil, in excellent tilth, where surface tillage is maintained throughout the whole season. Although good celery may be grown on uplands by means of extra care and attention, it usually grows best in rich, moist, bottom lands. Reclaimed marshes, whose soil has been pulverized and fertilized, are ideal celery plots, because there the moisture is sufficient even during the heat of summer. Celery cannot stand exposure to the direct heat of the sun, and on exposed places many growers find it necessary to shade the crop.

Celery seeds are very small and slow to sprout and are sown broadcast or in rows. If in rows the sowing is very shallow. The seedlings are tender and delicate, so that it is only in a well-prepared seed-bed that the plants can be satisfactorily raised. The site of the bed should be selected with great care, so as to protect it from hot or dry winds, and to make it convenient to water it every evening. Celery requires a great deal of moisture. The soil must be in such excellent tilth that it will hold moisture up to the very surface without the help of a mulch. Some growers do use a mulch in growing celery, but it makes the delicate seedlings so much more delicate that the loss from sun-scald upon transplanting is likely to be heavy. If you do use a covering of any sort, be careful to begin to remove it as soon as the plants begin to grow, and take it all off before they are up enough to be transplanted. But if you make your seed-bed carefully, you will not need a covering for it.

Even when you have taken so much pains to start your celery crop, the work is by no means done. To secure good, strong, stocky plants, they should be transplanted once or twice in the seed-bed before the final transplanting to the garden. It is essential in North Carolina, says Prof. Massey, to transplant celery once before setting in field or garden. This entails so much labor, that many growers are now using the thinning process in place of these various transplantings, and even in the seed-bed the young plants are thinned to stand two to three inches apart and the tops are sheared if they grow tall too soon. The plants may be safely cut back a third or even a half of their growth. In small garden plots, shears or a sickle may be used, but, in the large fields, growers generally use a scythe.

There is usually a good deal of loss in celery seed, so it is well to sow it very thickly, and then you may reasonably expect from 20,000 to 30,000 plants to the acre. An ounce of seed will plant about 200 feet of row, and if good, should give from 5000 to 10,000 plants, although where losses are very heavy the yield is frequently only 2000 to the ounce of seed. One pound of seed should give plants enough to set out four or five acres.

Celery is grown both as an early-season and as a late crop, depending upon the location of the plot. On the higher lands, it is either an early or a succession-crop, following early cabbages, lettuce or other short-season crops. But on rich, bottom lands, it is a whole-season crop, as the land there is too wet to be worked early in the spring. Some growers raise two or three crops of celery in a season from one plot, the later or main crop being planted between the rows of the early crop. As celery may be set out as late as the middle or last of July, even in the Northern States, the main crop does not interfere with the early crop, which may be set out as soon as the ground is ready.

For two crops, the soil needs more attention than where only one is raised, because cultivation and fertilizer must add and preserve the moisture which is natural to the lower levels. Celery needs potash and nitrogen, and these foods are supplied by unleached wood ashes and well-rotted stable manure. Coarse, new manures must not be used, as they make the soil coarse and also cause weeds. Only old, fine, well-rotted manure will do for the celery bed.

When tillage is given the growing plant, care must be taken not to disturb the roots. The soil may be stirred only at the extreme end of the tiny rootlets, and if fertilizer is applied it must be placed at the same point. Some growers make tiny trenches between the rows and cultivate and fertilize there. Celery is one of the crops that call for thoroughly intelligent care. In many localities where the weather is hot or dry, sub-irrigation, by means of tile-drains, has supplied the needed moisture for this thirsty crop.

There is an entirely new celery culture in the sterile sand of Florida by commercial fertilizer; but that is a subject by itself. The Florida Experiment Station will give particulars.

The plants should be four or five inches high when transplanted and the stems stocky and green. They are set from 10 to 12 inches apart in the rows and the distance between the rows depends mainly upon the method of blanching. To bring a good price in the market, celery must always be blanched, although many growers prefer it in its natural condition for their own use.

Celery is blanched in three ways: Blanching by boarding; by banking up with earth, or by blanching in storage pits. Boarding is generally applied only to summer celery, as it does not afford protection enough for plants left in the field after early October. It is the simplest and most economical method of blanching, and where used, the rows may be two or three feet apart to admit of horse cultivation.

For blanching by boarding, planks 12 to 14 feet long, one foot wide and about an inch thick are preferred. These planks are set on edge on either side of the row close to the root crown of the plants, and tipped until they rest against the tops of the plants with their edges only two or three inches apart. Either wire hooks or cleats nailed across the tops are used to keep the boards in position. This boarding or blanching process is begun as soon as the plants are tall enough to show a few leaves above the board. As the stalks shoot up in search of light, the leaves fill the spaces between the boards and exclude light from the stalks. Great care must be exercised in warm weather that the plants do not rot at the heart because of too great moisture. Experience will teach you that it is well to get good lumber that may be used many seasons, rather than cheap boards which will warp or crack in one season.

Blanching by banking with earth, often gives a better quality of celery, but it is much more expensive and cannot be so safely used in summer, as it tends to rotting at the heart. It usually requires two or three bankings or “handlings,” as they are called, during the season. The first is given when the plant has spread so as to make a head about eighteen inches across. Then it is gathered in the hand and held, while earth is banked up around it about two-thirds of its height. In ten days or a fortnight this is done again, and in the very tall varieties once again. When this method is used the rows are from three and one-half to four feet apart. Of late years large growers use a “celery plow” for banking.

When celery is to be blanched in storage it is usually “handled” once while in the field, so as to start the process of blanching. Afterwards the plants are placed so close together in pits or sheds that the blanching goes on until the crop is ready for market.

There is another method of blanching celery which is particularly successful in small areas. It consists of growing the plants so close together that the light is excluded and the crop blanches as it grows. It is then grown as close as six or eight inches apart either way. This is called the “new celery culture,” and is successful where the hose can be freely used to supply the necessary moisture.

Storing.

But the care necessary for growing celery does not end even with the blanching. It extends to storing, which is also important to the crop. There are several well-known methods, chief of which are storing in outside pits or cellars and storing in celery houses.

Usually the outside pit or cellar is a temporary affair and a very satisfactory one is built like the regular vegetable pit: the way to make that is given in another chapter.

If celery is to remain crisp and juicy, it must make a very slow growth all the time it is in the store-house, and should be kept just above freezing point.

When you prepare your celery for market, be sure to clean it thoroughly. This may be done by washing, or it may require scrubbing, but be sure to have it clean. Remove the outside leaves and trim the roots down to a point, then pack in boxes or trays. And right here comes in another reason for studying your particular market, because the number of bunches of celery packed in a box or tray—and even whether you use a box or a tray—depends upon the market you supply. It varies with different markets.

In the "new celery culture" where the plants are set so closely together that they blanch themselves, it takes 150,000 plants to an acre. This method of growing requires greatly increased quantities of fertilizers or results will be very unsatisfactory. The dwarf varieties of celery are most in demand, and the favorites for summer and fall are White Plume, Golden Self-Blanching and Kalamazoo; while for late winter and spring, Boston Market and Arlington are standard sorts.

The chief diseases are leaf blight and leaf spot and the fungi that attack the plants in storage. For leaf blight, dip young plants in weak solution of copper carbonate, and treat the young growing plants twice a week. It is well to read up on diseases; and for blight read the Department of Agriculture Report, 1886, pp. 117-120; Cornell Bulletin 132, pp. 203-205. To avoid leaf-spot, select seed carefully, treat it with Bordeaux mixture while in seed-bed, and continue its use if you fear an attack. Read New York Bulletin 51 and Cornell Bulletin 132. For dealing with the diseases that develop during storage, read Cornell Bulletin 132, and Bailey's "Vegetable Gardening," p. 229. If you wish to know all that celery specialists have discovered about this crop, read Greiner, Hollister, Rawson, Vaughan, Stewart, Von Bochove and Crider. These books may be found in some good public libraries or will be supplied by our house.

Understanding all this attention and care, you can easily see why there is big money in a successful celery crop, and why Florida's flat sand lands are making their owners rich raising celery—or raising rents and prices.

CELERIAC.

Celeriac is a form of celery, or at least is a very near relation to the real celery, and requires about the same soil preparation and the same conditions and tillage. Celeriac is frequently sown where it is to stand, but as the seed is as slow to sprout as celery, this is not really a wise plan. Sown in a seed-bed and transplanted, the crop gives far better results. In celeriac it is not the stalk but the enlarged, tuber-like root which is eaten, and the plant requires no blanching. It may be eaten raw in a salad, or cooked, as you like. Good roots should be from three to four inches in diameter and they may be kept through winter by packing in sand or moss as many other vegetables may be kept. Celeriac is sown in the same quantities as celery seed, the rows being only far enough apart to allow of cultivation, and the plants from six to eight inches apart in the rows. Being of a dwarf nature the close planting does not cause the plant to over-shade itself.

FOOTNOTES:

[7] NOTE.—Fullerton says that the narrow-leaved, deeply serrated plant called endive in this country, in France is the chicory or succory known to all Americans as a roadside weed with beautiful blue flowers like a very open aster.

CHAPTER XIX.

PULSE CROPS.

Peas and beans are the pulse plants, and although they are cousins they are widely different in their requirements. In this respect peas and beans resemble children, who though in the same family, do not always thrive under the same conditions or do best with the same treatment. Both these crops are leguminous, and, therefore, capable of storing the nitrogen from the air in their roots, and thus enriching the soil where they grow, yet it is often necessary to apply nitrogen to secure a quick start for early crops. This is especially true where the soil has not before been used to grow leguminous crops. The more we study plants the more we learn about children and the more likely are we to recognize the close relation between all forms of life.

PEAS.

Peas are a partial season crop, and do not require very rich soil. They are so hardy that the seed may be sown where it is to stand, even before frosty weather is wholly gone. It is best to plant the seed from three to five inches deep, which allows the roots always to be in cool, moist soil. A very rich soil tends to make the crop run to vines and leaves, so that a light soil is necessary, particularly where the crop is to be an early one. Peas should be early or late, because they like cool weather, and are apt to mildew if carried over into hot summer days. The fall crop may be planted early in August even in the Northern States. The plants should be from three to four inches apart in the rows. It takes a pint of seed, of the small varieties, for 100 to 125 feet of row, or one to two bushels to an acre. Where peas are grown in large quantities in a field, for canning, the seeds are sown broadcast and then it requires from two to three bushels to an acre. For early crops the dwarf varieties are preferred as they mature so quickly, and the tall, climbing varieties are planted for late crops. Planting and tillage for both kinds are the same. Peas should be planted in double rows only six or eight inches apart, so that the one row of supports, either brush or chicken-wire, preferably wire, may serve both rows in tall peas, while the dwarf plants support each other. Between each two pairs of rows the space should be wide enough to admit of tillage.

Very few farmers understand the value of peas to the soil or as stock feed. This is especially important for farmers of the Northern States, for peas will grow where corn will not, because of the cold; they do not need much soil preparation or after-tillage; they yield a good crop of forage that is excellent for fattening; they take any place in a good system of rotation of field crops, although it is most satisfactory to follow them with wheat; they may be sown at intervals of ten days, from very early in the season to very late, and when the crop has been harvested the ground is in better condition than before it was planted.

In Europe they grow peas with delicate pods, called edible-podded or sugar peas, which are eaten as string beans are, but these are almost unknown here. The two kinds of peas used here are the wrinkled-seed pea and the smooth-seed pea. The wrinkled variety is the best, but it is more likely to decay when planted very early. Both sorts of seed are found in dwarf and tall varieties of pea. The most popular of the very early peas are First-of-all, American Wonder, Philadelphia, McLean Little Gem, Daniel O'Rourke, and Blue Peter. Among the late peas the Marrowfat, Champion of England, Stratagem, Telegraph and Telephone are leading favorites.

Peas start so early that they do not suffer much from weeds, unless the land is infested with the annual wild mustard. This will choke the peas, but it may be destroyed by a spray made of eight to twelve pounds of copper sulphate dissolved in 50 gallons of water, when the plants are only a few inches high. This solution will not materially injure the peas.

The insect enemies are the "pea weevil" or "pea bug"; the pea moth, and the pea louse. The pea weevil lays its eggs on the outside of the pod, and the grub, on hatching, eats its way into the pea and while hiding there changes into a beetle of a brownish-grey color, and about one-fifth of an inch long. It does not come out until after the seed has been sown in the spring. This beetle spoils the pea for seed and even to a large extent for stock feed. Where the weevil has attacked the peas, it is the custom to place the seed in air-tight vessels or rooms and fumigate with bisulphide of carbon for several days. The proportion is one pound of bisulphide for every hundred bushels of peas. Great care must be exercised in using bisulphide, as it is highly explosive and very poisonous. But only the careless or stupid need get hurt; so there's no danger for you. Get explicit directions from your nearest Experiment Station, and follow them closely.

The pea moth attacks late varieties of peas most severely, and as no remedy yet used has succeeded in destroying the pest, or even in materially reducing its ravages, the best thing is to sow early varieties of peas and so escape its worst effects. It is seldom seen in moth form, but is common enough as a "worm," or small, whitish, somewhat hairy caterpillar, about a half-inch long. It lives inside the green pods and eats ragged-edged holes in the peas, which it then fills with excrement or waste matter.

The pea louse is pale-green in color, and clings in great numbers to the tips of the shoots, and sometimes covers the whole plant. It attacks whole areas of peas sometimes, and becomes a serious pest. However, its hold is slight, so that it may be easily knocked off. In small garden patches they are brushed off in pans and burned, while in large fields of peas what is called a "brush-and-pan" device is used, followed by the cultivator, which buries the lice or aphids.

To find out more about the culture of peas, get Farmer's Bulletin No. 224, U. S. Department of Agriculture, Washington, D. C., and for the best methods of dealing with the crop's enemies read Delaware Experiment Station (Newark, Del.) Bulletin No. 49.

Pea cultivation was recorded two thousand years ago.

BEANS.

All the well-known varieties of garden beans are tender to frost, needing a warm season and a sunny exposure. The seed is not sown until the weather is thoroughly settled and the soil in excellent tilth; then it is sown where the plants are to stand. The favorites in this country are the dwarfs; the chief advantage of the dwarf types is the saving of expense in supports, and the greater ease of cultivation. The early crop is usually eaten as string beans, though the best "string" bean is the kind that has no "strings to it." This variety breaks off with a clean snap and is often known as "snap" bean. Beans that are well suited to be eaten as string beans have thick, fleshy pods and very little fibrous tissue. In order that string beans may be of the best quality, the crop must make a quick and uninterrupted growth. A succession of beans may be had all summer by planting at intervals, and late in the summer season a new crop may be planted for late fall use. String beans are always in demand; and now, because of the southern crops, the markets of large cities are seldom without them all the year around.

Beans, like peas, are nitrogen gatherers, but if the ground where they are to be planted has not been used for peas or beans within a year or two, it is well to apply a little nitrogen at first to start the growth. The land should really be prepared for beans the season before you plant them, because new, fresh or coarse stable manure applied when planted, will make the crop rank, without increasing the yield. This is especially true of Lima beans. Spread the manure the fall before, so that it will have done its work before the spring planting begins; if more fertilizer is necessary, use some of the quickly available commercial fertilizers, those rich in potash or phosphoric acid being the best. The soil should be harrowed at least twice before planting and thoroughly pulverized. This puts the soil in good tilth and prevents the growth of weeds. Through the whole season tillage should be frequent enough to prevent weeds getting a footing or a crust forming about the roots, but the plants should not be cultivated while wet with dew or rain, as that renders the crop liable to spore diseases.

LIMA BEANS.

Late Lima beans demand such a long season and such continuous growth, that it is not always advisable to try to grow them in the Northern States, especially not the true Lima beans. The Sieva or Carolina bean is a Lima that may be successfully raised in the Northern States if due attention is paid to soil and exposure. It is not so high a climber as the large, true Lima, and therefore matures before the nights get too cool. It is a comparatively early crop, quite hardy for a Lima bean, truly annual, with thin, short, broad leaves, and a lot of papery pods much curved on the back, which burst open when the beans are ripe. These beans or seeds may be white, brown, or marked with red, but are always small and flat. Challenger is the favorite brand of Sieva bean. The true Lima is larger, whiter, and may be speckled with red, brown or black. The pods are fewer, thicker, and do not split when the seeds are ripe, and the vines are more easily injured by a touch of frost. Both the true Lima and the Sieva Lima may now be had in dwarf varieties.

String and Lima beans are not the only sorts in common use. The others are not picked until fully ripe, when the pods cannot be used. They are known as "shell" beans, and there are several kinds, all in high favor. These are mostly of the pole variety and mature late in the season. The preparation of the soil and the general culture are the same as for dwarf beans, the Scarlet Runner and White Dutch Runner.

There are more than 100 varieties of beans and no one book could give in detail all that is of interest concerning them, but the gardener who wants to know more of his bean crop may read Bailey, Bulletin 87 Cornell Experiment Station, and Cornell Bulletin 115.

Bush beans are sown in drills, 18 to 20 inches apart to admit of easy and frequent tillage, which is necessary to preserve moisture and destroy weeds; the plants stand from five to ten inches apart in each row. One pint of seed will sow from 75 to 125 feet of drill, according to the variety of bean used, or at the rate of one bushel up to five pecks of seed to the acre, when sown in drills. Fall, or climbing beans, and all Lima beans, are sown in hills, four or five seeds to a hill, and the hills are three to four feet apart.

Pole and Lima beans need supports and when poles are scarce you may put strong stakes in the ground at distances of 10 to 12 feet, and then run two rows of wire from pole to pole, one row near the ground and one near the top of the stake. Then from the top to the bottom wire, run cords, up which the beans may climb. In small, home gardens, growers often sow Lima beans in a semicircle of hills around one stake and then run cords from each hill to the top of the stake; but this method is not suitable for a large area.

But climbing beans, especially Lima and Scarlet Runner, can be ornamental as well as useful, and the wise gardener looks out for all such possibilities in his crops. If you have an old fence or unsightly building, plant your climbing beans against it, feed them well,

and they will make a good growth of green vines, which will be a pleasure to look upon, at the same time that they give a good yield. This is true intensive farming, as you are getting all there is out of your ground, and at the same time making your place more beautiful at no added expense, save the use of additional intelligence.

There is still another point to remember in planting Lima beans, and simple as it may seem, it is really one of those tricks of the trade which make all the difference between profit and loss. Plant your Lima beans _eye down_. Other beans will stand for anything in the way of planting, but Limas are particular and insist upon having their peculiarities considered. You have seen people just like that, and you know that a little special attention brings its own reward. It is the same with Lima beans—or indeed with any other crops—give them what they want and they will give you what you want in return. That is nothing more than a fair bargain, and the love of a bargain is ingrained in the American nature.

Commercial bean growing is a comparatively recent business, dating back only to 1839, although beans have been used for human food for many centuries. This branch of farming in New York State alone means the annual production of several millions of bushels of dried beans for commercial distribution.

The Northern States, Canada and California, are the chief bean-growing sections; in warmer sections the crop suffers severely from pests, so that it is not profitable to raise it. Southern bean growers use northern-grown seed to avoid the ravages of the weevil. Even in New York State some sections suffer more from this pest than others; beans grown in the northern counties being practically free from attacks. If you mean to grow beans by the acre, you will do well to read up more fully in Department of Agriculture Bulletins and in Bailey's "Cyclopedia of American Agriculture," Vol. II.

The chief disease from which beans suffer is anthracnose, which even the beginner may recognize when it has reached the stage where sunken brown spots appear on the pods; and when these spots have a tiny pink centre, you have seen the spore at work. The best known means of fighting it, is to select clean healthy seed, carefully hand-picked; go over the field as soon as the plants come up and weed out the affected ones; spray thoroughly with Bordeaux mixture[8] to which has been added resin soap. The compound should be as follows: Bordeaux mixture:—1½ pounds vitriol, 1 pound lime, 12 to 15 gallons of water. Resin soap:—½ pound resin, ¼ pound crystallized salsoda, 1 pint water (boil until clear brown solution is secured, then add to Bordeaux mixture). Apply first when the third leaf of the seedlings is opening, and repeat at intervals of ten to twelve days or after rain has washed the mixture off.

[Illustration: THE RENT PAYER.]

FOOTNOTES:

[8] NOTE.—Unless the under surfaces of the leaves as well as the upper surfaces be kept coated with the spray, Bordeaux will be of little avail. For the commercial grower of dry beans, spraying is not advised.—Samuel Fraser.

CHAPTER XX.

SOLANACEOUS CROPS.

This is a big word, but it means only that these plants belong to the nightshade family.

This division takes in tomatoes, eggplant, peppers and husk tomatoes. These require all, or nearly all, the season to mature, and they keep on making growth, particularly in the North, until killed by frost. They are all seed-bed crops requiring a great deal of quick-acting fertilizer, especially when they are young, and to secure a heavy crop you must give them an early start.

They are really of the same family as the potato, yet they are not grouped with that crop, because the parts eaten are the fruits which grow on their stems and branches, rather than the thickened stem or "tuber." They are hot-season plants and are usually grown in hills.

TOMATOES.

In almost all parts of the United States the tomato is easily grown; yet it requires a long, warm season, and soil in excellent tilth for best results. The seed is sown in a seed- or hot-bed, and the plants are allowed to grow from four to eight weeks before transplanting to the garden, although they may be transplanted once or twice in the seed-bed to secure free and stocky growth. For the small home garden the plants are usually handled in pots, but for commercial purposes they are planted in small flats not more

than 12 inches square, holding about two inches of soil. The earlier they are started the better, because they are less likely to suffer from fruit-rot and frost if they fruit early.

In the North, you must have vigorous, stocky plants, well in advance of the season, and a warm quick soil, to get a good crop of tomatoes. Too much fresh stable manure will cause rank vine growth and delay fruiting, so that the soil should be fertilized a season in advance and the manure thoroughly rotted. At the time of planting it is well to apply a light dressing of nitrate of soda, as this gives better results than twice the application when given later at intervals up to August.

At the South, tomatoes are grown in frames covered with unbleached sheeting by night and during cold snaps, but in the day this covering is rolled up and the plants are hardened by the air. Although tender to frost, the tomato vine is a fairly hardy plant, and will stand earlier field planting than is sometimes given it, if it does not get frost. We have proved by experiment that the yield is greatly increased by early transplanting. There is a profit in that.

Tomatoes give earlier and better results where the vines are trained, but that is only possible in small gardens. Where the plants are grown for canning, little attention is given them after transplanting to the field. Losses from rot are of course much larger there, but this cannot well be avoided.

In small gardens they are pruned to a single stem. Strong stakes are driven into the ground and cords are stretched between them horizontally at top and bottom. From these horizontal cords you may run perpendicular strings, to one of which each plant is tied. Plants pruned and tied up in this way, may be placed as close together as 18 inches, while if left to spread they require from three to four feet of space.

By pruning is meant the pinching out of each side branch as it appears, compelling the plant to put all its growth into one parent stem. Some growers even go so far as to cut off the tops of the plant as soon as three clusters of fruit are formed. I have cut off whole branches where the vines were too thick, without apparent injury. All this decreases the quantity of fruit that each plant will produce, but it greatly increases the earliness of ripening, and the size and quality of the fruit. Besides, the plants may be grown so much closer that the loss in quantity is not so great as would at first appear.

Henry Jeroloman of New Jersey, known all over the country as the "Strawberry King," has a tomato-planting trick that is worth noting. Mr. Jeroloman, by the way, raises about $5,000 worth from his eight acres annually, and he plants tomatoes at the foot of his grape-trellis posts and trains them to climb up the posts and along the trellis. And right here is where the real trick comes in: by training the tomatoes to climb up instead of sprawling all over the ground, he is able to plant his low-growing crops, like beets or turnips, close up to the vines and lose no space. That is one of the reasons why his eight acres bring in more than the average farm of 100 acres. Your profit will depend upon similar devices for "working" the soil.

The best rack for supporting unpruned vines, is a cheap, rough and simple affair, constructed by the grower himself as follows:—Run a row of stakes on either side of your tomato bed and nail a light board to each row about a foot from the ground, so that the distance between the two rows will be about three feet. Across this lay narrow slats, loosely. The plants lop on the slats, the fruits ripen uniformly, and usually with a smaller percentage of rot than where they lie on the ground.

If your garden is situated where frosts are apt to come as early as August, you should plant your tomatoes against the south side of the house or out-building and cover them at night,—a point worth noting for all tender plants.

In "Vegetable Gardening," Green suggests an ingenious yet simple method of raising enough tomatoes for family use where the season is too short to raise them in the field or garden. Get three or four barrels about the size of a coal-oil barrel, bore several holes in the bottom of each, then sink about one-third their depth in the ground in the warmest corners of your land.

When this has been done, fill each barrel about half full of fresh horse manure well tramped down, and pour over it a bucketful of hot water to start fermentation. On top of this put eight inches of good soil, then a mixture of well-rotted manure and good black loam in equal quantities up to about twelve inches from the top of the barrel. Heap manure up around the outside of your barrel. Plant, say three stocky plants in each barrel, trimming them to two shoots each. Tie one shoot from each plant to stakes or some nearby support, and let the other grow naturally over the side of the barrel. Give a gallon of water a day to each barrel and you will raise enough tomatoes in the season for a family of four or five persons.

The Iowa Experiment Station showed that untrained tomato vines gave the smallest yield and the largest percentage of decayed fruit; that staked vines gave a much larger percentage of sound fruit and the least percentage of decayed fruit of the whole

experiment; that hilling up did not give any striking results in any direction; and that, while mulching enormously increased the yield, it also greatly increased the tendency to rot.

Because tomatoes suffer so from frost, it is wise to hasten fruiting by every means, but if frost strikes before the fruits are ripe, the large green ones may be picked and placed in drawers or other dry, close places to ripen. Generally they color well and develop a good quality. If the fruits have not reached full size, the whole plant may be pulled with the fruits on, and hung upside down in a barn or dry building, and they will continue to draw nourishment from the plant and sometimes ripen.

From one ounce of seed you may expect from 2000 to 2500 plants; if planted in hills three by four feet apart, an acre will require 3630 plants. A large yield of tomatoes is from 12 to 16 tons per acre; the average is much below this. The favorite tomato in the American market is large, round and smooth, the Angular and other irregular-shaped varieties bringing a much lower price. Varieties run out so quickly that it is not advisable to give the names.

The friend that you make in the seed store will be able to keep you posted about such things—you can look in his eyes and tell if he is lying, which you can't do with a catalogue. Or you can ask the Agricultural Editor.

EGGPLANT.

You treat eggplants just as you do tomatoes, except that they need even greater care that the young plants are not checked in their growth, and a longer season. Eggplant is really a hot-climate crop, and so requires especial attention for early ripening in the Northern States. It grows best in the South, but does well as far north as New Jersey and Long Island. Further north it is seldom grown for more than home use.

Eggplant needs a long season, sunny exposure, a warm, loose, and rather dry but rich soil. It is started in the hot-bed and not transplanted until from six to ten inches high. It is such a finicky crop that if the plants are crowded or stunted even in the hot-bed, the yield is seriously reduced. For this reason, growers often start it in two-inch or three-inch flower pots, or in old, small berry baskets, as it is less likely to suffer a check when transplanted to the garden. Eggplants do not need so much moisture as peas or cool-season crops, and whatever fertilizer is applied must be quickly available. Perfect tillage is necessary from first to last.

Eggplants are set in rows far enough apart to admit of horse-tillage, from 3½ to 4 feet apart, and two to four feet apart in the rows, according to the variety of plant grown. The fruits are fit to eat when they have reached one-third their full size, and are desirable until they are fully ripe, when they lose their value as food.

Although the fruit may be left on the plant until fully grown, a larger crop is secured by picking before their full size is reached. For market, however, they must be well colored. The large varieties such as New York Improved and the Black Pekin bring the highest prices in the market, but it is difficult to grow them to perfection in the Northern States because of the short season. Some of the dwarfs, notably the Early Dwarf Purple, are more desirable. White eggplants are not popular, because they are usually an ugly yellow, while the striped and coiling fruits are regarded more as curiosities than as staple market products.

The eggplant is subject to several obscure fungous diseases, particularly in the South, and the only known remedy is rotation and destruction of the diseased vines. For the potato bug, which sometimes attacks eggplants, it is best to use Paris green, about one-quarter pound to 20 to 25 gallons of water, and plenty of lime. For leaf spot, use Bordeaux mixture. Get New Jersey Report 1890, p. 355.

PEPPERS.

Peppers are started in frames and when transplanted are set from eight to twelve inches apart in the row. They are cultivated just as tomatoes are, and, as they do not suffer from pests or diseases, the crop is more sure.

Peppers will thrive in a cooler season than tomatoes, and will even endure slight frost, but in all other respects they require the same treatment as tomatoes. They have only recently acquired any importance as a crop, and even now, their use in cooking being only semi-occasional, they are not very staple. Italians use them extensively, and as Italian communities grow, the demand for peppers will increase. We use them mainly for making pickles, for which purpose the small Cayenne, Chili and Cranberry varieties are grown. For stuffing, the favorite sorts are the large sweet peppers, Sweet Mountain and Ruby King. These peppers are not at all similar to the pepper-berries of commerce, which belong to other families.

HUSK TOMATO.

The husk tomato is an herb which produces a kind of papery skin containing a yellowish, glutinous berry. It is often spoken of as the strawberry tomato. It is very easy of cultivation on the tomato plan, although some varieties, notably the Cape Gooseberry, do not ripen well in the far North; the Dwarf Cape Gooseberry, however, does well as far north as Ontario. The soft, sweetish fruits may be eaten raw or cooked and are often used for preserves and pickles. There are several native species, some of which are called Ground Cherry.

CHAPTER XXI.

VINE OR CUCURBITOUS CROPS.

"Cucurbitous" is a fine large word, but you don't need to learn it. All vine crops are annuals and are tender to frost, although all do not need a hot-bed start. They are warm-season crops, and in the Northern States most of them need a quick start so that they can ripen before the summer is past. Well-prepared soil and a sunny exposure are desirable. They transplant with such difficulty that they are usually sown where they are to grow, but if not, it is best to start them on sods turned upside down, or in pots or boxes. They are always a main crop and are planted in hills. There is very little difference in the cultivation of any of them, and if you know how and where to grow one, you will generally do well with the rest.

Where you fail, you may usually lay it to the fact that your soil was not in condition to give the young plants a good hold and to get a quick start. If your soil is well prepared, well drained and properly fertilized, you will have little trouble, unless it may be from pests. The way to fight those is to sow seed freely, and be content to lose the greater part of your possible crop.

Some growers who make a specialty of melons or cucumbers, plant squash and pumpkin seed very early in the field that the young plants may attract the striped beetle and give the farmers the opportunity to kill the pest before the real crops are taken from the frames. That is a method of deceiving the creatures, but the end justifies the means.

Unless you live where the climate is cold and the season short, you may plant squash, pumpkin and cucumber in the open fields where they are to grow. Otherwise start them in frames, as muskmelons are started. The land should be given the best of surface tillage, and every effort should be made to start the plants so well that the fruits will have set before midsummer. All these vine plants need much moisture in the soil and if the preparation-tillage be neglected, no amount of after-tillage can make up for the first loss.

Watch the vines carefully so as to prevent one fruit setting much in advance of the others. It is better to pick the first one off if it is much ahead of the main crop. Otherwise there will be no uniformity of size or quality. If your plants run too much to vine, pinch off the shoots and let the vigor go to fruit-making.

These crops often succeed as early crop and main-season crop, by starting one about two weeks after the other. Spade up the ground loosely for a space of a square foot or two, and mix light, loose earth or barnyard scrapings with it to make the hill. It is well to add a handful of fertilizer to the earth; but if it seems cold and hard, remove it altogether and replace it by light, warm soil. Of course in the warm, light soils of the South this is not necessary.

CUCUMBER AND GHERKIN.

There are almost no special directions for growing cucumbers if the general directions for all vine crops are carefully followed. Cucumbers are planted in hills, usually four by four feet apart, though for the large, late varieties they may be as far as four by six feet apart. An acre contains 2722 hills when the distance is four by four feet, and it requires two pounds of seed to plant an acre, or one ounce to 70 or 80 hills. That will allow four or five plants to a hill. Remember to plant freely if the striped beetle is at work near your patch.

As cucumbers are eaten when young, it helps the yield immensely if each fruit is picked as soon as it reaches the table state. You should go over the entire patch every two or three days at least, to see that no fruit is ripening at the expense of the growth of its little brothers on the vine. If you want to keep some for seed, reserve a whole hill for that purpose.

For the early-season varieties which are planted in flats or seed-beds, the Early Russian, a small-fruited sort, is the favorite. For the later sorts the White Spine, in various strains, is the standard.

Gherkins are simply immature cucumbers, very small in size; they are used solely for pickles, usually sweet pickles. The fruits of the West Indian or Bur cucumber are also called gherkins. The treatment is the same as for cucumbers, but the fruits are pulled as soon as fully formed. It is quite profitable to pickle them yourself.

On the average, an acre will yield 100 bushels of cucumbers for pickling, but this yield can be greatly increased by proper care and attention. Under the best conditions, 400 to 500 bushels to the acre are possible.

MUSKMELON.

The muskmelon is native to southern Asia and was grown by the ancients. The melon grows best in light, sandy soil in warm, sunny spots, although it is raised for market in many parts of this country, and as far north as parts of Canada. New Jersey is an important melon-growing State.

Melons are planted in hills from four by five to four by six feet apart, according to whether early or main-season crop. The early crop may be planted a little closer than the main crop, and is in the field two or three weeks ahead. The quantity of seed is about the same as that used for cucumber planting and the same treatment is necessary. There are about 1185 hills to an acre, and two or three good fruits to each plant is a good yield. The most important varieties are the cantaloupes, which have hard, warty rinds, and are little grown in this country; the nutmeg or netted type, extensively grown here, and the winter melons, which ripen late in the season and are as yet little known here. The leading varieties to be found in the American market, are Rocky Ford, Osage, Montreal Market and Hackensack, but the melon is so variable that only types, not varieties, are constant. Diseases and insects are the same as in cucumber.

WATERMELON.

Watermelons are even more uncertain than muskmelons, because of their need of a long, warm season; therefore, they are but little grown in the northernmost States, except a few varieties which will ripen as far north as southern Ontario, if both soil and exposure be warm enough. Watermelon needs such a long season, such a warm, well drained soil, such attention to detail, to come to perfection, that it is not a very profitable crop for the average gardener. In the past, the south Atlantic and Gulf States have held first place as watermelon centres, and are likely to continue in that proud position even though the mid-continental States have taken up the industry.

Seeds are planted where the plants are to grow, but all danger of frosts should be past. The best soil preparation includes fall plowing that the winter frost may help powder the earth. The hills are made by mixing several shovelfuls of well-rotted manure with the soil and then covering the mixture with some inches of fine, soft earth. Plant the seeds in this and see that the soil does not bake or crust. This can only be avoided by careful surface tillage. The cultivation of watermelons must be done solely with hand-tools, as the vines are very tender and the least injury to them affects both quantity and quality of crop. The hills are usually ten feet apart each way, and there are only 435 hills to the acre. It takes four pounds of seed to sow an acre. When grown in the Northern States, plants may be started under glass, but great care must be taken to avoid any injury or check to the growth, during transplanting.

Beginners often find it difficult to tell when a watermelon is ripe. There are three recognized methods, but to the practiced eye none of these tests are necessary. If a melon “thumps” right, that is, if it gives out a dull, flat, dead sound, it is ripe, but if it rings hollow or musical it is not yet ripe. The next test is the yellowish cast to the side that has lain on the ground, along with a hard, rough, warty skin in that place; and the third is the way the melon “gives” under pressure of the hand. The last test should never be applied to melons intended for the market, because it bruises them inside.

What is called vegetable citron in this country is nothing but a variety of watermelon with flesh too hard to be eaten. It is not the true commercial citron, which is the fruit of a tree like the orange or lemon.

Insects or diseases the same as in cucumber. If you must know more of watermelon culture, get Bulletin 38, Georgia Exp. Station.

PUMPKIN AND SQUASH.

Although so closely allied, pumpkins and squash do not usually cross, despite the common notion to the contrary. They are distinct types of the same family. The standard variety of pumpkin in this country is the Connecticut Field. The fruits are large, orange-colored and smooth furrowed. They are used to make pies for man and as food for stock, while to the small boy they are

chiefly useful as "jack lanterns."

The pumpkin is often grown in corn-fields and in England they have a summer variety called vegetable marrow, which is in great demand, while our summer squashes, Crookneck, Scallop and Pattypan are also forms of the pumpkin. These are called bush squashes, and may be grown as close as three by four feet in the garden, while the regular pumpkin and squashes require to be planted eight to ten feet apart. It takes three pounds of seed to the acre for each, and a yield of two or three fruits to the vine is a large crop.

There are several leading types of winter or field squashes such as the Hubbard, Marblehead, Boston Marrow, Essex Hybrid, and Turban. To keep them through the winter they should be free from bruises or cracks, be fully ripe and have the stem on. A touch of frost injures them. They should be stored in a dry place with a temperature above 50° and placed on shelves or in shallow bins. Large growers have specially constructed, stove-heated houses for storing them.

A third type includes the Winter Crooknecks, Dunkard, Tennessee Sweet Potato Pumpkin, and some others. The culture of both squash and pumpkin is the same as for cucumber.

The insects from which they most suffer are: the squash bug and the melon louse. To rid the fields of the bug, keep them free from rubbish. Trap the bugs with bits of squash leaves and every day in spring pick off the old bugs. Read New Jersey Bulletin 94; New York Bulletin 75, and Florida Bulletin 34.

For melon louse read Kentucky Bulletin 53 as well as those already mentioned. Get lice in their winter quarters and destroy at first appearance. Use bisulphide of carbon as the bulletin directs.

Powdery and Downy Mildew are the worst diseases. For powdery mildew, spray with ammoniacal copper carbonate, and read Massachusetts State Report, 1892, p. 225, and Cornell Bulletin 31. For downy mildew, use Bordeaux mixture every eight or ten days, until frost, and read Massachusetts State Report, 1890, p. 211, and New York Bulletin 119.

CHAPTER XXII.

UNCLASSIFIED ANNUALS.

In this division of garden crops come sweet corn, okra and martynia, which have no relation to the other crops, and none to each other, except that they require about the same cultivation. They are all warm-weather crops and are grown for their immature fruits. They require "quick" soil, are not usually transplanted and demand little care, except good tillage.

SWEET CORN.

Although almost unknown in any other part of the world, in America sweet corn is one of the most important crops. One hardly ever sees even a small backyard garden without a few stalks of sweet corn, while the canning industry has grown to such enormous proportions as to require thousands of acres of corn every year. Sweet corn cannot be grown in the South unless the seed is gotten from the North every year. It thrives best in the crisp climate of the Northern States and of Canada.

This is the crop that gave rise to the famous joke at the "World's Fair" in Chicago. The Englishman asked the girl in charge, "What do you do with so much corn?"

"Oh," she said, "we eat what we can, and what we can't we can."

Afterwards Johnny Bull tried to tell the story. "So funny," he said; "she told me that they eat what they can, and what they can't they put in tins—why don't you laugh?"

Sweet corn requires more attention than field corn, both as regards earliness and the proper development of each plant. For this reason it is planted in hills rather than long drills, and in warmer and quicker soil, with quickly available fertilizer. Ground that has been plowed deep the fall before, and fertilized with well-rotted manure makes a good soil; if the ground be hard or cold, a handful of commercial fertilizer may be added to each hill.

Although corn is a hot-season plant, it is practically a surface feeder, so it cannot withstand drought as well as potatoes or other crops. That is why it is well to plow deep and make a good moisture-holding bottom in order to get good corn of any kind. That is also the reason for the frequent surface tillage given the growing plants.

Seed is planted for the early crop as soon as the ground is warm enough, and as corn rots quickly either in cold or damp ground, it is well to plant freely. Coating with tar perhaps preserves it, at least from the crows. The idea is to get as many ears as possible from each plant, so give plenty of room, the rows being three to four feet apart, and each hill from two and a half to three feet apart. For early crops use Early Minnesota, Early Vermont, Cory and Crosby and other popular brands. The Stowell Evergreen is the standard for late crops. Corn may be sown successionally, at intervals of a week or two, either for the home garden or for market supply.

In growing for market, earliness should be borne particularly in mind. The whole profit in corn may hinge upon even one or two days' delay. In fact, where you are competing with many other gardeners, a half day may make a big difference. You can get ahead only by having quick and well-prepared land, planting the earliest varieties and giving the crop good tillage after it has begun to grow.

Some gardeners force early sweet corn by placing a handful of fine manure in each hill, stamping it down hard with the feet. Loose dirt is then kicked over it and sprouted seed planted—that is, seed that has been soaked in warm water until germination has really begun within it. This is a good method where the soil is moist so that the seeds may get a quick start, but it is no good in dry soil. The manure acts like an individual hot-bed for each hill of corn.

Where this plan is used, thorough culture must be given, or the corn roots will remain in the manure during growing time and suffer from drought.

Corn is not the only crop that is benefited by the use of the feet in planting. Wherever the soil must be compacted about the newly planted seed, the feet can be used to advantage. So true is this, that Peter Henderson, the well-known New York gardener and seedsman, wrote a pamphlet called "The Use of the Hands and Feet in Planting," which is sent free upon application. It is well worth reading.

When it first comes into the market, sweet corn usually brings 25 cents a dozen ears; that is the time for the wide-awake gardener to sell his crop. Later it may fall to five cents a dozen, and usually sells as low as 10 cents; there is no profit in that.

If you pick the first ears as soon as they are well set, the second setting will be much better for it. (Very small, immature ears are fine cooked or raw, to eat, cob and all, but our people are not used to that.) It takes about a peck of corn to plant an acre in hills, and, if well attended to, the plants should yield from 8000 to 10,000 ears to the acre.

The insects and diseases include wire-worms, cut-worms, chinch-bug and corn-stalk disease. Short rotation, including fall cultivation of the land, will check the wire-worms. See Cornell Bulletin 107. Treatment for cut-worms is fully described in Cornell Bulletin 104. Ditching, plowing and harrowing are bad for the chinch-bug and good for your corn. Read Ohio Bulletin 69, Kentucky Bulletin 74, and New York Report 15, pp. 531-533.

It would be fruitless to take up your time with a discussion of corn-stalk disease here, when you can get it all by simply sending for Nebraska Bulletin 52.

OKRA OR GUMBO.

Although okra is really a Southern States perennial, it is cultivated as an annual, the seeds being sown every spring. It is grown for its pods, which are cut while still young and tender, and are much used for soups and stews. Of recent years the pods are also canned and dried for use in winter.

Okra takes about the same treatment as sweet corn, the seeds being sown where the plant is to grow, except in the Northern States. There the seeds are often planted in boxes, pots or sods turned over, simply because the season is not long enough to ripen the plants. The real okra is a large-growing plant that must be planted from one to three feet apart in rows that are three to five feet apart, but the dwarf and early-maturing varieties that are grown in the North, may stand as close as one foot apart in the row. There are no important insects or diseases.

MARTYNIA.

Martynia is grown solely for its half-matured pods which are used in pickles. The plant needs a warm soil, sunny exposure, and much room, as it spreads over three or four feet. It thrives under the same cultivation as is given corn and okra, and may be planted in frames or in the open as soon as the weather is warm enough. It is annual and native from southern Indiana to the Gulf.

CHAPTER XXIII.

HERBS, SWEET AND CONDIMENTAL.

A great variety of plants, medicinal, flavoring and decorative, are herbs, but we will consider only those used for cookery and usually called "sweet herbs." The very name brings memories of fragrant smells. If we cannot all say, "I know a bank whereon the wild thyme grows," yet few who have ever known a garden are unacquainted with the odorous bed of thyme, sage and mint. Although there is not such heavy demand for them in this country as in Europe, yet their use is growing, the favorite being sage.

Sweet herbs may be divided, both as to culture and as to products, into two classes:—the annuals and the perennials: those grown for their foliage, and those for their fruits. All are easily grown and demand little attention, and though they may be bought at any drug store, yet they who have once raised their own herbs find a pleasure in them that they will not like to miss. Annuals and perennials may be grown together and a very little plot of ground is enough to grow them all. Choose a place where they will not interfere with plowing and cultivating and let them stay, planting the annuals in the same place each year, and renewing the perennials as soon as they begin to lose their aromatic qualities or otherwise to fail. The annuals should be sown every year, but perennials may be propagated by division of clumps. Discard all the older clumps and replant only the newer, younger portions.

Those that are prized for their foliage, such as sage, thyme, hyssop, mints, tansy, horehound and wormwood, are usually cut when the plant is in full growth before the stalks have become woody. Cut the stems near the ground, tie them in bunches and hang them to dry in the attic, if you are fortunate enough to have such a treasure-hole, or in some cool, dry place. You may also cut the herbage from time to time during the season, but this weakens the plant and necessitates replanting. Those that are grown for seeds, such as caraway, coriander and dill, are allowed to ripen, but are picked before the seeds begin to fall. They are dried in-doors and the seeds threshed out for winter use. Bailey, in his "Vegetable Gardening," has a list divided as follows:—

ANNUALS (OR GROWN AS SUCH).

Anise Sweet basil Summer savory Coriander Caraway (biennial) Clary (biennial) Dill (biennial) Sweet marjoram (biennial or perennial)

PERENNIAL.

Sage Lavender Peppermint Spearmint Hyssop Marjoram Balm Catnip Pennyroyal Rosemary Horehound Fennel Lovage Winter savory Tansy Wormwood Costmary Tarragon.

CHAPTER XXIV.

PERENNIAL CROPS.

The vegetables in this group have little in common except their cultural wants or requirements, but these are so different from the needs of annuals that it is convenient to group them together. Because they occupy their places more or less permanently, it is necessary to choose a spot that will not interfere with the regular plowing and tilling of the farm or garden. Perennials need tillage in the spring and fall and are fertilized by top dressings, at both seasons.

ASPARAGUS.

The chief of the perennials is asparagus, which requires a deep, rich, moist, cool soil, with a warm exposure. It originally grew in rotten sea-weed on the shores and is a gross feeder, so the soil cannot be too rich. Sub-soiling to the depth of two feet is good for asparagus. It used to be thought that a layer of salt at the roots made a good fertilizer, but salt is no longer used in that way. It is, however, used to keep down weeds in the asparagus bed, especially the German salt known as kainit. This kills out weeds, saves cultivation, and adds potash to the soil.

If the land you have is hard and coarse, you should prepare it by planting it with some crop that needs a great deal of tillage, such as potatoes, for two seasons before you plant asparagus. During this time you should apply all the manure the land will carry, because, as the bed will last for twenty years, in the Northern States, you will have no other opportunity to put the soil in proper condition. Don't be afraid of making the soil too rich. Asparagus can take all you can give, and will repay your generosity.

As you make your asparagus plantation practically for a lifetime, you must exercise care and judgment in choosing the site. In a family garden a long row, say 75 to 100 feet, if you have the space, at the rear of the garden, is a good place. This not only puts it out of the way of other crops, but it also gives you a good background in summer and fall, for the herbage of asparagus is ornamental. Asparagus used to be planted in beds, but under new methods of farming, this plan has been abandoned. Rows are more satisfactory. When grown as a field crop this allows of horse-tool tillage and saves much labor.

Asparagus roots are wanderers and reach out for food in every direction, even more horizontally than perpendicularly, which is why it is unwise to have rows closer together than four feet. Seedsmen sell asparagus plants, but it is usually better to grow your own plants, although they take so long to mature. Seeds may be soaked in warm water for a day before planting and are then sown in drills and covered about an inch deep. The plants should be thinned to stand three or four inches apart in the row.

Give frequent tillage throughout the entire season, and in the spring following they will be ready to plant in their permanent place. Here they are set deep, in a furrow or trench, say six to ten inches, so that the young crown of the plant is covered two or three inches deep with loose earth or good fine compost. As the plants grow the trench is gradually filled. If filled at first, the young plants might not be strong enough to push their way up.

You will see from this that the asparagus plot must be deeply sub-soiled, for if you do not have the land properly prepared at the first, you will never have good results. Besides, unless the soil is rich in humus, asparagus cannot thrive at all, for it requires a moist soil at the roots all the season.

When you have planted your yearling seedlings you must give them another year before you do any cutting. A few stray shoots may be picked off, but it is advisable to wait until the plants are in their third year before cutting. To cut earlier may permanently injure your crop. It is also possible to injure it by continuing it too late each season, although every stalk should be removed even if it be too poor for use. The crop should be cut clean, and all cutting should be over before July 4th, in the middle Atlantic States. After that the tops do the growing and the more they flourish the better your asparagus will yield next year, for it is from the foliage which springs up that the roots and crown secure energy for the next season's work.

The tops should be mowed late in the fall, and generally speaking it is better to burn them than to allow them to rot on the bed as some growers do, because when the asparagus berries are plentiful you are apt to have trouble next season with seedlings; and even when this is not so, it interferes with the fall tillage which is so necessary.

Just as the young plants were covered with earth and manure the first year and thoroughly tilled in the spring, so must spring and fall tillage be carried on every year. The manure put on the plants in the fall, serves not only as a winter protection, but if not too coarse, may be cultivated under in the spring and afford that much more fertilizer to feed the crop. If it is too coarse for that, rake it off, cultivate thoroughly and then cover again with litter or manure, to afford nourishment and to preserve the moisture of the soil as well as to protect the young shoots in case of late frosts.

The whole value of asparagus lies in its tenderness and succulence, and the large shoots are most apt to have these qualities. The plant cannot grow large shoots unless it has plenty of food. Only rich soil and good tillage can supply the food needed.

Usually asparagus is cut off three or four inches below the surface with a long sharp knife, but one noted asparagus grower objects to this practice for two reasons. First, it increases the temptation to cut too low so as to get the stalks of uniform length as the market requires, whether or not of uniform quality; and second, it tends to waste and to the injury of the plants. He would substitute for this practice, careful hand-picking or breaking. The gatherer takes two rows at a time and breaks off the shoots just beneath the ground at the lowest point where the shoot will break with a clean snap.

When set at the proper distance of three by four feet apart, it requires 3630 plants to the acre, and 1 pound of seed should furnish that many plants. But seedlings vary so much, that some growers recommend sowing from four to five pounds of seed to every acre, so that only the best need be kept. A good yield is about 400 dozen bunches to the acre. Asparagus is always sold in bunches, the stalks of uniform size and length, and tied near the tops and butts either with bark or string; though many growers are now using rubber bands as being better for the stalks and a saving of time for the gardener.

Asparagus is usually sold green in this country, although if artificially blanched it is just as tender. When asparagus is grown for blanching it should be planted deeper than ordinarily. It is hilled up with a furrow plow just as celery is hilled up, and blanches as it grows. Blanched asparagus is in higher favor in Europe than here.

Asparagus is a native of Europe and Asia, and has been cultivated for more than two thousand years. It belongs to the lily family and several of its very near relations are cultivated in greenhouses for their graceful foliage.

The asparagus beetle is the worst enemy and must be steadily fought. In young beds, apply fresh air-slaked lime as soon as the larvae appear. It should be put on while the plants are still damp with dew, and only the greatest thoroughness can accomplish anything. Destroy all volunteer shoots. As the beds are cut, leave some small trap-shoots upon which the beetles will gather; cut these twice a week and destroy. In hot weather brush the insects off and they will bake on the soil in the sun.

It is so risky to use poisons on asparagus that is to be eaten, that Paris green may be used only in very rare instances; then the mixture consists of one pound of the poison to fifty pounds of air-slaked lime. Two applications are made, about a week apart.

Some gardeners turn a hen with chickens, or a number of young chickens, into the asparagus field as soon as the crop is cut. This is one of the best ways of keeping down the beetles, and the scratching of the fowls cultivates the crop. This will lessen your own work and increase the value of your chickens to you.

Rust is the chief disease, and for this there is no sovereign remedy. Every effort should be made to secure only vigorous plants, and in very dry weather irrigation should be practiced, if possible. Early in the autumn, cut, carefully gather together and burn, all affected stalks, and all asparagus brush whether garden or wild. Read Massachusetts Bulletin 61; Iowa Bulletin 53; Farmer's Bulletin 61, p. 30.

RHUBARB.

Of all the perennial garden plants rhubarb is the easiest to grow, and the most inexperienced may be sure of success. It is very hardy and the roots remain in the garden all winter, even in climates where the frost is heavy and the cold quite severe. But in spite of its hardiness and willingness to flourish under ordinary conditions, rhubarb responds quickly to good care and gives such enormously increased returns that it pays to attend to it.

Rhubarb likes a deep, rich soil, thoroughly cultivated and fertilized before the plants are set out. It is usually more satisfactory to propagate by roots than by seed, although some growers prefer to raise their plants from seed. Like asparagus, rhubarb will last twenty years, if given a good start and if the roots are occasionally separated. All this time it will yield large, tender, juicy stalks if the soil be in good condition, and if a little tillage is given to the plant in fall and spring.

Set out the plants in rows where the soil has been fertilized, is deep and in good tilth. The best strains of rhubarb will not produce good stalks if the land be hard or the subsoil high and hard. The rows should be four feet apart to allow of horse tillage. The plants may be from three to four feet apart in the row. During the growing season they require the same sort of surface tillage that you would give to corn or potatoes. If you are making the most of your rhubarb bed, you will give it quite a heavy coat of manure in the fall, to act as mulch to keep the soil from freezing too deep, and also to preserve its texture. During the storms of winter, the manure leaches away somewhat and fertilizes the roots, so that they are prepared to make an early growth in the spring.

The season for selling is short, as early in the summer the demand for rhubarb gives place to strawberries and other small fruits. It is the grower who has it early in the market who reaps profit from rhubarb.

By means of the New Rhubarb Culture, rhubarb may now be forced for market out of season, and then it brings the best prices of all. Roots are left in the garden until they have been frozen and are then transplanted to specially prepared beds and forced for the Christmas trade. These beds may be in the open field if one has a system of heating by steam forced through trenches, or they may be in specially constructed forcing houses; or, simplest of all, they may be in the house cellar, even though the floor be of concrete.

Rhubarb requires but little moisture and when it is being forced, it need not go deep to find its food, if the soil it has is rich enough. Three inches of earth will give it all the hold it needs, and if the light is completely excluded, the growth will all go to stalk.

If you have a cellar bed, screen it off from the rest of the cellar so that no light can reach it; a small kerosene-oil lamp with a chimney that has been thoroughly smoke-blackened, will give all the heat necessary to start growth. The stalks begin to shoot up looking for light and will do almost nothing in the way of leaf-growth because of its lack. In this way the whole energy of the plant is diverted into profit-making stalks.[9] The roots that have been forced for the Christmas market cannot be used again the following season. They need a season's rest. (Read J. E. Morse's "New Rhubarb Culture.")

But this absence of leaf, which is so desirable in forced rhubarb, would be injurious to the garden rhubarb. In out-of-door growth, the vigor and fruitfulness of the plants in any growing season, are largely determined by the spread of leaves in the preceding season. For this reason, after the cutting season is over, the plants are encouraged to develop leaves; the smaller and weaker ones being cut off that the large ones may grow still larger, but all seed stalks should be cut, so as to preserve the vigor for next season's growth of stalks.

When ready for market, rhubarb is tied in bunches of two to five stalks and an acre will produce about 3000 dozen bunches. That is a pretty good return when it requires only about a pound of seed to sow an acre in the first place.

Rhubarb is native to eastern Asia and has no serious insect enemies or diseases.

DOCKS AND SORRELS.

Those who are fond of very early greens will be glad to know of the garden varieties of docks and sorrels which come earlier than any other pot-herbs. They were originally imported from France where they are in general use.

The best varieties are the Spinage Dock and the Large Belleville, really a sorrel. The Spinage Dock is a week or ten days earlier than the Belleville, has larger, crisper, greener leaves and a less acid taste. Cornell Bulletin 61 says: "All these docks are hardy perennials, and are very acceptable plants to those who are fond of early greens. Some, at least, of the cultivated docks, can be procured of American seedsmen."

ARTICHOKE.

The Jerusalem artichoke, the variety best known in this country, and the French Globe or true artichoke, have little in common, yet both are used for food. The eatable part of the true artichoke is the flower-head, which should be cut before it has fully spread, else it will be woody. It is a strong-growing, upright, perennial, reaching a height of four or five feet, with large leaves. It is not always satisfactory to plant from seeds, as they cannot be guaranteed to reproduce truly. But when seed is sown it may be where the plants are to stand or in hot-beds.

The advantage of hot-bed sowing is that the plants may give heads the first year, while those planted in the garden require two seasons to produce eatable heads. The best means of propagation are the suckers which grow freely about the root crowns. Suckers are planted where the plants are to mature and give heads the second year.

Although the artichoke is perennial, it weakens after yielding two or three crops, so that it is well to replant part of the bed each year, thus keeping a succession of vigorous plants. In cold climates the heads are protected during the winter with a mulch of straw or litter. When boiled tender and served with Hollandaise sauce, made of melted butter and flour, the artichoke is a delicious vegetable, but it is comparatively little known in this country.

The Jerusalem artichoke is grown for its tubers, which are underground as in potatoes, and it needs much the same preparation and tillage as potatoes. It is usually fed to stock, especially pigs, but of late it is coming to be recognized as a good food for man, too. "If you will feed the pig, the pig will feed you," but we need not go through that troublesome process; for a varied vegetable diet alone is healthy for most persons—and much cheaper.

Artichokes are really more nourishing than potatoes, and the improved varieties may be used in place of potatoes. The plant is perfectly hardy, being native to the Northern States and Canada, and will take care of itself when once started, although it is better for having its roots divided, by digging them up. It will run wild, if wholly neglected, and become a troublesome weed, propagating itself indefinitely by means of its straggling, far-reaching, tuber-bearing roots. The only way to cure this damage is by thorough tillage, the first of which consists of fall plowing and the turning of pigs into the patch to root up the tubers.

The artichoke is more prolific than the potato, and will yield all the way from 250 bushels to 1000 bushels per acre with only ordinary care. For eating, the best variety is the Improved White French. The Jerusalem artichoke is not likely soon to supplant any other garden crop in this country, but it might well become a regular garden crop, as it will grow on land too poor for most other plants, requires little care, yields heavily, and is good food for man and stock.

SEA-KALE.

Sea-kale is one of the least known of the perennial garden crops, although where it is known it is well liked. It is a low, fleshy-stemmed plant whose shoots and young leaves are blanched and eaten as asparagus is. The plants may be grown from seed; in which case all but one main stem are to be cut off as soon as they appear; or it may be grown by division of roots. In either case, it is well not to cut from the plant until the second season. The shoots are blanched either by covering the crowns with fine, loose soil for a foot or even more, in the early spring, or by covering the crowns with a box and allowing the shoots to grow up in the dark.

After the young shoots have been picked off, the plants are allowed to grow as they will; for, like asparagus and rhubarb, the vigor, size and yield of the next season depend upon this season's growth of leaf and root. It flourishes best in deep, rich and rather moist soil. The plants should not be less than three feet apart each way, and they are much benefited by an autumn dressing of light manure or straw.

FOOTNOTES:

[9] NOTE.—You can get long stalks in the garden by putting a small cask, or half-barrel, with the ends knocked out, over the plant. The stalks will grow to the top and blanch some while growing.

CHAPTER XXV.

SPECIALTIES.

It is well to grow a variety of crops for your own experience and your own table. But for profit, it is best to specialize, because if you read up all you should know about several crops, you will have no time to raise them.

Specialization is the rule now in all lines of business, and as the farmer gets to be more and more a business man, he will adopt business methods, and push ahead. The big farm, partially cultivated, and covered with a great variety of crops which require as many varieties of cultivation to give good results, is a thing of the past, except where some individual farmer is too stupid to read the handwriting on the wall. It never paid as it ought, and it entailed tremendous labor. Now big areas are only cultivated where lots of help is employed, and diversity of crops can only be successfully practiced under the same conditions.

Today the custom of cultivating small areas is increasing, and where it is done for profit, the grower more and more tends to specialize. Secretary Critchfield, of the Pennsylvania State Department of Agriculture, said some years ago that "the greatest amount of money in farming was to be made in specialties," and that the country boy in deserting the farm was "running away from opportunity." This has since been proved true, and today it is possible for either girl or boy to make a good living from even a small piece of land, if she or he will only give intelligent attention to the matter.

It requires labor, to succeed in farming, but so does any other calling, if one wishes to master it, and there is no calling that assures so much independence. People must eat, and the food must be grown for them, whether the times be hard or easy; and even should times be so hard that you can't sell your product freely, you can eat it freely, and you can not be sure of food and room if you are in a shop or in an office. The American farmer and gardener are the nearest to free workers in the world.

The most unlikely things may bring profits when grown as specialties. One man who has a farm in Lewisburg, Pa., is making a good living from raising chestnuts. His profits on their sales average several thousand dollars a year. He made a study of chestnut growing, until he knows a lot about it, and has grafted young trees with Japanese and Paragon chestnuts, thus increasing the quantity and improving the quality of his crop. He has done so well at this, that the Pennsylvania State Agricultural Department has issued a bulletin setting forth in detail Mr. Sober's method of chestnut culture. If you are interested you can get the bulletin by writing to Harrisburg, Pa., for it.

Mushrooms offer a pretty good opportunity to make money, if careful attention is given to detail, but they are still mighty uncertain wild things. It is impossible to give the details of cultivation of specialties within the limits of a book, but if you apply to the Department of Agriculture you can get much information.

The Department publishes three bulletins which cover the subject:—Cultivation of Mushrooms, No. 204; Food Use of Mushrooms, No. 279; and Growing Mushrooms for Home Use, No. a233. Some mushroom farmers near Wawa, Delaware, according to a report in the Philadelphia _North American_, are clearing from $2000 to $3000 a year from four or five acres.

Asparagus, celery and many other garden crops lend themselves readily to special cultivation and yield a good profit. So also do onions and even potatoes. One man at least claimed to have produced as many as 3000 bushels of potatoes from one acre in one year. He published a pamphlet setting out his method, but it is now out of print. So big a yield entails too much labor for the average grower, but a third of that number of bushels would yield a handsome income. But, ordinarily, it does not pay to raise potatoes in a small garden.

Mr. C. E. Ford, who lived in Cherokee County, northeastern Texas, tells of raising two such incredible crops of potatoes annually from his land, and his method seems simple as set out by Finney Sprague of Chicago in a small book which was published in 1905.

Mr. Ford had a sandy soil with a clay subsoil three feet below the surface, which he says he ridged up into dykes; then he used immense quantities of cotton-seed for fertilizer as well as liquid manure. One of the important features was his rich fertilizing, and though it sounds expensive when compared with the ordinary quantities of manure used, it is really cheap if anything like such results can be had. Commercial fertilizers suited to potato growing may be used in place of cotton-seed, and the grower claims that the method may be followed from Canada to Texas successfully, securing at least two crops of potatoes a season.

According to his method, the seed used must be of uniform size, running about 80 potatoes to the bushel, and averaging about ¾ of a pound each in weight, smooth and bright. Half of such a potato is used to each hill, or if the potatoes weigh only six ounces, a whole potato is allowed for each hill. For intensive cultivation the potato must be sprouted before planting and for this purpose you need a "sprouting room." Any room, say 10 × 12 × 7 feet, if warm, dry, double-walled and lighted will serve the purpose; or you can construct such a house with sawdust filling between the double walls and double ceiling, having two windows, and a roof over all: an old ice house would do.

Lay two rows of two by four inch scantling on the dry earth floor, near the sides and across the end of the room opposite the door, and place on them a double row of barrels, each filled about three-quarters full of potatoes, or about three bushels to each barrel. When these have been filled this way, lay scantling across the barrels so as to accommodate other tiers of barrels, until you have about 50 barrels in the room. No earth or water must be used in the barrels; just the plain potatoes. In the centre of the room place your heating apparatus, which may be a small "bake oven" in which one barrel of charcoal will supply all the necessary heat during the four to six weeks of sprouting; or a small stove burning coal or wood so that a _low_ fire may be kept day and night to maintain a temperature of 80° to 90° Fahr., or, even a small oil-stove may be used.

[Illustration: A SHELTERED SUBURBAN GARDEN PATCH.]

Here the potatoes will sprout and send out rootlets having thousands of small tubers upon them, from the size of a bird's eye to that of a marble. If you start this sprouting four to six weeks earlier than the ordinary time of planting, you will get your crop just that much ahead of the regular season.

Only the best of seed potatoes are used, and Early Rose is the favorite variety, but Mr. Ford says, "that sort is best which is known to grow best in the section of the country where you live." In the ordinary culture of potatoes, it requires about 30 bushels of seed to the acre, and 300 is a large yield. By Mr. Ford's method, it takes 140 to 150 bushels to the acre, and the returns are claimed to be 3000 (three thousand) and more bushels. That is, using four or five times as much seed, you get 10 or more times as large a yield.

If you intend to experiment on this way of planting an acre, let it be as nearly square as possible, which will give you about 70 rows, each about 209 feet long. Ideal potato land is so light that the soil offers little resistance to the growing of the tuber; so thoroughly tilled and filled with humus as to be quite moist without being wet, and so richly fertilized as to contain a very large quantity of plant food.

Starting on the left side of your acre, with a narrow plow, turn a furrow to the left the whole away across; then turn and go back, turning a furrow to the left as you go, far enough from the first to leave a ridge about four to six inches across between them; then go round the whole thing once more, inclining the plow to the left all the way, and guiding it so as to leave the ridge. This will use up the three feet allowed to each row. Continue across the field after the same fashion, seeing that each row is three feet from each other row, and that the unplowed ridges or "balks," as they are called, are also three feet apart.

Mark the places for the hills on the top of those ridges, placing each hill 18 inches from each other hill. The plowed earth between the ridges is what is turned back to cover seed, to make the hills and to cultivate with afterwards, while the wide ridge affords a good surface for depositing the seed and for the expansion and growth of the tubers.

Two or three days before you intend to plant, harden off your potato sprouts by putting out the fire and opening door and windows until the temperature is as nearly as possible that of the outside. Then, all being ready, have the barrels carried to the potato field, on a hand-barrow by two men, not wheeled on a wheel-barrow. Knock off the hoops and staves, so that the sprouted mother potatoes may be freely but carefully handled.

Separate the mother potatoes with a wooden paddle, as it will do less injury than an iron one. The loss need not be more than 10%. Lift out one mother potato, being careful not to break the sprouts or rootlets. If the potato be a 12-ounce one, cut it in halves lengthwise, not crosswise, so that each portion shall have as many as 15 little tubers on it, so far as you can estimate quickly by counting with the eye. Lay each portion where the hill is to be, on opposite sides of the ridge, with the roots spread down the sides of the ridge, thus making a double hill, planted with anywhere from 40 to 60 little tubers, ready to resume growth at once.

Never plant less than 15 tubers to each hill, and if the half mother has less than that number, add a portion of another mother until you have that many. Only in this way can you estimate how many bushels you will have. If each half has more than 15 tubers plant them all. If you use 6-ounce potatoes for seed, plant the whole mother in each hill. Cover the seed with two furrows of the turning plow.

If the ground has been properly prepared, cultivated and irrigated during drought, practically every one of these tubers will grow to a uniform-sized potato, and 75 to 80 of them will make a bushel. Thus 70 rows with 140 double hills to each row, every hill containing 25 matured potatoes will, he says, give 245,000 potatoes, which at 80 to the bushel means 3060 bushels; if 30 potatoes to each hill, there will be 294,000 or 3675 bushels.

If a second crop is desired, have the mother potatoes ready when the first crop has been marketed and the ground once more thoroughly fertilized. Of course, whether it is first or second crop, the best tillage is none too good. Anything that stops the growth of the tuber at any stage, is fatal to your hopes of a uniform-sized crop, so be sure that there is no danger from drought.

In the case of the second crop, do not allow the potatoes to remain in the ground until touched by frost. This means pretty close watching, as the ripening of the potato is largely a matter of the last three weeks of growth, so they must not be dug too early, any more than too late.

Although this method will give far larger results than any other yet reported, it may not be practicable, nor may it give such phenomenal crops always; still, it is not the only case of enormous crops. As far back as 1828 crops from 900 to 1340 bushels per acre had been grown in England, and in 1884 the Editor of the _Rural New Yorker_ reported a yield of 1391½ bushels from an acre on the paper's experimental farm. In the light of such figures, the average of 100 bushels looks too mean to be considered. Why not grow more?

Potatoes cease to grow when they become dry, so the grower must see that the land is irrigated, and liquid manure is the best material, although plain water will do, if the soil is richly fertilized. Many growers now plant on flat land and hill up only to counteract too much moisture.

Then there are profits in small fruits if intensively cultivated. Strawberries will always find a market if they are large, ripe, sweet and clean. Anybody can grow small, sour ones, and they will sell, but there is no profit in the price. The market is never so glutted that fine, large fruit will not bring a fancy price. Be sure in picking, to have three baskets on a board, and have the picker assort the berries as picked. Usually, this will about double the price that you can get. A good yield is 6000 quarts per acre, but they have been known to yield all the way from 21,000 to 35,000 quarts per acre. (See "A Little Land and a Living," pp. 141-143.)

The good price is for the garden product that is better than its kind, and specializing on one thing helps to make you grow the best of that thing. You naturally try to find out all you can about it, and if there is an improved method, or somebody has grown a larger crop than you, you are going to know how he did it. Grow your family vegetables on a portion of your plot, but if there is room at all, save the rest for some specialty.

If you cannot grow crops at all, perhaps you can specialize on raising animals. You have a considerable variety to choose from, because, as I have shown in "A Little Land and a Living," and also in "Three Acres and Liberty," there is a market for everything, from bees and poultry to fish and silver foxes. (The foxes were sneered at, first off, but the Department of Agriculture has just published a bulletin on breeding foxes.)

CHAPTER XXVI.

WATCHING AND SPRAYING.

Now suppose you have prepared your soil properly, and planted your seed carefully; that your transplanting has been done, and your crops are growing; do you think your work is done, and you have only to wait for sun and rain to do the rest? If that is your idea, you are not cut out for a farmer. Get out of the business as soon as you can. There are no "soft snaps" in farming or gardening, on either a large or a small scale. But the man in love with his job, no matter what it is, is not looking for soft snaps, nor does he find his work hard. There is a reward in tilling the soil and in watching "the green things growing," as Riley has it, that is not excelled by the rewards of any other calling.

It is absolutely necessary that you should watch your growing crops, for only in that way can you keep in touch with their needs. The parent who neglects to watch his children and to look out for their physical needs, generally has doctors' bills and anxiety. A little watchfulness would have revealed the first stages of decay in the teeth; the early signs of adenoid growths; the symptoms of eye-strain, or the irritable state of the digestive organs, and the trouble could have been stayed. To be sure, the ounce of prevention costs something, but not nearly so much as the pound of cure. It is a question of business foresight, as well as parental affection, to watch the child, and the crop, and forestall disease.

Crops need careful watching, and to forestall most diseases there is nothing better than spraying. Once upon a time the man who sprayed his crops was a rarity, and his neighbors were not sure that he had not taken leave of his senses, but now the man who does not use the spray, is the notable exception—a monument of foolishness.

If you take the pains to find out what your soil will grow, you will know what insects and diseases are likely to attack your crops, and you can plan your campaign against them with intelligence.

Begin at the beginning, which is in the winter. First find out what spraying mixtures are best for dealing with the pests you are to meet. This can be done by writing the Department of Agriculture or by the study of books. Then study agricultural papers and Department bulletins as to the best spraying machines or nozzles on the market, and buy what you need.

Where any doubt about the quality of seed exists, it is often a wise precaution to spray it before planting, but you must spray your growing crop on the very first sign of insects or diseases. Remember that bugs do not like poison, and will not go where it is; therefore, you must take it to them in good quantities. Partial spraying is little better than none. Do the job thoroughly, when you start in to do it at all. See that the whole plant from root to top is thoroughly saturated—stem, branches and leaves. One spot untouched by the spray makes a sure refuge for the bug. Don't sympathize with his homeless condition at the expense of your crop.

Bordeaux mixture is a cure for almost every variety of plant disease. It consists of sulphate of copper (blue vitriol) and lime, diluted with water. The principal use of the lime is to make the mixture stick to the plant and to render the copper sulphate less caustic, and one thorough spraying, if rain does not come for a day or two, will cling to the plant for a couple of weeks. This mixture can be safely used even before there is any sign of disease, and it then acts as a preventive. But where disease is severe, apply it every few days, because the new leaves and shoots offer so many breeding places for the disease spores.

To make 12 gallons of Bordeaux, use one pound of copper sulphate and one pound stone lime. Be sure to use wooden vessels, as vitriol eats tin; an oil barrel, sawed in halves, makes good tubs for dissolving the vitriol and slaking the lime. Put one to one and a half gallons of water in the tub and hang the vitriol over night in a piece of burlap, which just touches the water. Slake the lime in the other tub by adding water as fast as the lime takes it up, and no faster. When both are properly dissolved, fill the spray barrel about one-eighth full of water and add the solution of vitriol. Add enough water to the lime barrel to make 2½ or 4 gallons and then strain the slaked lime into the spray barrel through a wire fly-screen or two thicknesses of potato burlap. Fill the barrel with water enough to make 12 gallons of mixture, and stir thoroughly for some minutes. If your spray has an "agitator" attachment, you need not trouble further, but if not, you must stir the mixture thoroughly every few minutes while spraying.

Bordeaux mixture should be made fresh for each spraying, but the vitriol and lime may be prepared ahead in large quantities, if they are not mixed, and are kept covered to prevent evaporation. Thus forty pounds of vitriol may be dissolved in 40 gallons of water, and forty pounds of lime slaked in 40 gallons of water. Four gallons of each will make a basis for 50 gallons of Bordeaux mixture.

The only disadvantage to Bordeaux mixture is that it discolors the plant, it being a "blue whitewash"; and those who object to the discoloration often use the ammoniacal carbonate of copper, rather than the sulphate. But this is not so sure a remedy, neither does it stick so well. It is made by dissolving an ounce of carbonate of copper in a pint of water and adding it to a quart of ammonia. If the ammonia is strong, use only enough to thoroughly dissolve the copper, otherwise it will injure the plants. Cork the mixture tightly and when wanted for use, add from 8 to about 20 gallons of water to each ounce of the copper. This is used principally on fruit that is nearly grown, or upon purely ornamental plants, to avoid discoloration.

Bordeaux cannot cure internal diseases of the plants. These may be caused by insect borers at the roots, or by some incurable bacterial trouble, and in this case there is nothing you can do but root up the affected plants and destroy them, and then study out how you can prevent its happening again.

Sprays for insects usually consist of some form of arsenic or of kerosene emulsion, and occasionally whale-oil soap is used. The most common form of arsenical poison is Paris green, of which about 2000 tons are used annually in this country; this is mixed in the proportion of one-half pound of Paris green to 100 to 150 gallons of water and one-half pound of fresh burnt lime.

However, where the insects are very bad, as potato bugs often are, the same amounts of Paris green and lime may be mixed with only 50 gallons of water. Paris green is too caustic to apply stronger than that, except in very rare, specified cases. The Paris green should be mixed with a little water till it is smooth, before it is added to the larger quantity of water. Sometimes it can be sprinkled on, but the only sure results are secured by using a spray, either hand or power.

Sometimes Paris green is added to the Bordeaux mixture, and the crops sprayed for insects and diseases at the same time. When this is done, you regard the Bordeaux as water, and add the Paris green in the same proportion as you would add it to water. In this case you need not add the lime, because the lime in the mixture is sufficient. London purple is sometimes used in place of Paris green for the same purposes, and in exactly the same proportion and ways, but it is not so easy to know how strong it is as with Paris green, and it is being used less and less each year.

Another preparation is arsenite of soda, which is made of white arsenic, two pounds; carbonate of soda (washing soda) eight pounds; water two gallons. These must be boiled in an iron kettle, which should not be used for any other purpose, for about fifteen minutes, or until the arsenic dissolves. Some water will evaporate during boiling, so, before bottling, add enough to make the full two gallons. This will keep a long time if tightly corked. To make a spraying solution add one-half pint to 25 gallons of water. The quantity given is, therefore, enough to make 8 barrels of 50 gallons each. Unless mixed with Bordeaux, add two pounds of slaked stone lime to each barrel. Be sure to mark your bottle of solution plainly, "POISON."

Arsenate of lead clings to foliage better than any other arsenical poison, and since it does not burn foliage it can be used alone, in the proportion of from one to five pounds to 50 gallons of water. It was first used in 1892 against the gypsy-moth and is annually growing in favor.

All insects which feed on the outside of plants are divided into two classes—the chewing or biting insects like beetles and larvae (worms), and the sucking insects, which include the various scales, plant lice, and squash bug. The chewing and biting kinds are killed with the Paris green solution, but the sucking sort need kerosene and preparations which kill by contact.

There are many ways of making the standard kerosene and soap emulsion, but Bailey recommends the following method as the best:—Put one-half pound of hard soap into a gallon of boiling soft water; as soon as the soap is dissolved, add two gallons of kerosene or coal-oil. This mixture should be of a milk-like consistency, which can only be secured by running it through a pump vigorously for fifteen minutes or more. For use on plants or trees, it is diluted with ten to fifteen times its bulk of water. It can be used stronger than that on trees in the winter. It is sure death to scales and plant lice if applied early enough; this is another proof of the value of watching your growing crops.

Within a few years, pumps have been invented which will perfectly blend water and kerosene without the addition of soap, and this is by far the better remedy. Without soap, the proportion of kerosene can be increased to even one-fourth the quantity of water, without injury to the plants, if the application is made while the sun is shining. This emulsion is fatal even to the dreaded San José scale. As experiments are constantly going on along this line, the up-to-date farmer or gardener will keep in touch with the latest discoveries.

Whale-oil soap, one pound of soap to four or five gallons of water, used to be a popular remedy, but it is rapidly giving place to kerosene emulsions, which are more easily prepared and less offensive. Tobacco dust will drive away cucumber and melon

beetles, if liberally applied, and will lessen the ravages of the flea-beetle. But Bordeaux mixture well applied will do the same.

For treating cabbages or other crops late in the season, white hellebore is often substituted for Paris green, which is a deadly poison. It may be applied dry, alone or mixed with half as much flour; or in solution, one ounce to three gallons of water.

Spraying enormously increases the yield of any crop, and indeed sometimes makes all the difference between good crops and no crops. So long as insects and diseases exist, any patch in any part of the country is liable to attack. Because you have escaped so far is not to say that you always will escape, so be ready for emergencies. Timeliness and thoroughness are two essentials, and these can only be secured by combining watching with spraying. It pays. Six years of potato spraying at Geneva, N. Y., increased the yield 122 bushels to the acre when sprayed five times during the season. Where only three sprayings were given, the increase was 93.6 bushels per acre.

You may be discouraged by these infinite details of care and management: but if you have not the time or the inclination to attend to them, that is not a reason for neglecting the study of Intensive Farming.

It is a reason for not undertaking a greater variety of crops than you can master; a succession of well-chosen plants will fill all the time you choose to give. I am showing how the best results can be obtained, but the most ordinary farmer will find his returns vastly increased by applying as much of these methods as he can manage.

For instance, at the South, the uneducated negro finds that his cotton crop is often increased, from half a bale per acre to two bales on each acre, by merely putting in a clover crop before the cotton.

Apply what you can learn, as far as you can: the power to learn more and to use it will come by use.

CHAPTER XXVII.

FERTILIZERS.

A fertilizer is something added to the soil in order to increase the crop yield. Chemical fertilizers are very valuable when very intelligently used—but look out for them. People seem to have a great love for all sorts of complicated ways of doing things that nature will do naturally, and any one who proposes unnatural processes like vaccination, or like medicining the soil, should be required to make a very strong case for it.

Besides, you remember the story about the darkey who has been playing poker. He said: "Tell you, boys, I dun los' a heap o' money las' night."

"How much, Mose?"

"A hunnerd and eight-seben dollahs an' fohteen cents."

"Golly! dat wuz a heap o' money."

"Yas, siree, and de wust ob it wuz, de fohteen cents wuz cash."

So it is with the boughten fertilizers. Sooner or later they have to be paid for in cash. The outgo is certain, but the income not so certain. Therefore, be sure you know just what you are doing, and why, before you buy. Of course there are times when commercial fertilizers are absolutely necessary if only to start the growth, but we should be sure what we are getting.

When we try to find out something about fertilizers, we get such technical and complicated explanations about phosphates and nitrates and other "ates," that the ordinary amateur or beginner just takes some one's advice; while the professionals mostly stick to what they have been doing. But the subject is clear enough if it is clearly stated.

Nitrogen and potash are about the best elements in artificial fertilizers and perhaps the hardest to retain. We have learned that nitrogen can be best and cheapest added to the soil by means of certain cover crops, or crops sown only to be turned back into the ground as green manure. It is also present in large quantities in stable manure, if it has not leached away before being put on the field. But this book could scarcely tell you all about the best ways of handling manure to get the best returns. The Government, however, has done this, in Bulletin 192, and you cannot do better than send for it and study it carefully. You will learn from it the immense importance of taking proper care of the manure you have, and how to get the best possible results from its use. Also,

what sorts of manure are best for what special purposes.

If the manure is carefully handled, that which is obtained from stock fed for soiling purposes—that is, especially to provide manure—is the best. It contains almost all the elements that the growing crops took from the soil.

One well-fed dairy cow will produce 12¾ tons of manure in one year, says Prof. E. B. Vorhees, and this manure will contain about 117 pounds of nitrogen, 77 pounds of phosphoric acid, and 89 pounds of potash. This much stable manure, if all the constituents are saved by housing and careful handling, will grow about 70 bushels of wheat and the accompanying straw. As all this nitrogen, phosphoric acid and potash have been drawn from the soil first in the crops fed to the cow, the only way to keep up the fertility of the soil is to return them to it. In the form of commercial fertilizers these would cost more than $30, or 20 cents per pound for nitrogen and 4½ cents per pound for potash and phosphoric acid.

So if you keep one cow and feed her well, she will return to you almost her value in manure each year, to say nothing of the milk and butter your family can have. The family horse, as well as the cow, will give you valuable returns in manure, if you know enough or care enough, to preserve it properly.

When immediate spreading on the fields is not possible, the manure, both liquid and solid, should be kept in a tight pit, or under cover. If too much litter has not been used, the liquid part will prevent loss from too rapid fermentation. But if there is litter enough to make the manure very dry, some water should be added from time to time to let fermentation go on without loss. Manure thus cared for will be ready for use on the land at any time that it is needed, and will contain practically all the necessary fertilizing properties.

A German proverb says: "The manure pile is the farmer's bank." All farmers these days know the value of good manures, which accounts for their buying so much commercial fertilizer, but some day they will know the value of saving the whole of the stable and barnyard manures, so as to avoid the cost of commercial fertilizers. Then there will be less of that unscientific talk of "depleted soils," and no grumbling about "decreased yields."

Sea-weeds, ashes, "mucks" and bones are all valuable as manures if handled properly. The Maine Agricultural Experiment Station, at Orono, Me., has published a bulletin, No. 74, on the manurial values of these, which will be sent upon application, and is well worth the reading.

The farmer should remember that commercial fertilizers are only to be used to supplement manure, not to take its place, and that when he buys any, it must be the best. He cannot afford anything else. The man who says, "I know my land needs potash, but I cannot afford to buy it," is making a mistake. Suppose he should say "I know my children need bread, but I cannot afford to buy flour!" His neighbors would think he had gone crazy.

It is just as foolish to deny his land what it needs. He should get whatever it needs; for if a soil needs any certain ingredient, whether potash, phosphoric acid or nitrogen, it is cheap at a high price, while anything else is dear at a low price. Your soil must be fed as surely as your children must. You can get credit at the store or at the bank to buy fertilizer, when you could not get it to buy an automobile.

Potash is really one of the cheapest fertilizer elements on the market, but farmers get the idea that it is high because it is present in large quantities in all high-grade fertilizers, and almost absent from cheap grades. Just as a man's wages cannot be estimated by the number of dollars he gets each week, but rather by the amount of the necessities of life that he can buy in return for the number of hours he has worked; so the price of fertilizer must be judged by the amount of plant food it contains, rather than by the money cost per ton. That is what makes high-grade fertilizer really cheaper than the low grades which cost less money.

For example, take the most popular of the $25 a ton fertilizer, "2-8-2." This contains 12 per cent. of plant food, or 240 pounds to the ton, made up as follows: two per cent. nitrogen, eight per cent. phosphoric acid, and two per cent. of potash. This brings the cost of this cheap fertilizer to 10½ cents per pound of plant food to the ton. Now if the farmer bought a ton of plain muriate of potash, it would cost him $50 per ton, but he would get 50 per cent. of plant food, thus making the actual cost only five cents per pound of plant food, less than half the plant food price of "2-8-2."

Few farmers want to buy the potash separately, and they complain that the manufacturer charges high for it in fertilizer where it is present in large quantities. But a little investigation will prove that this is not so. Take for example, the "2-8-10" grade which sells generally for $30 per ton. Here you have 20 per cent., or 400 pounds, of plant food to the ton. That brings the cost of plant food per pound to 7½ cents instead of 10½ cents as in the cheap grade. The manufacturer has added $8.00 worth of potash to the mixture

and has taken out some of the worthless filler, so that the extra cost in money to you is only $5.00.

The increase in yield more than offsets that extra cost. There are still other potash fertilizers that contain no nitrogen, the lower grades selling for about $16 per ton, and the higher grades for $20 per ton. The plant food in the lower grade costs 6■ cents per pound and in the high grade only a tiny fraction over 5½ cents per pound. If you are spending your money for commercial fertilizers, you will find that the best is the cheapest. No matter what the mixture, if you figure it out, you will find that the high grade costs less per pound for plant food than the low grade. And it is plant food you are after, not worthless filler.

The New York Experiment Station in one of its bulletins offers the following comment on this point: "The high-grade goods sell on an average nearer to their actual plant-food value than do the low-grade goods. In general, the higher the grade of the goods, the lower the cost of each pound of plant food."

Before you raise any crop you must know your soil, not by chemical analysis which is interesting and often helpful, but by finding out what it will grow by nature and what is the easiest way that nature can be helped; and the quicker you can find out these things the better for your prospects. The simplest and quickest method of finding out what fertilizers your soil needs to grow your crops, is by using the paraffin basket. This is a very pretty experiment and one in which you can readily interest the children so that they may get their knowledge early.

The requirements are galvanized wire netting of one-eighth inch mesh; paraffin, which can be bought cheaply at any druggist's; and a pair of scales which will weigh accurately to one-fourth of an ounce.

Cut your netting into strips 10 inches long and 3½ inches wide; fasten the ends of strips together by hooking the end wires into the mesh or with small rivets. Then cut the wire at the bottom of the cylinder so as to make lugs about a half inch deep and bend the cut pieces under to form a partial bottom. Cut a circular piece of netting that will fit inside and drop it in, thus completing the bottom of the basket. Melt the paraffin, and while hot dip the top of the basket into it for about one inch. Draw it out, that it may cool, and dip again until a solid rim of paraffin is formed. Number each basket, as it is easier thus to keep a record of it. Place them on a tray, or in a shallow box, for greater ease in handling.

Gather the soil in small quantities from different parts of your field or garden and mix it together. If you took it from one spot it would not be representative, any more than a Congress elected entirely from one section of the country could rightly be called a House of Representatives for the American people. Divide this whole amount of soil into equal parts, having one more part than you have fertilizers to test, because you should have one basket of untreated soil to act as a check to judge results by. Eleven sorts are usually tested, which makes it necessary for you to make twelve baskets altogether.

1. Untreated soil.

2. Soil with dry manure, at the rate of five tons per acre.

3. Soil with lime, one ton per acre.

4. Soil with nitrate of soda, 200 pounds per acre.

5. Soil with sulphate of potash, 200 pounds per acre.

6. Soil with acid phosphate, 200 pounds per acre.

7. Soil with nitrate of soda and sulphate of potash, 200 pounds each per acre.

8. Soil with nitrate of soda and acid phosphate, 200 pounds each per acre.

9. Soil with sulphate of potash and acid phosphate, 200 pounds each per acre.

10. Soil with nitrate of soda, sulphate of potash, acid phosphate, 200 pounds each per acre.

11. Soil with nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each per acre, with lime, 2000 pounds per acre.

12. Soil with cowpeas, 5000 pounds per acre, with lime, 2000 pounds per acre.

It is important that the small portions of earth be fertilized in the same proportion as is here given for the field, so to 7¾ pounds of dry, finely pulverized soil, add one ounce of any one of these fertilizers. Mix very thoroughly and pass it through a sieve at least

twice. This is still much too strong for use, so take one ounce of this fertilized soil and add it to five pounds more of soil, mixing and sifting as before. Then you have soil and fertilizer mixed at the rate of 200 pounds to the acre. For testing larger applications, make your first mixture with proportionally larger quantity of fertilizer.

For mixing lime with soil, take only 11½ ounces of soil to one of lime for the first mixture; for cowpea vines, four ounces of soil to one of vines, and only 1½ ounces of soil to one of manure. One ounce of each of these mixtures to five pounds of soil will give the right proportion of each to the acre, or, one ton of lime, five tons of cowpea vines, and ten tons of manure to the acre.

After you have added the fertilizers to the soil, it is left standing in pans or boxes for several days, being watered with rain water or melted ice water and frequently stirred. Do not use well or hard water, for those contain lime or salts, only rain water. Moisten the soil at the end of a few days until it is in the best condition for planting seeds. You soon learn to judge this.

Divide the soil in each pan into five equal parts and put one part in each of five wire baskets, pressing it down at the bottom and sides. After this is done, brush off the soil that has been forced through the mesh of the netting. The basket should be filled to within one-half inch from the top. The baskets are now ready for planting.

A couple of days before planting, put wheat grains between moist cloths, cover with wet sand and place in a warm spot to start germination. Take from these sprouted seeds those that are of the same size and development, and plant six in a straight line in each basket, being careful to plant all to exactly the same depth. Then cover the soil in the basket about one-fourth inch deep with clean, dry sand, dip the whole basket, down as far as the rim you have already coated with paraffin, into melted paraffin; cool, and dip again and again until it is completely covered with hardened paraffin for about one-sixteenth of an inch, and you have nearly completed your task.

See that the pots have the best possible conditions of light, temperature and moisture, as nearly as you can make it like what they would have in the field, being careful to keep all the baskets of one set together. Water them frequently. If you have weighed some of the baskets as soon as planted, you will know how much water to supply, for you must keep weight as close as possible to what it was at the beginning.

Fifteen or twenty days are enough to show you what fertilizer your soil most needs, and you can then go ahead and get it ready for crops. This is a test solely for soil needs, not for plant requirements, so it is not necessary to grow the plants any longer than just to show which basket flourishes best. It holds good in the field as well as in the basket.

One thing must be borne in mind, that weight must be accurate. If the farmer hasn't time or patience probably his wife would make the test. She has time and patience for everything that is put upon her.

CHAPTER XXVIII.

MORE ABOUT FERTILIZERS.

In the past we believed that fertilizers acted as plant foods and that the substances to be applied must contain one or more of four elements which are probably the most important to the plant, namely: Nitrogen, phosphorus, potassium and calcium. Several other elements go to make up the plants; but these are considered most difficult for the plant to secure from the soil and were therefore of the most importance for the farmer.

Trials, by experimental work with different plants, soon showed that the forms of combination of these elements make a great difference. For example, nitrogen is now applied either in the form of nitrate of soda and of potassium, which is called saltpetre, or in the form of sulphate of ammonia; or, it may be applied as organic matter in dried blood, tankage, hoof- and horn-meal and even muck.

Both the nitrate and sulphate forms are readily dissolved, but the nitrate form is the one in which plants take up their nitrogen, so that either nitrate of soda or saltpetre is specially valuable for forcing a quick growth. The effect may be seen upon plants in a very few days after it is first applied. But sulphate of ammonia, although it will dissolve, must be changed into a nitrate, in the soil, before the plants can use it, and this probably takes several days, hence, it is not quite so quick acting.

The organic forms of nitrogen vary much in their usefulness. The nitrogen of dried blood or tankage is the most easily absorbed. These substances are sometimes sown at seeding-time, and become useful later in the season when the soil becomes warm. Other forms, however, as muck, leather parings, etc., are used considerably in making some low-grade fertilizers. Notwithstanding

the tradition that you must bury an old shoe at the foot of the vine, the nitrogen in these may never be of very much value.

The phosphorus is found in fertilizers both in forms that will dissolve and in forms that won't. Acid phosphate and dissolved bone contain a large portion of phosphorus in the form of a soluble phosphate of lime; this is often marked on the bag as being equal to 12, 14, or 16 per cent. of phosphoric acid. Ground phosphatic rock, also called "floats," and raw bone-meal contain phosphorus combined with lime in the form of an insoluble phosphate.

Basic slag is still another form of phosphate of lime, which, although insoluble, readily becomes available as plant food in the soil.

Potassium occurs in various forms of combination, one of the most common being muriate of potash; another form is sulphate of potash. Kainit is another fertilizer which contains potassium, and wood ashes contain a small percentage. In all of these the potassium is generally spoken of as potash and the first two are said to contain the equivalent of 50 per cent. potash. Kainit usually contains 12 to 14 per cent. Wood ashes may contain about 3 to 6 per cent. Kainit and muriate of potash have an acid effect upon the soil, and it is wise to apply them some time before the crop is to be sown, even the fall previous, if the soil retains plant food fairly well.

The commonest kind of calcium is quick-lime or lump lime. When this is "air-slaked" it becomes what is called carbonate of lime. Fifty-six pounds of lump lime contain the same amount of calcium as 100 pounds of air-slaked lime, and in using these it makes very little difference whether we apply the quick-lime or the air-slaked, provided we apply equal amounts of calcium and that the particles are equally small in both cases. In other words, 56 pounds of quick-lime or 100 pounds of air-slaked lime may be used, but both should be in as fine powdered form as possible before they are sown.

Like every other fertilizer, lime is of no use until it is dissolved, and the finer it is ground before it is applied the further it may be spread and the sooner it will dissolve. It is seldom wise to apply more than from one-half ton to a ton of quick-lime per acre at any one time; and it is safer to apply this quantity every three or four years rather than larger quantities at shorter periods. Lime should be applied to the land when there is a crop upon it which can use it with advantage. A crop like clover or alfalfa, which covers the land completely, will make the best use of lime. It may injure potatoes, because it makes the land more favorable for the growth of scab, a disease which attacks potatoes.

Much money can be lost by the unwise use of fertilizers, and the best way one can positively know whether it is wise to use them is to try it thus, say, with radishes, lettuce, or beans; a patch containing two or three rows may be fertilized in one way, the next one in another, others with various mixtures and, in order to determine the values of these it will be wise to leave untreated "check plats" between some of the strips. The following outline will show how to make such an experiment on about half an acre:

Plat 1.—Nothing[10] · · 2.—200 pounds nitrate of soda per acre in · two or three applications. · · 3.—600 pounds acid phosphate. · · 4.—Nothing. · · 5.—100 pounds muriate of potash. · · 6.—100 pounds muriate of potash and 200 · pounds nitrate of soda in two or three 198 feet.· applications. · · 7.—Nothing.[10] · · 8.—100 pounds muriate of potash and 600 · pounds acid phosphate. · · 9.—100 pounds muriate of potash. · 600 pounds acid phosphate. · 200 pounds nitrate of soda. · · 10.—Nothing.
..... 144 feet.

One hundred pounds per acre is one pound for 48 square yards, a strip, say, one yard wide and 48 yards long.

It may be necessary to repeat the experiment several years, before we can be sure what will give the best results; but we shall learn much that will help even during the first year.

In mixing fertilizers, care must be taken not to mix those which injure one another; thus nitrate of soda and muriate of potash, both take up moisture from the air quite readily, and when mixed with other substances are liable to make the whole mass pasty, or even to run together and bake in the bag; these should be mixed but a short time before they are to be applied. Nitrate of soda and acid phosphate, when they are mixed and allowed to stand, become damp and act chemically upon each other, and the result is loss of fertilizer elements into the air; the same is true when basic slag and sulphate of ammonia are mixed together.

We are frequently advised to apply fertilizers to the crop while it is growing. Nitrate of soda is generally used in this way, and to aid in spreading it, it is often mixed with acid phosphate. Now both of these substances, as well as muriate and sulphate of potash, are likely to burn the foliage of plants with which they come in contact; hence, broadcasting these over growing plants on a damp morning is liable to do serious injury to the foliage; it is safer to apply them with a drill.

Value in Fertilizers.—In estimating the value of fertilizers it is the custom to speak of the unit of valuation. A unit is one per cent. of a ton, or, in other words, 20 pounds. For example, if kainit contains 12 per cent. of potash and is sold at $12.00 per ton, then there are 12 units and they cost $12.00; therefore one unit costs $1.00, and since the unit is 20 pounds, the actual cost of the potash is 5 cents per pound. If muriate of potash, guaranteed to contain the equivalent of 50 per cent. of potash, is selling at $40.00 a ton, then we find that 50 per cent. potash is 50 units; if 50 units cost $40.00, one unit will cost 80 cents, or in this form 20 pounds cost 80 cents; therefore one pound will cost 4 cents.

Now, if these are prices free on board the cars at New York, and potash is the thing we need, we must remember that in order to get equal amounts of potash delivered to our own farm, we must pay freight and haul four tons of kainit instead of one ton of muriate of potash. In other words, with these figures the higher-priced fertilizer, counting in dollars per ton, is really the cheaper article, counting in value.

Any one who will secure the latest fertilizer bulletin from the nearest Experiment Station will usually find the approximate values of one pound of nitrogen, phosphoric acid and potash in the different fertilizers worked out in some part of the bulletin. These may be used in deciding whether it is better to buy and mix the fertilizers at home; then one may know what is going on the land and the form of combination it is in.

Manure contains all of the elements we have discussed in more or less fixed forms. The liquid manure from animals contains a large amount of the nitrogen passed from the body and is of particular value. The most useful parts of the manure are the ones which are easiest lost; hence, if manure is piled and allowed to ferment, or if the water from the roof of the barn is allowed to wash it, serious loss occurs.

A ton of fresh manure has all the value it ever will have, and if there is a piece of land upon which it can be spread, it should be done at once. The liquid manure should be soaked up by the bedding, and applied at once to the land. The holding of manure in piles or pits always causes loss of valuable elements. Sometimes we may have to hold it, but every effort should be made to arrange the crop so that it can be applied somewhere each day as made. Manure has a special value because it furnishes humus, which greatly helps the physical condition of the soil, and the bacterial and other microscopic life in the soil.

FOOTNOTES:

[10] NOTE.—If the yields of plats 1 and 7 do not agree closely, the effect of the fertilizer can be closely estimated by comparing the yield of each with the check plat nearest to it. Another interesting experiment is to lime one-half of each plat.

CHAPTER XXIX.

ROOT HOUSES AND VEGETABLE PITS.

In the North, we have to protect our gathered crops and to store them safely for a profitable market, but we do not need an expensive barn or cellar for that. A root house or vegetable pit will do instead.

This is the way to make one: in a warm, sandy or gravelly soil a pit is dug from one to two feet deep and sixteen or more feet wide, the length depending upon the crop you have to store. The sides of the pit are lined with one or two planks placed edgewise and held in place by stakes driven into the ground. Stakes are then driven into the bottom of the pit throughout its entire length; these support the ridge-pole four or five feet above the floor of the pit. Boards are laid from the edge of the pit to the ridge-pole to form a sort of gable roof. The support of these is strengthened by another girder carried by stakes driven half way between the margin and the ridge-pole. Then longer boards, from twelve to fourteen feet in length, are laid from the edge of the pit to the ridge-pole, slightly overlapping each other, and nailed lightly in place at the top ends. The pit being only a temporary structure, the boards are not securely nailed, as the same lumber will do for another pit next season. At distances of about ten feet some boards are left without nailing to serve as entrances, and at each place a stake is driven to mark the opening.

Such a pit will protect crops until severe freezing weather. After that, the board roof should be covered with straw, grass or other litter, and where the weather gets very cold, manure and earth are often added as the outer layer. The advantage of this pit is that it contains a large body of air which secures uniform conditions from day to day, and celery, leek, Brussels sprouts and even cabbage may be stored by setting in compact rows, so that they may make a slight root-hold and avoid shrivelling.

But there are many varieties of pits used for storing vegetables, and in Kalamazoo, the American celery centre, the favorite celery storage house is a permanent structure with windows at regular intervals along the roof, to give the necessary light for the workmen. These houses have wooden ventilating chimneys, and are usually heated with stoves so that the temperature may not fall below freezing point.

CHAPTER XXX.

SOME SMALL FRUITS.

The home garden would scarcely be complete without a strawberry patch, and hardly anything gives better returns. Strawberries grow in various kinds of soil, but a light, sandy loam gives the earliest berries, because that is the earliest, warmest soil. It takes only a few well-developed, well-cared-for plants to supply a family with berries enough, and the care is no greater than would be given corn. But you should make a careful selection of your plants. Small, weakly plants, or plants that have already been in bearing, are no good for your purpose. Therefore, buy from an honest dealer. Plants for setting should have been grown for that purpose purely, and not have been allowed even to blossom, as the important thing is to have a vigorous root growth, and well-formed crown.

This sort of strawberry plant will yield large, delicious berries about ten to fourteen months after setting out, and although a plot containing 100 plants requires not more than a half-hour's work a week to keep the plants in condition, after they have been well started, yet the yield will be about a quart to each plant.

To get such a return, you must first put your soil in good condition for planting. Have the soil finely pulverized and thoroughly fertilized with well-rotted manure, ground bone or wood ashes.

Having prepared your bed and got good strong plants, it is now time to set them out. Before doing so, trim the roots even, and cut off all but a leaf or two on each plant. The easiest way is to take them in bundles of 25, fasten together and cut the roots of all at once. But do not expose the roots to sun and air during planting. Keep them covered with a damp cloth. Lay the roots carefully in the ground, spreading them out fan-shape, and see that the crown of the plant is level with the surface of the soil, and firm the soil well around the roots. A properly set plant begins to grow at once, becomes larger and has more fruit crowns than a carelessly set plant. So be careful to start right.

Set the plants out in rows 18 to 24 inches apart, and 15 inches apart in the row. If each plant is set in a little hill by itself as you would set corn, you will find it easier to cultivate and also to keep the weeds down. It is as necessary to keep strawberries clear of weeds as it is any other crop.

Cultivate as soon as all the plants are set, and continue to do so once a week during the whole season. Pinch off all blooms the first year and cut off the runners. By so doing the plant will spend its energy on root growth and in producing more fruit crowns for bearing the next year. It never pays to crowd strawberry plants. Give them room and keep them in hills with cultivation and you will get both pleasure and profit from your patch.

It pays to mulch strawberries. As soon as the first hard frost has come, cover the bed with about three inches of litter of salt hay or straw. This prevents the ground freezing and thawing during the winter. In the spring you clear a space over each plant for the leaves to come through, but leave the mulch on the ground. It not only keeps the soil from drying out, but it also keeps the fruit from getting dirty from sand or mud.

From the first ripening, pick your berries as soon as they redden, every day if necessary, and let the picking be done in the early morning, before the sun has dried them. The berries keep longer and have a better flavor.

As soon as the plants cease fruiting, remove the mulch and cultivate. A handful of bone-meal mixed with the soil between each plant will have a good effect. In a few days the plants will put out runners. Allow one runner to grow from each plant, and layer this between the old plants in a straight row. "Layering" is covering the runner at one or more points with earth, or really planting it. It will develop roots at these points and become a strawberry plant. In from two to three weeks it will have got a good start, and then you can take up the old plants. In this way you can renew your own strawberry patch every year at little trouble or expense, if you get good plants to start with.

Some reference to the possible yields of strawberry beds has been made elsewhere in this book, so it will not be necessary to repeat here, but you will be making your own records soon, if you follow these simple rules.

Raspberries and blackberries succeed in any soil that is not too wet and heavy, and there are good profits in their growing. If you intend to take up the culture of these fruits, you will do well to read "Bush Fruit," by Prof. F. W. Card. The bushes of both should be cut back and pruned in the spring, the raspberry being easy to handle with ordinary hand-shears, but a blackberry hook is better for dealing with the sharp thorns of that bush.

As soon as the fruit is gathered the fruiting canes of the season should all be removed; then in the spring, cut back all canes. This makes them stockier and stronger. They should be supported by wires stretched on either side and fastened to crossway pieces attached to stakes driven at each hill, for these fruits should be planted in hills, too.

Plantations are generally renewed every five or six years, although with good care yearly, they last longer. The yield varies from 1200 to 10,000 quarts an acre; the difference lies partly in the canes, and partly in the cultivation.

The home garden would scarcely be complete without currant and gooseberry bushes. They are easily grown, the gooseberry, in particular, requiring very little care and yielding large returns. It can be grown in clayey soil, though like the currant, it prefers a deep, moist, rich soil, especially a rich soil.

Strong one-year-old plants are the best to set out, and two- or three-year-old canes yield the best and largest quantity of fruit. All wood older than that should be carefully pruned. The same cultivation applies to both—well-rotted stable manure and shallow spring tillage.

The worst pest is the currant worm, which eats the leaves almost as soon as they unfold. Dust the bushes with powdered hellebore when the leaves are wet, or mix the hellebore with water and apply. Then there is the leaf blight, which attacks the leaves as soon as the fruit is ripe, and almost strips the bushes of foliage. This should be sprayed with Bordeaux mixture to stop its ravages, because if allowed to progress it weakens the bush, and the fruit next year will be small and of poor quality.

The grape-trellis is a common sight in the gardens of the New England and Middle States, but not so common as it will be when the gardener understands how comparatively easy it is to grow this fruit. A well drained, thin soil, with a warm southern exposure will provide for starting a good grape-vine.

The vine needs a trellis support always, and the pruning must be looked after, else the numerous runners will draw from the plant so that it cannot fruit properly. Keep the runners pinched off during the fruiting season, and in the fall cut off the old canes, leaving only the new, vigorous canes for next season. It may be two or even three or four years before much pruning is needed, but after that it must be attended to regularly.

Each new cane must have plenty of space, light and air, to prevent rot and mildew of the fruit, so that the number of canes you can allow to grow, depends upon the strength of the vine, the space to be covered and the root growth.

You may fancy other small fruits that you have room for in your garden. Any good agricultural paper will give you the information or name the book you need. Fruits are another means of making your plot pay, so you might as well grow a few at least.

CHAPTER XXXI.

THE POULTRY RUN.

Even the hen is intensively cultivated these days, and that makes room for her and her chicks on the small patch. It is perfectly amazing how little the ordinary farmer knows about poultry, although he has raised some, more or less, from time immemorial. The modern farmer is too wise to be caught with the extravagant stories found in some poultry papers, of the profits to be made from a hennery, though at the same time he is not wise enough to believe that with careful attention and improved methods, the hennery can be made to pay well.

It is for the benefit of the farmer who is neither too wise nor too ignorant to be taught, as well as for the villager and the intensive farmer, that this chapter is written.[11]

One of the new systems, Philo's,[12] extensively advertised, makes it possible for people with but little room to keep a small flock. By this system, the hens are always kept in confinement; but with some extra care and proper treatment they do well and yield great results; which is in harmony with the modern theory of intensive culture.

The first thing to be decided is what kind of poultry to keep. Chickens are the most popular of the various domestic animals suitable for the intensive farmer. Turkeys and guineas do not thrive well in confinement and are difficult to rear in a commercial way. Farmers who have free range, especially if they are adjacent to woodland, may do well with a few of these less domesticated birds. On the other hand, ducks and pigeons do even better than chickens in confinement, but there is less demand for the product.

The first essential for success with poultry, as with crops, is to secure good stock; the very best possible. To buy fowls simply because they are cheap is poor economy. Much better buy well-bred stock at five dollars and upwards, for they will not only give more eggs, but their brood will be worth more, so that in a year you can build up a fine flock of your own.

The second essential is to keep them in small companies, not more than six hens in a pen; still better results can be had with four. These are the days of intensive culture and chicks will respond to it as surely as field crops. Like the crops, they need abundance of food, to force growth and vigor and egg production. Care must be taken in the selection of food, but you are always safe on lots of oats, wheat-bran and green stuff, with some lean beef now and then. Corn should be fed sparingly to heavy fowls, but is an excellent diet for Leghorns or for any chickens on free range. Running water, or plenty of fresh water should be furnished. An open water vessel is best, although almost any self-feeding fountain is good. Place it about ten inches from the floor that no dirt may be scratched into it.

Fresh air and sunshine are necessities, but drafts should be avoided. Cleanliness is vital; if only a few hens are kept, all droppings should be removed every morning, and sand or lime or ashes sprinkled on the roosts and boards. If the food is good and well balanced, the premises kept scrupulously clean, and the fowls protected from storm and wind you will not be greatly troubled with disease or weakness. Daily care, never slackening, is the price that must be paid for success.

The poultry house should be in a sunny spot, on a hillside sloping to the south, if possible; but no one need be kept from chicken raising if such a spot cannot be had, for many successful plants are not so well situated. A light sandy soil offers the same advantages as a southern slope. Such locations or soils are not only much dryer but also much warmer, for the snow melts and the frost leaves the ground earlier in the spring than on northern slopes or in clay soils. The advantage of this earlier season is just as real as in a more southern latitude.

One of the main defects of poultry houses has been that they were built for people, rather than for hens; being too high, they are not easily kept warm in winter. The house itself should be well built to exclude storm and wind, but the southern side should be largely enclosed with muslin, which is much better than glass, as it affords an entrance for air without draughts, and furnishes plenty of light.

The roosting room may have a ceiling close above the roosts; this can be made of round poles or narrow boards, laid an inch or more apart, and over these there should be spread a covering of hay or straw. This will give ventilation, and yet retain most of the heat, especially if a thin muslin curtain is placed before the fowls during the night.

In the warmer localities, on the Atlantic coast from New York south, and in the Mississippi Valley anywhere south of St. Louis, curtain fronts are not necessary, but, instead, a part or all of the south side of the poultry house is made of poultry netting.

If chickens are to be raised in large numbers, incubators must be used; those holding two to three hundred eggs are most commonly used. After the chicks are hatched, comes the serious question of brooding them, especially during the winter. All kinds of little chicks need air and sunshine even more than older folk, and not many buildings allow of either; consequently, we must consider brooding out of doors, where air and sunshine can always be had. Fortunately, the experimenting has been done by others, so now we may avail ourselves of the knowledge they have gained, as many successful people are doing.

With properly constructed brooders and brooder coops, it is perfectly practicable to care for chickens from hatching to full growth, out of doors, at any time of the year, without artificial heat. This does away with all danger from fire and over-heating, and gives the chickens a vigorous constitution that will enable them to withstand all the ills to which chickens are liable.

These suggestions are not given as great discoveries, but they are a brief summary of the practical points of chicken raising, and are all workable. Some of them are given by the Rev. W. W. Cox, as the results of years of personal experience in the business. He

is now making a specialty of raising White Orpingtons, and is brooding out of doors, with success.

There are many branches of the "chicken-tree," the more important ones being breeding stock, or fancy poultry; egg farming, broiler farming and roaster growing. Running a public hatchery, and selling day-old chicks, is the latest development, and is indeed so intensive that it links manufacture to farming, for the building site is the only ground required. These branches are recommended to the inexperienced poultryman in the following order:—1st, Egg farming; 2d, roaster growing; 3d, fancy poultry; 4th, broiler production.

Egg farming, properly conducted, is profitable in almost any locality. Roaster farming has proved a great success near Boston, but has not been largely introduced into other localities. Fancy poultry is a money-making game for those who are successful in winning prizes at the show, and getting well advertised as breeders. The broiler business, seemingly the most profitable branch, has in practice been a source of loss to many investors. The cause of failure in the broiler business, lies chiefly in the difficulties of artificial incubation, especially in the winter season.

Incubation is to the chicken raiser what the hot-bed is to the tomato raiser. If incubation is a failure, the whole business must fail. For the poultryman with a few dozen, or even several hundred fowls, hatching with hens is to be recommended, unless he keep Leghorns or Minorcas; these varieties not being good brooders. Convenient arrangements for setting hens in large numbers will be a more successful investment than incubators. For duck farms or Leghorn egg farms, or any poultry business on a large scale, artificial incubation is a "necessary evil."

The Central Hatchery, only now being established here, although in use in Egypt for centuries, promises to solve this difficulty. The advantage of centralizing the hatching is that it admits of better methods than are available on a small scale, and also allows one man to devote his entire energies to this feature. Such hatcheries may be handled either by private individuals, or, as in the case of the creameries, may be co-operative institutions run for the good of the whole community.

A continuous house can be built with small compartments for each flock, and separate runs for summer use, though the colony plan is preferred by some, and has its advantages, among them being the fact that the flocks are more widely separated, so there is less danger of any disease spreading; and if any particular house becomes infected, it can be cleansed without disturbing the whole plant.

The colony plan requires considerable less expense in housing and other equipment than the yarded plan. The expense for food is also decreased, because of the greater number of insects and green food that the hens get from the range.

The following plan of poultry keeping is, perhaps, the simplest known, and for that reason, the most successful. By "successful" I do not necessarily mean the most profitable, but the surest of paying a reasonable profit. The plan is that of using inexpensive colony houses, which are located in a large yard or small field. These houses are built very light; they are floorless, and are moved frequently, either by team or by a pole-pry. By this method the droppings are distributed directly on the soil without the usual laborious work of scraping the dropping-boards.

In the poultry field some green crop is kept growing as much of the year as possible. As a general rule a crop cannot get a start in a poultry range, and so a plan of rotating the chickens in two or more fields, is desirable. No more profitable combination of "small" farming can be found than that of rotating poultry with the leafy vegetables (lettuce, spinach, cabbage, etc.) which utilize to the greatest advantage the rich, nitrogenous manure. Under this system, the hens are fed grain, chiefly corn, and beef scrap in hoppers, and water is supplied in the simplest way possible, preferably from a running brook. The chief point to be kept in mind is to cut down the number of necessary visits to the poultry houses, thus reducing the labor cost.

The custom of raising chickens on fresh ground every year is of value to the farm, but the one disadvantage has always been the expense of fencing. In a recent issue the _Rural New Yorker_ told of the plan of one wide-awake chicken raiser which can be followed by anybody. His plan is to sow sunflower seed with a drill, at the earliest possible moment in the spot where you wish the fence to be; then drive stakes at intervals along the row and stretch two-foot chicken wire over them. Even the wire will confine the chicks when they are small, and by the time they have grown big enough to get over that, the sunflowers have grown up and made a "chicken-tight" combination. Hens are too stupid to think of flying over such a barrier, yet the poultry raiser can come and go as if there was no barrier.

This is not only a cheap fence, but it affords the necessary shade for the fowls in hot weather. They lie about among the stalks scratching in the cool earth and getting a dirt bath at any time in the day. Then late in the season the sunflower heads are cut down

and the pullets do the harvesting of that crop in short order. No other variety of fence can be used for food when its usefulness as a barrier is past. You could easily put up this sort of a fence yourself, and as the sunflower is a very hardy plant, you might even try sowing the seed in the fall, so as to get an early start in fence building in the spring.

You must be willing to give your time and attention if you are to succeed. One man who has had a good deal of experience writes me about the new method of chicken raising as follows:—"No doubt it is a valuable contribution to the subject of intensive cultivation of poultry. It involves, however, the most intensive and persistent labor, to which very few men are willing to subject themselves, and I am one of that class. I have had enough. Still, I need more income, and I am thinking, just a little, of Indian Runner ducks, which demand cheaper buildings and less care than chickens. Yet I cannot raise much enthusiasm on the subject, and I shrink from the constant attention to details which even they require."

But even if you are not prepared to raise fowls after this fashion, there is no reason why you should not keep a few hens and raise a few chickens for your own family use. If you hatch in incubators, use eggs that are laid the day you put them to hatch, and with good management practically all of them will produce vigorous chickens that can be induced to lay early, if pullets, and can be fed for market, if cockerels.

Eggs are more profitable than chickens, especially if you can produce them out of season, and this depends upon the time of hatching, the feed and care. A flock of 25 fowls will produce eggs and chickens enough to add a tidy sum to the income, if you feed and house them right. And the feeding need not be much of an expense, if you save the table scraps and give corn, cabbage and other green stuffs, buying whatever wheat and oats you can't raise. In winter, change their drinking water frequently and see that it is slightly warmed. If you cannot provide running water, then you must give them clean water many times a day all the year around.

As a matter of fact, the amount of effort expended is pretty closely related to the profits to be derived. Whether you raise hens, ducks, geese, squabs, or any of the many animals now raised for profit on the home acre, you must study their needs just as you must study plant needs, if you are to succeed. Only by the use of intelligence can you expect to reap profits, and to natural intelligence must be added study. A man could not expect to be a successful teacher of mathematics unless he had studied all the authorities in his special line, and kept himself in touch with all the new theories as they were advanced. So it is with the farmer. If he does not read the papers that deal especially with his calling, he cannot keep in touch with the improvements and discoveries constantly made in his line. He should take in at least two standard agricultural papers. In a community where there is no public library, the farmers might agree among themselves to take one or more different papers each, and then exchange. In this way they could keep in touch with all, at the expense of only one or two.

It will not be worth while for anybody to take up this work with any hope of success, who expects to go at it with "a lick and a promise" idea. It is only by thorough, careful, intelligent and persistent effort that anything worth while can be accomplished. For the person who will undertake the task in that way, there is an opportunity; but he will need to have patience and some money while getting started and learning the business. By all means, start in a small way, and find out a lot of things which only experience can teach you; after that you can gradually increase your plant with comparative safety.

FOOTNOTES:

[11] NOTE.—This chapter has been specially revised by Milo M. Hastings, the author of a new and thorough work, "The Dollar Hen." Mr. Hastings was formerly the commercial poultry expert of U. S. Dept. of Agriculture.

It will be impossible in the brief space available to go into detail concerning all the up-to-date methods of poultry production. I can only call attention to the system by which the industry is being modernized and by which, also, it may be made to yield handsome profits to the intelligent and aggressive poultryman.

[12] NOTE.—These systems mean small numbers together. A few eggs in the incubator; a few chicks in a brooder; a few youngsters in a colony coop; a few layers in a small house. The Philo poultry plant covers 40 × 40 feet.

CHAPTER XXXII.

ORGANIZATION.

We hear a great deal about the farmer waking up to the fact that his calling is a business that must be conducted upon business principles, if it is to pay. Anybody who knows anything about the farming methods, or lack of methods, of the past, will recognize

that this awakening has not come a moment too soon. Neither is the farmer wide enough awake even yet. But the feeling is growing, and much of the credit is due to the farm papers, the agricultural colleges and the writers of books on farming and gardening on a small scale.

Somewhere, hidden in the heart of almost every man, is a longing to own a bit of land and grow vegetables or fruits; and it is to this man that the new order of things means most. He has had business experience, and will naturally apply business principles to anything he takes up.

It is not many years since agricultural colleges were looked upon with amusement, if not with scorn, by the very people whom they were intended to help. The "scientific" farmer was classed with that other hopeless being, the "book farmer." But the colleges and books kept on doing their work, and the college-bred and book-made farmer kept on doing wonderful things with soils and crops, and now there is scarcely a farming community that does not number among its leading members a farmer of one or both sorts. So does time work changes.

Boys who intend to be farmers are now sent to agricultural colleges, and the wise farmer takes in good agricultural papers and reads agricultural books. He has organized himself into granges and other associations and is fast learning the value of co-operation. All this tends to elevate his calling, a calling which is naturally more dignified than any other, and to make himself and his labor of more real value to himself and to his fellows.

But even yet there is too much haphazard arrangement of the farmer's work, and for this reason he is always struggling and finding little leisure. It is partly due to the lack of organization in his work. If he has not too much land, and if every month has its appointed tasks, the farmer will move along from task to task, with at least as much leisure as his city brother. So get your work mapped out, and attend to things as they need attention, instead of leaving a lot of small things to pile up and in the end cause hurry and confusion.

Plan your work and work your plan.

In the month of JANUARY prepare for spring work in your garden. Whether you devote your plot to vegetables or fruit, lay it out now in your own mind or, better still, on paper. Get catalogues from seedsmen who advertise. Most of them get their catalogues out in January. They are business men and know the value of an early start. Make up your mind what you want to grow, being sure to plan for plenty of the things you eat,—and then select the things you mean to experiment with during the coming year. Follow a well-arranged planting-table, such as was published in _Suburban Life_, of New York City, in March, 1908.

If you have fruit trees on your plot, this is a good time to begin to spray them. If you don't get ahead of insects and diseases, they will soon get ahead of you. If you intend to do any grafting, secure the scions now and keep them buried in sand in a cold cellar, or even out of doors, until the sap begins to rise in the trees. Then you are ready to work without loss of time. If there are holes in the trees, clean them out and fill with cement. You won't have time for this in the spring, and the gypsy-moth, or some relative of his, will select the hole as a ready-made breeding-place. Paint all wounds or breaks in the bark with good paint or tar. On warm days do the necessary pruning.

Look out for your live stock, even it if be only the family horse and cow. They will serve you better for careful attention. Warm the bit on cold mornings before putting it in the horse's mouth, and look out for signs of possible toothache. He suffers from that as well as you. Have him sharp-shod for slippery weather. If the barn is cold, blanket your cow as well as your horse, give her plenty of warm bedding and see that she and the horse have salt at hand at all times. Don't give either animal ice-cold water to drink. Take the chill off it. A hot mash will not do either of them any harm on a cold day. You like hot food in winter.

Look after the comfort of your poultry. Dust them well for insects. Give them fresh, slightly warmed water every few hours during the day. Vary their food somewhat and give some corn and meat-scraps. Be sure the meat is good, as spoiled scraps lead to disease. See that they have green food, and as much exercise as possible; keep their house clean and well ventilated, but free from draughts. If you are going to raise broilers, get your incubator busy, but it is too early for hatching chickens for layers. If you have no incubator, but mean to get one later, read up all about them now. Don't buy blindly.

Get out your fencing stuff, if you have fences to build; and read up all you need to know about your soils and the value of fertilizers, etc. Don't wait until spring to know what it is best to do with your plot. Learn that in advance, so that when spring comes you may put your knowledge into practice without delay.

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The same general instructions hold good for FEBRUARY. Give constant care to your stock whether many or few. See that your tools, planters, sprayers, plows, etc., are all in order. Many valuable hours are lost in gardening-time because of neglect of this precaution. Repair those that need it and are worth it, and consult catalogues for the new machinery you must buy, and buy only the best of its kind.

If you are using hot-beds or even cold-frames, you can prepare them and begin to plant some seed during February, such as radishes, lettuce and early cauliflower.

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MARCH is still too early for out-door planting in the North, because if the seeds get chilled, they will be slower in growth than those planted later; but well-made hot-beds are getting in their good work at this time. Eggplant, tomatoes, early cabbage, onions, parsley, peppers, etc., are all to be started before this month is out.

If the ground softens up so that you can go out on it at all for working, you may sow your grass seed and spring oats and barley that they may get the advantage of spring rains and be well grown before the dry, hot weather sets in. You find many farmers neglecting their stock at this time of year, but it is bad policy. Keep up their rations.

If the storms of winter have strewn your plot with branches of trees and other wreckage, clean it all up; the wisest plan is to burn it. Clean the out-buildings; sort over your seed, and see if any insects have got at them during winter; test them between moist papers or cloths as described, to see which are worth planting; clean out vegetable bins, burying all decayed vegetables. Be ready to take advantage of the very first of the out-door-planting weather. Every day of preparation now counts for three in results.

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APRIL is a busy month in farm and garden. Preparation-tillage is in order, if the ground is not too moist. Too much stress cannot be laid upon the importance of thorough preparation of the soil before the planting begins. What you neglect in this line cannot be made up later in the season, and you will suffer in field and pocket. Be sure that your soil is neither too wet nor too dry when you begin operations, and when you are through, be just as sure that it is thoroughly pulverized and fertilized, so that it can retain moisture and afford the right bed for the tender seeds. Then plant all the hardy crops as directed in the chapters on crop raising in this book.

Get your neighbors to co-operate with you in clearing out neglected roadside corners and in destroying weeds. It will pay. All the crops in the neighborhood will profit from this action. Don't turn the stock out to feed until the grass has made some growth. You don't want the roots gnawed out.

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Even in the northernmost parts of the New England States, much of the out-door planting is done in early MAY and the rest a little later in the month. Now is when you begin to realize the value of having done all your preparation work early. Planting potatoes, peas, beets, cabbages, turnips, to say nothing of beans, corn, pumpkins, squashes, cucumbers, etc., will take all your time every day that is not spent in cultivating and using the wheel-hoe. Besides, your strawberry beds will be needing a good deal of attention, and your chicken-run should have its location changed for awhile.

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There are no idle times for the intelligent farmer, but the beautiful month of JUNE is generally the busiest. Indeed, it is often so busy that the farmer does not have time to know how beautiful it is. But you can have time. Arrange your work; drive it instead of letting it drive you, and you will be surprised how much time you have to look up and to realize that it is a glorious thing just to be alive. But this cannot be if you have neglected your work from month to month. The smell of ripening strawberries, of new-mown hay fill the air before this month is gone; the sky is the bluest, the grass the greenest, the trees the freshest of any month in the year. Don't lose those delights without having known that they have come. Cultivate yourself as well as your soil, and life will be better worth the living.

* * * * *

JULY is the real haying month in the Northern States. There are scores of things to do. Many of the fall-crop vegetables are to be sown this month, and the ground must be put in good condition as soon as the early crop is off. But busy as you are, it is good to take a day off occasionally and see what your neighbor is doing. Perhaps he has some scheme by which he has forced his crop ahead of yours. If so, compare notes and learn what you can.

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In New England they sow the winter crop of turnips in the early days of AUGUST. Be careful that the root maggot has not got into the ground where you plant them, for, if he has, you would better save yourself the labor of planting in that spot. You want to starve the maggot, not to feed him. Cultivate all your crops carefully this month. Perhaps they didn't get all the attention they needed during haying, and as the weather is apt to be pretty hot and dry, you must do all in your power to keep the moisture. Therefore, good maintenance-tillage is in order. Cut down the weeds on the roadside that have escaped you before. It is a costly mistake to allow them to go to seed. You will have to work a good deal harder and get less for it next year if you let them go to seed this year. "One year's seeding is seven years' weeding."

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If you have fruit trees, SEPTEMBER is one of the finest months in the year, both for the looks of your place, if it has been properly kept, and also for your profits. The early fruit brings good prices, and if you have shown foresight in planning out your garden, you have planted some fruit trees that will pay you. Harvesting begins this month, and you want to be sure that everything is in readiness. Have your bins and cellars thoroughly cleaned and aired, so that there may be no delay when crops are ready to be stored.

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OCTOBER calls for extra care for your fruit trees, because frosts are to be expected. Winter apples should be picked before they are fully ripe and kept in a cool place, but where they cannot freeze. If you intend them to last all winter and into the spring, you should sort and pack them carefully, seeing that no bruised fruit gets into your barrel or box. One bruised apple in a barrel may cost you half a dozen or more of the finest.

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Although in some places it may be necessary to begin fall plowing earlier than NOVEMBER, yet, generally speaking, this is the month for that work, and unless frosts come early, you can plow about all through the month. It is the month for finishing up the fall work and getting ready for winter. There is no better time for gathering up whatever rubbish may have accumulated—all the vines and garden waste that you cannot use for plowing under—and making a bonfire of it. That is a work the boys will delight to help in, and if you will save the actual burning for evening, you will make them extra happy, and glad to do some more cleaning up. Work is best done in the way that brings the greatest amount of pleasure.

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DECEMBER has its joys and its work as well as June. The stock are almost always shut up now and get only what you give them, either to eat or drink. Be careful to keep their troughs scrupulously clean, and occasionally feed both horses and cows a little molasses. To keep the stable well ventilated, take out a window and fit in a frame covered with muslin or cotton sheeting. This will help out the ventilation and shut out the draughts. If it is hinged at the bottom, so that it can be opened on clear days, it will be all the better.

And now just a word for man's other faithful friend, and the children's guardian, the dog. He feels the change in the weather, too. If he should begin to scratch his ears or rub them on the ground, clean them carefully with lukewarm water in which bran has been boiled, and add a little white castile soap. When you have rinsed and dried them dust a little dry boric acid into them. He'll be more comfortable and so will you. Stonehenge or Youatt "On the Dog" will tell you all about him.

See that your farming tools are all well housed where neither rain nor snow can get at them. If you were too busy to thoroughly clean and oil them before putting them away, do it now. The long winter evenings will afford you plenty of time to read up on any matter in which you are interested. At the end of the year you will be astonished to find how much you have accomplished without being rushed or overworked, just because you organized your work and followed a definite plan. Like all other good things, it pays.

When we are exhausted or rushed, it shows that either we have been doing the wrong thing, or doing the thing wrong.

CHAPTER XXXIII.

A FEW PRACTICAL "DON'TS."

Don't imagine that you cannot do anything with a bit of ground. You can.

Don't run away with the idea that the farmer's life is all fun or all labor. It isn't. It is a mixture of both, and fun and labor are equally healthful and profitable.

Don't think that breaking up the surface soil for an inch or two is the same as plowing. It is not. The old proverb is good advice for the farmer—"Plow deep while sluggards sleep." To plow in the fall is to lessen your spring work by at least a third. Spring plowing is easier because of it, and the work of the harrow is lighter.

Don't begrudge manure. All forms of life require food. If you want your plants to grow, feed them.

Don't plant tiny, tender seeds in hard, cold, lumpy soil and expect them to grow. They won't. Pulverize your soil, warm it with sun, air and manure; make a cosy little bed for your seeds, and while they snuggle into it, they will be sending out little sprouts all the time to see what the rest of the world is like. Just as it is good business policy to treat your hired help as if they were human beings with feelings, instead of mere tireless machines, so it pays to make your seeds comfortable.

Don't forget that your plants like air, and that what they get by their stems and branches is not enough. The roots have to breathe. So keep the earth about them stirred somewhat, that the air may get to them.

Don't skimp the supply of moisture. Although you don't want to drown out the seeds by soaking the ground, yet you must so till it that it holds all the moisture the plant needs. You find your craving for water greater in summer than in winter, especially if you are working hard. Well, the plant is working hard, if it is growing. See that it has its drink of water always at hand.

Don't decide to let the weeds on the roadside grow, just because they seem "nearer the other fellow's plot" than yours. There are no "other fellows" in a matter of this kind. It does not take long for the weeds he has to get to you. If he doesn't know the importance of cleaning even the road, and you do, just set him the example. He'll soon ask you why you did it. After that, he'll probably do his share. At any rate you will have done yours.

Don't try to grow more and better crops than your neighbor, just for the "fun of getting ahead of him." Grow them to prove how much can be done with your facilities, and to show him, as well as yourself, how much more pleasure and profit he can find in gardening than he has known before. Next year he'll probably show you a thing or two.

Don't think you have to emigrate to some far-away spot to make a living from the earth. All soil can be made to produce if you use brains as well as labor. Begin where you are, no matter how small the plot. Learn to do it in little before you try it in large. If you have no plot where you live, try to get the use of a vacant lot in your town or city. Put up a tent and live in it. You and your family will be the better for roughing it a bit. There's lots of fun in camping if you go about it in the right spirit.

Don't be afraid to ask advice from the Department of Agriculture. They are conducting their experiments for your sake, if that's the sort of knowledge you want. If it were not for you and thousands like you, they would not need to discover so many of Nature's secrets. Get the benefit of their discoveries.

Don't think you can farm without proper tools, any more than a man could print a paper without a printing press. The old-fashioned, small hand-press, would stand a poor show beside the new power presses. So with old-fashioned, hand-gardening tools. You can do more work with a wheel-hoe than with ten hand-hoes, and it isn't so painful either. Get only the tools you need, but be sure to get them, and get the best of their kind.

Don't let your tools stand out in all weathers, and don't forget to clean them and see that they are oiled. A dirty farm implement may mean the spread of disease; unoiled bearings may mean injury from rust or breakage. Save time and expense by a little care.

Don't expect eggs from dirty or ill-fed fowls. The natural returns from such conditions are vermin and sickness; and you'll get them.

Don't expect to take everything out of the soil and put nothing back. The soil is like a bank account, so long as you keep adding to it, you may draw from it. But if it is all "draw" and no "add," then you will soon come to the end of your resources. Feed your soil and it will feed you.

Don't plant poor seed. You can't afford it. The best is cheapest. If you have poor seed on hand, throw it away—or perhaps it might do for the chickens. No loss can be so great as the loss of planting it.

Don't forget that women are apt to make good gardeners, because they are willing to "fuss over" necessary small matters. If you do not like to attend constantly to "little things," if you "hate details," you will be unlikely to make a big success of intensive culture. The man who does best is the one who loves to compare soils and fertilizers and seeds, and to try how many seeds sprout and how long they take; who is interested in the temperature of every hot-bed; who watches for just the day to use the wheel-hoe on this row and the hand-plow on that; who finds the time only too short while he sets out onion seedlings; who enjoys putting up nice bunches of vegetables or packages of fruit. In short, the man or woman whose interest is in watching the crops instead of the clock, is the one who succeeds in garden work.

Don't delude yourself into thinking that you must have a fine house before you can take up gardening. A shack is as good as a palace, and better, if you can afford the one and not the other. Anything that can be ventilated and made weather-proof will be enough. After you have made your fortune, if you have not in the meantime learned the value of simple living, build your fine house, and be as splendidly uncomfortable as even the worst Philistine could desire. But while you are earning your fortune, be comfortable. It pays.

Don't think you must throw up your job and rush into farming for a living, unless you have had some experience, or have a snug little bank account to depend upon while you are learning. Get your experience on a small piece of land first, while still holding down your present job. Be sure you like the work and that you are willing to give all necessary time and attention to it.

Don't think that this list exhausts all the "don'ts," practical or otherwise. There are dozens of others. But it is well to leave something to the imagination and to experience. You'll learn them for yourself and remember them better for it. Nevertheless, it will do no harm to attach the rules for farm buying submitted to the American Jewish Association. They run as follows:

Don't think about buying a farm if your wife won't live in the country.

Don't believe in agents when they tell you gold-brick stories.

Don't chase after big farms.

Don't buy a farm unless you have money enough left to buy a cow.

Don't run too much in debt when you buy your farm.

Don't pay a deposit on your farm until you have consulted a lawyer.

Don't forget to insure your farm buildings in a reliable company.

Don't buy a farm unless you are able to meet the mortgages.

Don't buy a farm unless you have consulted those who know.

Appendix I.

The island of Guernsey in the English Channel, only from four to seven miles long, and three to four miles wide, supports a permanent population of 41,000 and an additional visiting population each year of about 30,000 persons. Only 11,623 acres are under cultivation, but if the glass houses and frames were placed in line they would extend for twenty-eight miles, or all around the island, and up the centre for almost its entire length, and would average about 10 feet in width. The farming lands are valued at twelve hundred dollars ($1200) an acre, and are rented at 10 per cent. of their value. The exports of this land in fruits, vegetables, flowers and cattle, amount to more than two and three-quarters millions ($2,752,000) annually. In addition to this, the farmers produce all that the 71,000 persons consume, as well as hay, oats and forage for horses and cattle; and about $500,000 worth of butter, poultry, eggs, pork and beef. At a conservative estimate, the island produces about four and a half millions' ($4,500,000) worth of farm and garden stuff each year, or a little less than four hundred dollars' ($400) worth to the acre.

Don't you think we Americans, with our improved machinery and intelligence, can get much more out of our land—when we try?

If the State of New York were all cultivated and populated at that rate it would produce nearly $15,000,000,000 worth annually and sustain 233,641,473 people, or about three times the population of the entire United States. So we are not going to suffer from "over-population" or "pauper labor" just yet.

Appendix II.

French Gardening, and Other Gardening Under Glass.

Intensive cultivation reaches its climax for the present in what is called the French System, in vogue in and about Paris, and in some parts of England, where rents are so enormously high that even an inch of space counts, and must be made to produce its utmost. It has not been in favor in this country, because, so far, the pressure of rent has not compelled people to look so much after the inches. But, if the present land-tenure system continues, there is no telling when the French system of cultivation will become a necessity. In its simplest terms, the French system is hot-bed cultivation with perfect fertilization and irrigation, usually without artificial heat. The secret of it is—manure, unlimited quantities of it, of the finest quality and rotted to about the condition of leaf-mould. The beds are made on the top of the earth, the foundation being fresh stable manure that has been turned several times and thoroughly sweetened. Cover an area sufficient to accommodate the number of frames you intend to use, with great quantities of manure, so that after it has been tramped, pressed and rolled flat, it will be from 6 to 8 inches deep at least. Sometimes it is made two feet deep. The frames are then placed on this bed, the manure extending well beyond them on every side, and a distance of 18 inches is left between the rows of frames. A layer of fine, rich, dark soil, mixed with manure that has been rotted during the previous season, is then spread on, to the depth of six inches, pressed down and raked. The bed is then ready for planting. Generally four crops are grown in each frame, radish, lettuce, carrots and cauliflower being the usual combination.

The radishes are sown first, quite thinly, then a thin layer of carrot seed. These are covered with about half an inch of fine soil well pressed down. Cabbage-lettuce is next set out, the plants being placed nine inches apart, and, so far, three crops are growing at the same time. The fourth, cauliflower, is not planted until the radishes are off,—in about three or four weeks,—the lettuce has been cut and the carrots are showing well above the ground. Then three or four cauliflower plants are set in each frame between the carrots.

But one of the most interesting parts of this work is the growing of the lettuce and cauliflower plants for transplanting to the hot-bed frame. These are grown under "cloches" or bell-shaped glasses 17 inches across the bottom and 15 inches high, on a seed-bed prepared just as the hot-bed was prepared, except that the manure foundation is anywhere from 12 to 15 inches deep after being pressed down. These beds are not covered with frames, but the cloches are placed on them in two rows, and within the circles made by them the seed is sown.

As soon as they come up, they may be transplanted from the cloches to the hot-bed direct, or they may be pricked out under other cloches, four plants to a glass, usually one Cos lettuce and three cabbage-lettuce. These are again transplanted to the hot-bed where the radish and carrot seed were sown, and follow the radish in being picked. Lettuce seed is also sown in cold-frames about the first of October and successive sowings are made until the end of that month.

Immediately after the lettuces are picked the bed is watered and weeded, and among the growing carrots the cauliflower is set out. Cauliflower is grown under cloches, the seed being sown as lettuce seed is, under the glass or in the open seed-bed, from October to November, and pricked out under the cloches as soon as the plants are well up. They can be planted out in the hot-beds in February, and are ready for market between the middle of May and the first of June. About April the process of hardening begins, and by the end of that month the frames and sashes are removed and the beds stand in the open. During the time the crops are growing under glass, they need a great deal of attention, that neither the sun nor the frost may injure them. For this reason they are covered, uncovered and recovered several times during each day with mats or frames.

When the cauliflower is off, the bed is forked over and planted with endive, spinach, celery or other garden crop. When the season's crop has been harvested in October, the soil is gathered up in a great heap, and the beds are topped with decayed manure in the leaf-mould state. This is the best thing to plant in, and if one had enough of it, the crops could be grown on a concrete floor; because in such soil plants find all that they need.

To bring it down to the fine point, the French system consists of manure, more manure, irrigation, availing of every ray of sunlight, and unremitting care. It requires three years to get the system in good working order, and here such intensive cultivation seems unnecessary. It shows what man will do in the way of developing the possibilities of nature, when by law or custom he is debarred from free access to the land, and must needs make a very small portion yield a great return.

We are not in much danger of Malthus's over-population, and the much-talked-of "pressure of population." Where so tiny a piece of soil can be made to support so many and give them a good living, too, it is foolish to argue that the cause of poverty is found in the increase of population. This country alone could support many times the population of the whole world today if natural opportunities were free. It has been said that 80,000,000,000 could then be more comfortably supported here than 80,000,000 now are. To find the cause of most of the poverty, and even crime, in the world, we must look beyond the population statistics to the restrictions and monopolies that prevent population from providing for its own needs from natural sources. And when once you begin to investigate monopolies, you will find the mother of them all—Land Monopoly.

* * * * *

A new sash for use in hot-beds and cold-frames has been placed on our market within a year or two, for which its makers claim many desirable things. It seems as if their claims were being well sustained by the experience of those using the Sunlight Double Glass Sash, as it is called. The frames are made of red cypress and are fitted with rustless springs and stops to hold the glass in the grooves and thus do away with the expense and bother of glazing. There is a space of dead air between the two layers of glass, which resists the cold from without, and prevents the escape of heat from within. The sash are sufficiently air-tight for ordinary weather, and when the thermometer falls, the moisture which has gathered between the two layers of glass, freezes and seals the sash practically air-tight.

The makers claim that Sunlight Double Glass Sash save more than half the labor, worry and expense of growing plants in cold-frames and hot-beds, and insure better plants, and, therefore, better crops, than can be secured under the same conditions from single-layer sash. They do away with the necessity of covering the frames with mats or boards, being warmer than the single-layer sash even though covered with mats or boards. Frames or beds filled with half-hardy plants, such as lettuce, cabbage or cauliflower, need no extra covering even in zero weather; and as far north as northeastern Ohio, with the thermometer nearly down to zero, even tomatoes, peppers and eggplants have been raised without additional covering, although this may not always be done. Light is never excluded from the growing plants by night or day, and in the short winter days of this climate, there is some advantage to that. Even when snow and ice lie on the sash, there is some light getting to the plants, and in clear weather the heat from the sun's rays during the day is stored up in the bed and held by the double glass with the air-space between. That is why even in zero weather the half-hardy plants need no extra covering.

It is quite possible that the gardeners of this country may make a system of their own for intensive cultivation, to equal and perhaps excel the French system with its repeated covering and uncovering of the frames. The sash are made in Louisville, Ky.

Appendix III.

At Maylands, Mr. Joseph Fels' "colony" in England, all the land is under intensive cultivation, and the rules for getting the best results from hot-beds are simple enough for anybody to follow. They emphasize the advice given in this book and are, therefore, printed as an appendix, so they may be easily consulted. They are furnished by the superintending gardener of Maylands, Mr. Thomas F. Smith, Maylands, Essex, England, for this book, and are as follows:—

GENERAL INSTRUCTIONS TO MAYLANDS SMALLHOLDERS.

"It is possible to put the frames to a variety of profitable uses during the winter and spring, but under the special circumstances of our community, and the arrangement for co-operation, it will be best for all to follow one plan, and the produce can then be handled in bulk. To this end, I suggest that the frames be used for radishes and cabbage-lettuce, then cleared for pricking out tomato plants; afterwards, during the summer, used for cucumber or melons.

"During the last week of September, prepare a bed of about a square yard by digging. Break it up fine; cover it with two inches of prepared, sifted, well-rotted manure and soil in equal proportions. Sow broadcast, thinly, a few inches of cabbage-lettuce seed—Watkin & Simpson's Early French Gold Frame will be very suitable. Cover with ¼ inch prepared soil and press evenly all over. Place a wooden framework round the bed and cover with a sash. Do not water. If the sun shines brightly in the middle of the

day, cover the sash, and uncover as soon as the sun's power is gone. In 4 or 5 days the plants will be up, and as soon as they can be handled they must be pricked off in frames standing on beds prepared in a similar way to the seed-bed, except that the soil inside must come half way up the board. Prick them out 2 inches apart, and do not water. They will stand here during the winter and the work now is to watch them carefully, remove any decayed ones or any showing mildew. If any mildew shows, dust over lightly once or twice with flowers of sulphur. Keep as dry as possible. In hard, frosty weather cover the frames with mats, but remove these whenever possible, and give air on very mild days.

"Towards the latter end of January prepare the hot-beds, by mixing well together equal quantities of old, dry manure and fresh manure. In both cases this must be 'long.'[13] Shake out the lumps and lay the manure down to the depth of 18 inches. Keep level and beat down gently with the back of the fork. Make the beds wide enough to extend at least 9 inches beyond the frames. Tread the manure down and level up any hollows. Lay the frames on straight and level. Fill up inside one-third the depth with similar manure to that used for the bed, then add 2 inches or so of the prepared soil. Rake the soil well, to leave it level and remove lumps. Put on the sashes and cover with mats. Any of this work must be finished the same day it is begun and covered up. This is of importance, as frost, snow, or rain might set in, and spoil the bed. The remaining beds must be made in the same way, all joining up so as to form one entire bed without any spaces between. The frames are butted together at the ends, and are set 1 foot apart between rows.

"Two or three days after finishing the first bed, it will begin to get warm, which may be seen by the damp inside the glass. Now sow radishes (French Breakfast Radishes—white-tipped) thinly broadcast. Cover them up lightly with dry prepared soil, well sifted; press down evenly. Set out the whole bed with lettuces at 9 in. apart. Before planting, the lettuces must be carefully examined, all decayed leaves removed, and doubtful plants rejected. Use only the strongest plants. Handle very tenderly, so as not to bruise them. Cover the bed every night with mats. When the radishes are up, give a little air on the opposite side to the wind, but be careful not to overdo this, as the lettuces thrive better with very little air. If any decayed leaves are seen on the lettuces, remove them. If the heat in the frames slacks, as may be seen by the radishes not moving quickly enough, place littery manure all round and between the frames up to the lights. The radishes will be ready for gathering the fourth week from sowing, and should be cleared off a bed within 10 or 12 days. When they are all gone, water the bed well between the lettuces with a fine 'rose'-nozzle hose. Choose a dull, mild day for this, between 11 and 12 o'clock. The lettuces will be ready for marketing five or six weeks after planting, which will be about the middle of March.

"About the beginning of March, make up a hot-bed for one frame of three lights or sashes. Make it two feet thick, and at least a foot beyond the frame all round. Fill up the inside as before, and pack round outside. When the heat is steady, sow the tomato seed, thinly, in rows about 1½ inches apart, keeping at least ½ inch between the seeds. Cover and press down, then scatter lightly all over, a sifting of fine rotted manure. Water well, cover up, putting mats on. In seven or eight days the seed should be germinated. Keep a watch on it and remove the mats the moment it is seen to be breaking through. Water gently with a fine rose, using chilled water. Give all the light possible now, and water as required, keeping the soil just nicely moist. As soon as the first pair of rough leaves show, begin to prick off; if the pricking off is not commenced early the plants will be getting 'drawn' before it is finished.

"After cleaning the beds from which the lettuces were taken, fork over lightly and add 3 inches more soil; press all down very firmly and prick out tomato plants 3 inches apart. Do not water. Keep close for a few days until the plants begin to move, and cover at nights. As the plants show growth, water gently and give air on mild days, gradually giving more water and air until the first week in May, when the lights may be taken off on all mild, genial days. By the middle of the month leave air on at night, and the last week the lights may be removed altogether. The weather must be carefully watched, as May is a very changeable and treacherous month; it is very usual for frosts and cold weather to return about the middle of the month, and protection must be given if necessary.

"The ground where the tomatoes are to be set out, should have been prepared during the winter by digging or deep ploughing; a moderate dressing of natural manure should have been added if the ground is poor, but the ground which has previously been heavily manured and cropped with vegetables will be preferable, no manure being added for the tomatoes. After digging, give a dressing of basic slag 10 cwt. to the acre. Have all finished not later than end of February.

"About the middle of May, if the ground is dry, dress with sulphate of potash 1 hundredweight and sulphate of iron, ground fine, ¼ hundredweight to the acre, then go over all with a hoe and chop down all weeds and level all hollows; do not rake. At each end of each row, where it is intended to plant the tomatoes, drive in a pointed stake of 2 by 4 in. broadway to the row, at a slight angle away. The stake should enter the ground 2 ft. and stand out 1 ft. 9 in. Then in direct line with the stakes, at intervals of 10 ft. drive in

studding boards ¾ inch × 2 in. × 2 ft. 6 in. long, to stand out of ground 1 ft. 9 in. The narrow way of the board should be in the line of the row. Now fix 16s gauge galvanized wire to the stake at one end, and draw tight and fix to stake at the other end. Fix wire to top of stakes by small wire staple. This should all be done before the plants are set out.

"During the last week in May and first week in June, the plants should be set out. Water well in the frame, then gently pull the plants and place as many upright in a basket as it will hold. Drop about twenty at 18 in. apart; then one person with a small, thin graft, or a garden trowel, should insert it about 4 in. into the ground at an angle, and press upwards, slightly raising the soil without disturbing it. A second person should insert the damp roots of the plant in the nick and tuck them carefully to the bottom, into the damp soil; remove the tool gently and press the soil firmly on to the plant with the heel. Do not water. I have tried many ways of planting tomatoes in the fields, and this I found to be the best method where large numbers have to be planted. Where only a small quantity are being handled it is best to grow them in strawberry baskets or pots, and put the plants out with the roots undisturbed.

"In a week or two, if the weather is genial, growth will be observed, and then a dressing of nitrate of soda may be given, about 2 hundredweight to the acre. It should be crushed fine and mixed with three times its bulk of dry earth or ashes. At the end of June the plants should be thoroughly sprayed with strawsonite. After spraying, it will be time to go over the plants, and remove all the side shoots, keeping the plants to one stem only. When the plants have grown long enough to reach 6 in. above the wire, they should be again trimmed of shoots and tied to the wire, resting the stem of the leaf on the wire before tying. Leave the tie rather slack for expansion of stem. After trimming and tying, spray again with strawsonite. This work should all be completed by the beginning of August, if the season is suitable to growth. If rain falls immediately after spraying, repeat it.

"The fruit should begin to show color by the middle of August, but this varies considerably with the season and the age of the plants when set out.

"As soon as the fruit shows pink, it should be gathered and taken to the packing shed. Do not gather the fruit green if it can be helped, but wait for a change of color. These gatherings should be continued at least twice a week so long as the fine weather continues. If the weather changes to wet after a long dry spell, it is very probable that many of the fruit will crack, and then it is advisable to gather the fruit green, if quite fully matured; this will save them from cracking. If the weather is cold and dull, the plants should be sprayed with Evans' Aseptic Spray. This will not leave a stain on the fruit. After the second week in August, the plants may be topped, as this will help the fruits to swell, and fruit setting after this date will probably be useless. Keep the side shoots removed, and remove and shorten bottom leaves to let the sunlight into the plants. Remember this: plants allowed to grow close and crowded are much more liable to disease, and spraying does not thoroughly cover them; also plants with many shoots make less fruit, of a smaller size, and take longer to ripen; therefore anyone taking the trouble to raise plants and set them out, and neglecting them afterwards, is acting very foolishly.

"Continue to gather the fruits as ready, keeping a sharp look-out after the end of September for signs of frost. When this is feared, gather all the full-grown fruit on the plants whether green or not—they will ripen in-doors; but exercise some judgment, and do not gather fruit which is not full grown. This may color, but even if it does, it will be shrivelled and a bad color, and will spoil the market for better fruit. It is better to leave the immature fruit on the plants, as the frost may pass without doing any material damage, and there may be several weeks more of mild weather, which will give several more pickings of full-grown green fruit. I have picked in this way until the first week in November, some years.

"The fruit must be graded into 'best smoothing,' 'small smooths,'—which description does not include very small fruits, but only those just too small for an even sample,—'seconds,' and 'thirds.' Seconds are good sound fruit, but include all the misshapen ones. Thirds are sound odds and ends—it is better to avoid the grade if possible. The fruit is sent to markets in baskets.

"Tomatoes may be obtained from the open in July by sowing the seed a month earlier, and growing on with more room in pots. If each plant has 9 in. square of space, and is properly attended to, it will have small fruits set when planted out, and ripe fruit can be gathered in July.

"_Ridge Cucumbers._ Prepare a good hot-bed as for tomato seed, and on the last day of April, sow the cucumber seed, two together, at 1½ in. apart all over the bed; cover with soil, press down, do not water, close up and cover with mats. The seed will be up in 2 or 3 days. Give water, plenty of light, but no air; cover at night. Have ready a mild hot-bed—the bed the lettuces were removed from, if forked over, will probably do. As soon as the rough leaves are showing, lift each pair of plants gently with a little soil and pot into large 60s, burying up to seed leaves. Water as required. Harden gradually by end of May, and plant out first week in June at 2 ft. apart in rows, and 4 ft. between the rows. A bed into which a heavy dressing of manure has been dug during the

winter will do very well. As soon as set out, the plants must be protected by some means, such as placing a flower-pot at night over each plant, or with paper cones pegged down. It is also advisable that hurdles covered with straw be run down every 3 or 4 rows to break the wind. If the plants are helped in this way for a week or two, they will repay it later on. After planting they should be watered, and this should be repeated if the weather continues dry. Before they begin to run, mulch all down each side of the rows with long straw stable manure. Fruit should be ready middle of July.

"For using the frames after the above plants have been removed, I recommend Frame Cucumbers. Melons would do equally well, but are rather more difficult to grow, and I advise cucumbers for a year or two until experienced. Make up a hot-bed precisely the same as for Ridge Cucumbers. Fill as many 60s pots as are needed half-full of prepared soil after covering the drainage hole with broken china. Put one seed of Telegraph Cucumber on the soil in each pot, fill half the remaining space with soil and press down with the bottom of a pot. The soil should be of a nice dampness when used, as the seeds are better unwatered; the pots, if new, should be soaked in water before use. Cover up close and keep mats on until seed is up, then only mat at night. Give no air, water with tepid water as required, shade from strong midday sun and keep interior of frame moist by dewing over early each morning. Give the plants room for the leaves to spread. As frames are emptied of the tomatoes and ridge cucumbers, without waiting for all of them, fork them over lightly and raise slightly in centre; on this mound put half a bushel of prepared soil, which should consist mainly of chopped sod with the grass removed, a little decayed manure, and a little finely sifted burnt earth or old mortar rubbish. Cover up close for a day or two for the sun to warm the soil, and then put two plants in the middle of the light, about 6 in. apart. Pinch out the centres, allowing only one shoot to grow from each plant. These should be taken from one plant upwards and the other downwards in the frame. Keep the growth thin; remove old leaves, one now and then; avoid overcrowding; if this seems likely, cut some of the shoots right out. Keep the frame moist, give plenty of tepid water, whiten about half the glass in the centre and splash the remainder. If these instructions are carried out, there will be an abundance of cucumbers to cut for market.

"The frame cucumbers are packed in flats, numbered according to size, but usually 3 to 4 doz. Put a little hay at the bottom, then cover with paper, put one layer of fruit very carefully on this and a sheet of paper over, a little more hay, another sheet of paper, then a layer of fruit and so on. Three layers generally fill the flat.

"Ridge cucumbers are generally sold by count or in bushels, but when grown especially fine may be sent in flats as above."

FOOTNOTES:

[13] NOTE.—"Long" manure contains a good deal of litter that has not decayed, so that the manure does not break up into fine particles as "well-rotted" manure does.

Appendix IV.

The _Farm Journal_ for November, 1908, gives the following condensed list of the short courses offered by the various State Agricultural Colleges:

Specialized knowledge is the keynote of modern farming success. Why not give your boy or girl a chance to acquire some of this knowledge? In winter there will be a let-down of farm activity, and many of Our Folks could, if they tried, attend one of the short agricultural courses provided free by nearly every State. In many cases the only expenses are for board, books, etc., and the total cost of a few weeks' course is thus very small. Many grown farmers attend these courses; there is no age or citizenship limit in most States.

For catalogues and full information write to any of the addresses given, mentioning this book. For instance, if you live in Alabama, direct your letter as follows: "J. F. Duggar, Alabama State Agricultural College, Auburn, Ala."

Alabama. J. F. Duggar, Auburn: Offers a nine-month course in agriculture, and a two-year course.

Arizona. R. W. Clothier, Tucson: Offers a two-year course in irrigation, engineering, farm management, dairying and vegetable gardening, designed especially to equip students for farming under Arizona conditions.

Arkansas. John N. Tillman, Fayetteville: Short winter course in agriculture begins first Monday in January, lasting two weeks.

California. E. J. Wickson, Berkeley: Five different short courses covering special branches of farming. Write for particulars.

Colorado. B. O. Aylesworth, Fort Collins: A short practical course in agriculture and domestic science is offered by this institution.

Connecticut. C. L. Beach, Storrs: Dairy and creamery short course of twelve weeks. Pomology course of twelve weeks. Poultry course of six weeks. All courses open Tuesday, January 5th. A six-week forestry course begins November 2d.

Delaware. H. Hayward, Newark: Offers a six-week special course, from January 4th to February 15th; and a special "Farmers' Week" from January 4th to 8th, inclusive.

Florida. Andrew Sledd, Gainesville: A two-year course specially adapted to the farmer's boy. The instruction is of an applied nature with sufficient technical research to lead the student to question well the reasons for the various farm operations. College moved from Lake City to Gainesville.

Idaho. H. T. French, Moscow: Short courses are offered in dairying, extending one year; and farmers' short courses in dairying and horticulture, extending six weeks, beginning about middle of January.

Illinois. Eugene Davenport, Urbana: Offers a two-week course in agriculture, and also in household science, beginning January 13th.

Indiana. J. N. Skinner, Lafayette: Four courses of eight weeks each, beginning January 18th, as follows: Agriculture and horticulture; animal husbandry; dairying; household economics.

Kansas. E. R. Nichols, Manhattan: Offers a ten-week farmers' short course, beginning January 5th; a ten-week short course in dairying, beginning January 5th.

Kentucky. Clarence W. Mathews, Lexington: The college is now occupying its new building; offers a ten-week business course in agriculture, beginning January 4th. Tuition free to residents of the State.

Maine. W. D. Hurd, Orono: Offers an eight-week course in dairying, farm crops and horticulture; a special poultry course; and a "Farmers' Week."

Maryland. R. W. Silvester, College Park: Ten-week course in agriculture begins Tuesday, January 5th. Terms: Board, $40 for whole course; tuition free.

Massachusetts. J. A. Foord, Amherst: 1, dairy farming; 2, horticulture; 3, general agriculture; tuition free; begin first Wednesday in January and continue ten weeks. Bee culture; begins fourth Wednesday in May and continues two weeks.

Michigan. R. S. Shaw, East Lansing: Eight-week courses in general agriculture, horticulture, creamery and cheese making, beginning January 5th. No charge for tuition; board and lodging cheap.

Minnesota. E. W. Randall, University Farm, St. Paul: Farmers' short course opens January 15th and continues four weeks. Dairy school opens November 16th and continues four weeks.

Nebraska. A. E. Davisson, Lincoln: The winter course opens January 4th and closes February 20th.

New Hampshire. Fred Rasmussen, Durham: A ten-week course in dairying begins January 5th.

New Jersey. E. B. Voorhees, New Brunswick: Offers three short courses, beginning December 1st and closing March 5th, as follows: General agriculture, dairy farming, market gardening and fruit growing.

North Carolina. C. L. Newman, West Raleigh: The seven-week course in agriculture begins January 11th; the one-week course in agriculture, January 4th.

North Dakota. J. H. Worst, Agricultural College P. O.: Winter short courses in cooking and sewing are offered for the young ladies. Also winter lecture courses for the men about farming, stock raising, etc.

New York. L. H. Bailey, Ithaca: Five winter courses, in general agriculture, in dairying, in poultry husbandry, in horticulture and in home economics. These courses begin December 8th, close February 24th. (See also New Jersey.)

Ohio. H. C. Price, Columbus: Offers a ten-week course in agriculture, and a similar course in dairying; both begin January 11th. Also a four-week course in domestic science, beginning February 1st.

Oklahoma. J. H. Connell, Stillwater: Several instructive short courses are offered. Write for particulars. Five hundred students attended these courses last year.

Pennsylvania. Alva Agee, State College P. O.: Five winter courses in agriculture, beginning December 1st and continuing for twelve weeks. Write for particulars.

Tennessee. H. A. Morgan, Knoxville: An excellent series of short courses are planned for the new year. Write for particulars.

Texas. S. E. Andrews, College Station P. O.: A two-year course in practical farm work. Send for details.

Utah. Registrar, Agricultural College, Logan: Offers winter courses in agriculture or forestry, domestic arts or mechanic arts, beginning January 5th.

Washington. E. E. Elliott, Pullman: Offers an eight-week course in dairying and a twenty-week course in agriculture.

Wisconsin. H. L. Russell, Madison: Offers a twelve-week dairy course, beginning November 4th; a general course (fourteen weeks), beginning December 5th, and a ten-day farmers' course, commencing February 2nd.

Wyoming. J. D. Towar, Laramie: The winter course of eight weeks begins January 4th.

Information regarding the short courses of several State colleges was not received in time for insertion here, and so such States are necessarily omitted from the foregoing list.

TRANSCRIBER'S NOTE

Illustrations in this eBook have been positioned between paragraphs.

Obvious typographical errors and punctuation errors have been corrected after careful comparison with other occurrences within the text and consultation of external sources.

Some hyphens in words have been silently removed, some added, when a predominant preference was found in the original book.

Except for those changes noted below, all misspellings in the text, and inconsistent or archaic usage, have been retained.

Pg 111: 'LEEK' replaced by 'LEEKS'. Pg 112: 'cultivaiton' replaced by 'cultivation'. Pg 272: 'profitble' replaced by 'profitable'. Pg 282: 'cions' replaced by 'scions'.

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An idea that saved a business

Leonard Dreyfuss

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An Idea That Saved a Business

An Idea That Saved a Business

_By_ Leonard Dreyfuss

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The Idea

The General Manager of a large Department Store sat in his study one night, puffing away at a big black cigar, with a real worried expression upon his face. Things were not right down at the Store.

Two months previous he had accepted the position as General Manager, and it had been gradually dawning upon him that he was waging a losing fight. The Store had an equipment and over-head based upon a total annual business of seven million dollars and was barely doing four.

For days he had been reviewing his Organization; the activities of his competitors, the possibilities of the City itself, the opportunities for the elimination of expense that might serve to reduce the over-head. It was a brain racking circle of thoughts and figures that seemed to lead nowhere but back to the starting point.

Sitting in his Study he tried his best to find a solution of the ever-increasing problem. Musing upon the situation aloud he said, "boiled down to a single sentence the problem seems to be this--how am I going to get the greatest amount of money in the shortest possible time?" The next thought was "to whom shall I look as an example of how that can be accomplished--who gets the greatest amount of money in the shortest possible time?" Suddenly he sat up as the thought struck him forcibly--"why, it's the Circus that in the shortest space of time produces the greatest result."

He couldn't shake the idea and the next morning he had determined that he would seek out the General Manager of the largest Circus Company traveling the Country and ask him to what it was they attributed their success.

The General Manager was a man who, like most true Executives, acts on impulse, and he made up his mind that he would take the first train to where the Circus was showing and talk with its General Manager.

Fortunately the Circus was then located in a City about one hundred miles distant, and the General Manager made the trip.

In conference with the Circus man the next day he told him what he had in mind. "You folks," he said, "it seems to me, more than any other business, get the greatest amount of money in the shortest possible time--how do you do it?"

The Circus man laughed. "It is more simple than you think," he said. "We simply are most careful students of advertising; we plan and place our advertising so that ALL THE PEOPLE know when we shall arrive and how long we shall stay. We have found that some people read the newspapers, a great number; and some ride in Street Cars, quite a few; but that ALL PEOPLE who can come to our Circus use the great outdoors. Therefore, we spend eighty per cent. of the money we have for advertising, outdoors. By the use of outdoor publicity we get our greatest 'punch.' The Poster offers a use of color and size that dominates, and the eye cannot escape it. Then we so build our copy that 'he who runs is compelled to read.' We are specialists in evolving compelling copy--we are psychologists who have accurately gauged the public's mind. We cater to the great masses, rich and poor alike. We must understand humanity in its entirety. So we use the Poster and painted signs--we tell our message in color and size and we reiterate it on every Highway and Byway until you cannot escape the message of the Circus and its appeal."

The two men talked for a number of hours, and finally the General Manager said, "if your plan is a success for the Circus, why not for some other business? Is there any particular reason why your method can only be successful for a Circus Company?"

"No," said the Circus man, "I think the method itself is sound and would, to a large degree, prove efficient for mostly any business, if as carefully planned as ours."

The General Manager of the large Department Store, riding back to his City, thought over all that the Circus man had told him, and this one thought persisted in his mind--"Why not for the Department Store?"

Next day he laid plans for an Outdoor Advertising Campaign. He called in his Advertising Manager and a Representative of the Outdoor Advertising Company of his City, and said to them, "I want to place outdoor advertisements so that, no matter where you stand on any widely traveled avenue in this City at any point of circulation, you will be greeted by a dominant reminder of our Store. I am going to make this Institution _synonymous_ with _shopping_. I am going to so constantly reiterate that message, and I intend to do it in so attractive a way and with such compelling copy that the public will be unconsciously attracted to us in larger numbers than ever before. I am going to inaugurate within such changes as will make OURS the finest place to shop, rendering unquestionable service and having a 'come again' atmosphere about it; and I will look to the outdoor advertising that we will do to help build for us this prestige that, to my mind, is so necessary for an Institution such as ours."

The General Manager was an enthusiast not given to half measures--one of those leaders of men who act instinctively and is nine-tenths right.

He said to the Advertising Manager, "I have set a figure of twenty thousand dollars as my limit for this Outdoor Campaign, and I want you to buy the most dominant Outdoor Display that was ever planned in this City. I want to go over every bit of the copy with you before it is finally executed, and I want the copy changed every month with a complete re-arrangement of both color scheme and message. I want to make, as I stated before, _our Institution synonymous with shopping_."

Seven years have gone by, and the General Manager is President of his Company, which is now doing some twelve million dollars' worth of business yearly.

No, the increase of eight million dollars in their business is not due entirely to this wonderful Outdoor Campaign that was put forth. The untiring energy of the General Manager, his far-sightedness and ability in re-organizing his Institution, have all gone to make this Department Store the wonderful business it is. It is significant that today his Company is still spending eighteen thousand dollars per year for Outdoor Advertising.

The General Manager said to me the other day, "I believe in our Outdoor Advertising because I have proven its value. It tells my message _to all the people_: To the Foreigners and the Illiterates who cannot read the newspapers and have money to spend, and who can absorb a simple message told to them, pictorially and in large size and color--to the _school girl who is the mother of tomorrow_, and to the busy man who rides in his motor car to and from his factory and glances only occasionally at his newspaper.

"Mind you I hold no brief for Outdoor Advertising alone--I am a consistant user of newspaper space, probably the largest in this City today, but I attribute the first growth and stimulus of our business to the wide-spreading use I made of Outdoor Publicity.

"I do not believe that a Department Store can be successfully advertised by Outdoor Advertising alone, any more than I believe it can be most successfully advertised by newspaper advertising alone. I believe that a Department Store is best served by a judicious combination of both."

This General Manager, as I said before, is President of his Institution today, one of the wisest men in the Department Store field in America.

And the best part of this Story is that it is _absolutely true_ and was told to the writer almost as set down.

NOTE

Our organization has the advantage of a merchandising experience covering a period of 40 years. We have served clients who have grown from infant industry to corporations doing fifty million dollars or more per year.

We have carefully collected and compiled sales and advertising data, a great deal of which is applicable to all business.

We have a sane, workable plan we should like to present to you.

UNITED ADVERTISING CORPORATION.

[Illustration: _Advertising compels the trend of trade_

UNITED ADVERTISING CORPORATION]

United Advertising Corporation

Samuel Pratt _President_ Leonard Dreyfuss _Vice-President_ Alfred V. Van Beuren, _Secretary-Treasurer_

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Extraneous closing quotation mark on page 14 removed. All other apparent punctuation errors remain unchanged.

Spelling error “consistant” on page 14 left uncorrected.

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The wilderness

Amy E. Mack

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THE WILDERNESS

BY

AMY ELEANOR MACK

(Mrs. LAUNCELOT HARRISON)

AUTHOR OF “A BUSH CALENDAR,” “BUSHLAND STORIES,” “SCRIBBLING SUE,” ETC.

Illustrated by John D. Moore

AUSTRALIA: ANGUS & ROBERTSON LTD. 89 CASTLEREAGH STREET, SYDNEY

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TO SUSIE

WHO LOVES ALL LIVING THINGS

[Illustration: “_A soft mauve mist_”--_White Cedar_]

THE WILDERNESS

Once, long ago, part of it was garden, and the clearing between the redgums and ironbarks was planted with fruit trees and roses; but the gardener went the way of all flesh, and those who came after him did not have the same love for the garden. Now the bush has reclaimed its own, and roses and fruit trees are half hidden by the tangle of wild things which have gradually crept over them. Each spring the fruit blossoms still shine out on the unpruned trees--all the lovelier for their disorder--and mingle with the gold of the wattles; myriads of undisturbed bulbs--ixias, freesias and sparaxis--send up their blooms among the long swordgrass, outrivalling the blooms in my own well-worked garden beds.

Lovely as the bush-girt garden must have been in its orderly days, it now holds joys undreamed of then. With the creeping return of the wattles and tecoma, the mistletoe and hardenbergia, have come back many of the shy living creatures which had been driven away by the gardening; and now that there is no more digging and planting to disturb them they live as happily as if they were a hundred miles away from men and houses, instead of in the midst of a popular suburb.

Fortunately the wilderness is not a desirable building allotment. The little creek which bisects it makes the site too damp for a house, and so no ruthless builder casts a speculative eye upon it. But the creek is an attraction for numberless creatures--birds, butterflies, bandicoots, frogs, and myriads of those tiny living things which we carelessly group together as “wogs.”

To the entomologist the wilderness would be a perfect paradise, for it is the breeding place of many things--not all loved by the ordinary mortal. Many species of ants have their homes down there; and paper wasps love to make their wonderful many-celled nests on the old fruit trees. Cicads crawl out of the soil each spring and creep up the gum trunks to shed their husks before they wing out to fill the wilderness with their humming song.

[Illustration: _The Paper Wasp’s many-celled nest_]

Trapdoor spiders lurk down near the creek, and many of the web-making ones spin their light gossamer from branch to branch. Antlions have their little pits to trap the unwary, and dragonflies flitter restlessly over the water.

[Illustration: _The Dragonfly_]

Most interesting of all to the non-entomological mind are the butterflies. Down in that tangle of trees, grass and ferns are to be found the larvæ and pupæ of many butterflies which in time develop into living jewels. On dull days, and in late afternoons, the funny little caterpillars of the small blue butterflies march out in a solemn procession to feed on the thick fleshy leaves of the mistletoe which grows so lavishly throughout the wilderness. Later they wander down from the mistletoe clumps and enter the nests of the stodgy brown sugar-ants to pupate. It is strange to think that these gay, blue creatures rise from among such queer bed-fellows to flutter round my garden flowers. For in time all the full-fledged butterflies leave the denseness of the wilderness to hover over my beds of zinnias and larkspurs, outshining the brightest blossoms. Most gorgeous, I think, are the vivid turquoise blue and black ones called Papilio, which attract me by their name as much as by their beauty. Very lovely, also, are the big brown butterflies with the eyes on their wings, while there is a distinct fascination about the little "skippers" which vary in shade from cream to brown, and which are known by their different flight.

[Illustration: _The vivid turquoise blue and black Papilio_]

The man who made the wilderness garden must have had a true Australian love, for even in the cultivated beds he planted native things. Along the upper fence he put a row of silver wattles; most of them are long since dead, and their bare branches serve as supports for the wandering tecoma and the red-berried solanum. But their children are scattered throughout the wilderness, making a silver-grey mist, which in spring gives way to a golden blaze. They are in every stage of growth, and as the older trees die off there are always new ones coming to perfection.

Pittosporums, too, he planted, which fill the mild spring evenings with their heavy sweetness; and many Christmas-bushes. These enjoy the wealth of food which comes from all the leaf-mould and decay, and at Christmas time each year their rosy branches glow like beacons through the green glade.

[Illustration: _The formal cypress shape of the Native Cherry_]

Close by the creek grows one of the loveliest of the wild trees, the native cherry (_Exocarpus cupressiformis_). There is quite an old-world charm in its formal cypress shape, which seems to reprove the irregular gums and she-oaks; and the gold-green of its tender tips stands out in lovely contrast against the blue-green and silver-grey of the other trees. When the setting sun catches it through the taller tree trunks it glows like a fairy Christmas tree, and one can picture the little folk dancing round it in a ring. It grows at the very edge of the once cultivated plot, and I think the planner of that garden must have stopped short just there in order to save the lovely thing. Beyond all this is natural bush, with tall spotted pink orchids pushing through in the spring-time, under the golden pultenea and dillwynia, and in summer a white cloud of snowbush.

There is a peculiar fascination in the mixing of wild and tame in that wilderness. The white shasta daisies growing higher than my head in their effort to see the sun through the too protective red-shooted gums; the orange-flowered mistletoe drooping from the tall ironbark to touch the appletree below, seem to me symbolical of that mixing which should come so naturally between things--and people--of this land and of the old.

[Illustration: _The orange-flowered Mistletoe_]

Of all the trees in the wilderness there is none which so completely satisfies me as the white cedar (_Melia composita_). It grows on the upper edge, close to my verandah, and I know it through every varying phase. I never can decide in which season I love it most. It is one of our few deciduous trees, and after its pale golden leaves have dropped it is bare for a short space. Then a soft mauve mist breaks over it, and it is covered with a myriad lilac-coloured, lilac-scented blossoms, which pour their perfume lavishly into the world. I think it is a much lovelier tree than the lilac, for, while its colour is not so deep, the flowers grow in much lighter, more feathery fashion, and the whole effect is that of a mass of misty lace. While the blossoms are at their sweetest the little green leaf-tips have been bursting through. They grow swiftly from slender fingers to waving tassels, and then to open fans, and by the time the flowers are finished the tree is dressed in a beautiful fern-like foliage of glossy green. Nor do its charms end here. The flowers have left behind them hundreds of small green fruits, which grow and ripen, and by the time the autumn comes again and the leaves begin to fall they are ready to provide a beautiful feast for the birds. And so comes the white cedar's crowning charm.

A tree without birds in its branches is like a room without books on its shelves--the birds are the crowning charm. The poet knew that when he wrote ecstatically of--

A tree that may in summer wear A nest of robins in her hair.

My white cedar does not wear any nest in her hair, but each autumn her charm is enhanced by the beautiful green oriole in her branches.

In autumn the fat green berries have grown golden and juicy, and the oriole comes to feast upon them. He really has no right to be so near Sydney nowadays, for he is one of the larger birds, which have been driven back by the advance of the city; but somehow or other, in the mysterious bird way, he learned of my white cedar, and each year he comes to spend a month or so in the wilderness, feasting on the berries, and in between meals filling the autumn day with his lovely, clear ringing song. He is one of the lucky birds, whose voice matches his form in beauty. For he is, indeed, a beautiful bird, with his olive green back, creamy breast streaked with black, and bright red eye and bill. He is big enough, too, to show up in the landscape, and towards the end of his stay, when the cedar is nearly leafless, he makes a lovely note of colour on the bare branches against the blue sky.

[Illustration: _The beautiful green Oriole_]

But he has rivals in the wilderness--many rivals, both in voice and appearance. I am not sure that the blue jays are not more lovely to look at. Their silvery bodies and black faces are not so gay, of course, but they are slim and slender, and they float through the tree-tops with wonderful grace. They come in flocks to the wilderness during the winter, and it is a joy to watch them swaying in the tree-tops, then darting suddenly down to catch an insect on the wing, and up again to their swinging perch. Pity 'tis their voice has no beauty, but is just a querulous squawking note.

Handsome creatures, too, are the dollar-birds which visit the wilderness every year and drift amongst the tall tree-tops, displaying the silvery dollars on their wings against a blue-and-brown background. But their voices!--a small boy compared them to a lot of mad frogs, and the description is not inapt. Fortunately for our ears these harsh-voiced birds are short-stayed visitors, but many of the birds that linger in the wilderness are true singers.

As I write the air is filled with the glorious song of the butcher-birds, which stay with us all through the late summer and autumn and sometimes come in the spring. I have heard all the old-world songbirds--the nightingale and the lark, the blackbird and the thrush--heard and loved them all. But for sheer beauty and volume I know no bird whose voice compares with the butcher-bird's, and I think it is a sin that he should be so named.

It is not his habit of making an occasional meal from a small bird that has given the butcher-bird his name, for many birds have the same habit. It is his peculiar custom of storing his food that has gained him the reputation of keeping a "butcher's shop." Most birds kill an insect as they need it and either eat it or carry it off to their nestlings. The butcher-bird thriftily makes a small collection of insects and lays them in a row. I have seen him lay a huge brown grasshopper and a slim praying mantis side by side on my garden rail, and then fly off and hang another grasshopper in a slender fork of a wattle.

Gould, in his famous work, pictures the butcher-bird with a blue wren hanging from a fork in the tree beside him, a picture which naturally ruined the bird's reputation. I am happy to say I have never seen that horrid tragedy, and from personal observation I think that insects are a much more usual part of his diet than are little birds. At any rate, with such a beautiful voice he deserves the benefit of the doubt. I hope it is not characteristic of us that in naming him we should have overlooked his rare beauty and pounced on his little weakness, though I cannot help thinking that in more aesthetic lands he would have had a name more suited to his beautiful song.

[Illustration: _Our best autumn singer--the Butcher-bird_]

The butcher-bird--since I must call him so--is our best autumn singer, but in the spring his place is taken by the grey thrush. He is next, I think, on the list of our songbirds, and his sweet ringing call holds all the freshness and joy of spring. He is such a darling bird to have about the place. He perches on the redgum or the wattles, which stand in line with the white cedar, and he looks down at me with his big round eye in the friendliest fashion. So graceful he is, too, and so elegant in his neat grey coat, that I always place him in my mind amongst the beautiful birds, though some might call him plain.

Whilst you might dispute the grey thrush's claim to beauty, no one can deny that of two other of my songbirds, the two thickheads, or thunderbirds, as they are sometimes called, because they burst into song after a clap of thunder or any sudden noise. The

yellow-breasted one is very gorgeous, with his white throat and black face; but the rufous-breasted one is handsome, too. Sometimes he breaks into a whip-like note, which has earned him the name of "ring-coachie" amongst small boys. Once, on a rare occasion, the coachwhip bird himself sent his call up from the little creek. As every one knows, the coachwhip bird is a shy, furtive creature, rarely seen by anyone but real bird observers, though his voice is common enough in the gullies. We are nearly a mile away from the gully where he lives, and he must have crept up through the intervening gardens to have a look at the wilderness. Just once he came, but though I have looked and listened I have had no sign or sound of him since.

A very familiar birdcall in the wilderness is that of the cuckoo--or I should say "calls of the cuckoos," for there are five different sorts, with five different calls, amongst our regular visitors. Of course, none of them says "cuckoo." Once I used to cherish a secret feeling of resentment that we should have so many true cuckoos in Australia without one possessing the call associated with the name. But after four English Mays, in which the cuckoo calls all day, I thanked fate that I lived in a land where the cuckoo did not say "cuckoo" from dawn till long after dark. For a more monotonous birdcall I have never known. Our big scrub-cuckoo, the Koel, is nearest to it in monotony; but the five that visit the wilderness have quite different songs. True, the fantail and the two little bronze cuckoos have merely plaintive Whistles, but the big pallid cuckoo has a fine ringing song right up the scale, and the square-tailed calls over and over a distinct phrase, in a higher key each time.

[Illustration: _A simple creature_]

The shrike-tit, that gorgeous yellow-and-black fellow with the black crest, is one of the loveliest birds amongst our regular visitors, and one of my favourites, for he has such an unsuspicious nature. His long drawn out, rather plaintive note is very easy to imitate, and we can always bring him down to us by repeating the call. Again and again I have seen the simple creature hurrying through the wilderness in response to a human whistle, and flying wonderingly from tree to tree in search of his calling rival. Sometimes he comes within a few feet of us, dancing with rage and chattering angrily at the hidden intruder, before he discovers the fraud and flies off in disgust.

[Illustration: _The attractive Lalage_]

A visitor which has a particular attraction for me is the Lalage. I like his smart coat of black and white and grey, and I like his sweet trilling song, but what I like most is his name--his scientific name. For he is one of the few birds whose scientific name is preferable to the vernacular or the colloquial; _Lalage tricolor_ is far prettier and easier to say than "White-shouldered caterpillar-eater," or the stupid "peewee lark." Other birds that visit us occasionally are parrots. I have noticed five kinds--Rosellas, Mountain Lowrie, Blue Mountain parrots, and two little green lorikeets. They have always come when the eucalypts are in flower, and I love to see their gay bodies flashing against the creamy blossoms as they feed noisily on the honey. If only people would realize how much life and colour they bring to their gardens by retaining food-giving trees, I am sure they would not be so ruthless about cutting down trees to make way for roses and dahlias. No bed of flowers could be so soul-satisfying as the sight of a flock of parrakeets feeding in the honey-laden blossoms of a flower-covered bloodwood.

Just as gay as the parrots, though very, very much smaller, is the red-headed honey-eater, or bloodbird, as he is more familiarly known. He is also a honey lover, and visits us when the trees are in blossom. His bright red-and-black coat makes a vivid spot of colour, and his pretty little song adds to the general harmony.

The profusion of mistletoe in the wilderness brings us the mistletoe-bird. Few people really know this tiny steel-blue crimson-breasted fellow, or his plain grey little wife. Yet his single whistle, like that of a small boy who has just learned to whistle through his teeth, is one of the commonest sounds in the bush, and the mated birds call continuously when feeding in different clumps, as if they feared to lose touch with one another. One of the great charms of a wattle, which till lately stood beside my verandah, was that its leafy tops were beloved by the mistletoe-bird. When he had taken his fill of the luscious and viscid berries which dropped from the redgum by the gate, he would retire to the wattle, hide himself amongst the grey-green foliage, and pour out an ecstasy of song in the tiniest of voices. Many birds, even to so bold a fellow as the butcher-bird, have this habit of hiding amongst the thickest leaves and soliloquizing, but none has a more impassioned utterance than the little mistletoe-bird, though none has so slender a song.

Sometimes we find their nest, one of the most wonderfully built of all birds' nests. It is woven from fine plant fibres and silky seeds, and is hung from a slender twig, with a little entrance at the side; it is very like a little purse of felt, save that it is not so harsh to the touch as felt.

[Illustration: _Spine-billed Honeyeater_]

One more of our visitors I must mention, and that is the native canary, which comes each year, builds his little domed nest in a sapling, and fills the air with his sweet song. Then there are the everyday birds, the dear, familiar things which are with us all the year round. Every gardener knows them--blue wrens and tits, jacky winters and yellow robins, redheads and spinebills, peewees and kookaburras--they are the usual inhabitants of our suburban gardens, and dear to us all because of their friendly, fearless ways. Other birds come and go, but they stay with us all the time, building and breeding in the wilderness each spring. In the two years that I have known this wild patch I have counted seventy-two species of birds passing through. Some, as I have said, are there all the time; some come at certain seasons, sing for a space amongst the tree-tops, feed for a week or so on the berries and blossoms, then pass on to other feeding grounds, while others stay just for an hour, glad of a safe and sheltered resting-place on their long, mysterious journeys to and fro across the land.

[Illustration: _So tame and friendly--Blue Wrens_]

Fascinating as the wilderness is by day, it is at night that one feels its deepest spell. Then all the strange elusive creatures come out from their hiding places, and go about their business in the tree-tops or down under the thick shrubs. One needs keen hearing to know the wilderness by night, for eyes alone are not much good.

I can never make up my mind which I love most--the birds that live all the year round in the wilderness, and are so tame and friendly that they come right up on to my verandah and sit and sing within a yard of my chair, or the visitors which bring the feeling of distant places with them, and carry my thoughts far, far away. But of one thing I am sure, and that is my gratitude to the man who left this little wild patch in the heart of the houses to be a sanctuary for all wild things. Noisy people passing by may think it is a mere empty patch of trees; but we who have sat silently on our verandah through the long still summer evenings and listened to the whisperings and stirrings, know that there is a distinct world of living things waking and moving down there in the shadows.

[Illustration: _Long-nosed Bandicoot_]

First of all there are the bandicoots, two kinds of them, amusingly named the long-nosed and the fat bandicoot. One stumbles over a few of their holes by day, but no other sign of them is there; yet at night out they come by the dozen. We hear them rustling through the long swordgrass, right up to the garden where occasionally--not often--they do considerable damage by rooting amongst my bulbs. Their queer little cough always betrays them, though I must admit they do not seem at all anxious about hiding their presence. It always gives me a distinct thrill of pleasure to hear that quaint little note just beside my verandah, and its wild touch is a happy contrast to the jazz music thumped out by my neighbour's pianola. More silent than the bandicoots, though no more stealthy, are the ring-tailed 'possums, of which there are quite a number in the wilderness. Last summer one built on the roof of our verandah, and every evening, as we sat having our coffee in the dusk, we used to hear his little patter across the flat roof. We could see him leap forth into a branch of the tall wattle which bent towards the verandah, then up and across to the taller redgum beyond, and away down into the heart of the wilderness. Sometimes when the hot summer nights have driven off sleep I have heard him in the dawn, scrambling back to bed, just as the birds have been waking up. I must confess that I felt very proud at having such a rare and distinguished lodger.

[Illustration: _The Big 'Possum_]

Occasionally we see the big 'possum. I am not quite sure where he lives, though I know two or three likely spots; but now and then he comes right out into the open, and we both see and hear him. One moonlight night he was feeding on the cedar berries not ten yards from the verandah, and even if his clawing and crunching of the berries had not betrayed him, he was quite visible as he hung on the swaying bough amongst the fern-like leaves, while every now and then as he moved I could see his big eyes shining brightly in the moonlight.

[Illustration: _Then there are Owls_]

Then there are owls--three or four sorts of them--which drift in absolute silence from place to place. On moonlit nights a sudden shadow floats on the ground before you, and if you look up quickly enough you will see a white form settling silently on a branch or post. If you keep very still and watch patiently you may see him dart down to catch some flying insect, or make a sudden swoop at a mouse in the grass below. How they see their prey is always one of the wonders of nature to me, but apparently they never miss. I like the names of my owls--the delicate owl, the masked owl and the Boobook owl--the last so named from his familiar double note "Boo-book."

The old mopoke, who for many years got the credit for the boo-book owl's note, lives in the wilderness, too. Like most of the nocturnal creatures, he likes the tall redgum which stands beside my gate, and he sits there for an hour at a time constantly uttering his soft mysterious note, "Oom, oom, oom." Sometimes he comes closer, on to the fence, or even on to the verandah post itself. In the daytime he sits silently for ages in what must be a most uncomfortable position, pretending to be a branch of the tree, but at night he gives himself away by his "Oom, oom, oom," for even the dullest human knows that trees don't say "Oom, oom, oom." Still, he is clever at catching his food, and the nocturnal insects find him as formidable as the owls.

Whenever we have a few days rain the little creek in the wilderness fills up, and then the frogs make high holiday. Most people will tell you that a frog croaks, and leave it at that. But, as a matter of fact, in proportion to their numbers, there is as great a variety in frog songs as in birds'. Once you have realized the differences you will wonder however you were so stupid as to think them all the same. There is the deep "Craw-craw, craw-craw" of the big green tree-frog, _Hyla coerulea_; the familiar chant, "Craw-awk, crawk, crok, crok," of the golden tree-frog, _Hyla aurea_--I give you their scientific names because they are so charming--the slow "Kuk-kuk-kuk," and the high, piping, hurried "Cree-cree-cree-cree" of two other _Hylas_. Then there is the insect-like "Crikik, crikik" of the little brown _Crinia_, and the harsher "creek" of the tiny brown toadlet. The two frogs which rejoice in the name of _Limnodynastes_, "King of the pool," have quite different notes. One has an explosive "Toc, toc, toc," like a machine gun, and the other calls "Kuk-kuk-kuk-kuk." Then the funny old burrowing frog calls softly "Oo-oo-oo-oo," and sounds more like a bird than a frog.

On fine mornings after rain, when the croakings overnight have told me what is afoot, I visit the little creek to see which of the frogs have spawned. A patch of froth, like soapsuds, with tiny spheres of black and white embedded in it, is the egg-mass of one or other of the two species of _Limnodynastes_. Two kinds of eggs are neatly arranged in cylindrical bunches round the submerged roots and grasses. Each egg is surrounded by a sphere of clear jelly, and a thin gelatinous matrix envelopes all the eggs. Those of _Crinia_ are black and white, those of _Hyla ewingi_ brown and cream. Floating on the surface, as if peppered over it, are the brown-and-white eggs of _Hyla coerulea_; while hidden under the debris round the edges of the water I find the much larger eggs of the little _Pseudophryne_, twenty to a nest, with the gaily orange-marked mother toadlet in attendance.

[Illustration: _A balloon almost as big as the frog itself_]

All are amusing, as frogs have ever been since the days of Aesop and Aristophanes; but there is none so amusing as the big green tree-frog, _Hyla coerulea_. He is the one that makes the great frog concert in moist places, and many a bad sleeper has cursed him for croaking on all through the hours of darkness. But once you have seen one of these frog gatherings you can never feel quite the same about their chorus. Amusement will temper your irritation. They come from all round the neighbourhood to the meeting place, and in the dusk you may even trip over the large green frogs hopping along the footpath on their way from neighbouring gardens. Often the gathering numbers hundreds, and they sit about the edge of the pond, in the grass, and on the stones, chanting loudly. And at each deep note a great balloon swells out in front of the throat, a balloon almost as big as the frog itself, going up and down, up and down, as each deep note goes out and the breath comes back for the next boom. I know of nothing in the whole bush quite so ludicrous as a frogs' party, and I must confess that the knowledge that so few people have attended one adds to its interest. There is a rare satisfaction in being on intimate terms with the really shy, strange, wild creatures. If you would share my pleasure all you need do is to keep a little wild patch of bush near your home. For wherever there is sanctuary the shy bush things will come and make their homes beside you.

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The Russian road to China

Jr. Lindon Bates

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THE RUSSIAN ROAD TO CHINA

[Illustration: A MAID OF OLD MUSCOVY (From a painting by Venuga)]

THE RUSSIAN ROAD TO CHINA

BY

LINDON BATES, JR.

WITH ILLUSTRATIONS FROM PHOTOGRAPHS

[Illustration]

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CONTENTS

I. THE PATH OF THE COSSACK 1

II. THE GREAT SIBERIAN RAILWAY 25

III. IN IRKUTSK 71

IV. SLEDGING THROUGH TRANSBAIKALIA 114

V. IN TATAR TENTS 173

VI. THE CITY OF THE REBORN GOD 220

VII. RUSSIA IN EVOLUTION 273

VIII. THE STORY OF THE HORDES 322

IX. CHINA 364

ILLUSTRATIONS

A MAID OF OLD MUSCOVY _Frontispiece_ From a painting by Venuga

YERMAK'S EXPEDITION TO SIBIR, ATTACKED BY THE TATARS 8 From a painting by Surikova

CHURCH OF ST. BASIL, MOSCOW 20 Ivan the Terrible blinded its architect that he might never duplicate the masterpiece

BRIDGE OVER THE IRTISH 38

ALONG THE TRANS-SIBERIAN RAILWAY 38

DINING-CAR SALOON--VIEW OF THE LIBRARY 46

CITIES OF NEW RUSSIA--TIUMEN, TOMSK, PERM 50

ISLAND OF KALTIGEI, LAKE BAIKAL 68

VILLAGE OF LISTVIANITCHNOE, LAKE BAIKAL 68

THE ANGARA RIVER, IRKUTSK 76

THE CATHEDRAL, IRKUTSK 76

A CHAPEL IN IRKUTSK 86

BOLSHOISKAIA, IRKUTSK 86

THE BAZAAR, IRKUTSK 90

THE ICE-BREAKER, YERMAK--LAKE BAIKAL 98

THE ORGANIZERS OF THE CHITA REPUBLIC 108

BAIKAL STATION 116

THE HIGHLANDS OF TRANSBAIKALIA 116

SLEDGING SOUTHWARDS 126

SIBERIAN TYPES--PEASANT, VILLAGE STOREKEEPER 136

PEASANT TYPES 150

A CHICKOYA GIRL 164

A TROITZKOSAVSK STUDENT 164

A WAYSIDE TEMPLE 178

A MONGOL BELLE AND HER YURTA 186

A ZABAIKALSKAIA BURIAT 186

A MONGOL “BLACK MAN” 206

TEMPLE OF GIGIN, URGA 222

TEMPLE IN THE URGA LAMASERY 228

A PROSTRATING PILGRIMAGE 234

A GRAND LAMA 244

CHINESE MANDARIN 256

GIGIN, THE LIVING BUDDHA 256

CHINESE ARCHWAY, URGA MAIMACHEN 262

THE GREAT WALL 270

THE KREMLIN, MOSCOW 282

RUSSIAN TYPES--DRAGOON, CONSTABLE 292

STREET SCENES IN MOSCOW 302 (The Tverskaia Gate, Loubianskaia Place)

RUSSIAN TYPES--PEDDLER, POLICEMAN 316

THE MIRACLE OF ATTILA'S REPULSE 332 (From the painting by Raphael in the Vatican)

ON THE ROAD TO THE MING TOMBS 342

THE GLORY IS DEPARTED 360

THE BRIDGE AND TABLETS IN PEI-HAI 368

HSUEN-WU GATE, PEKING 374

PEKING, WHERE THE ALLIES' MAIN ASSAULT WAS MADE 380

SUMMER PALACE OF THE EMPEROR 388

MAP OF ASIA, SHOWING ROUTE FROM MOSCOW TO PEKING 392

THE RUSSIAN ROAD TO CHINA

I

THE PATH OF THE COSSACK

An ancient way leads across northern Asia to the Chinese borderland. The steel of the great Siberian Railroad harnesses now the stretch which mounts the Urals, pierces the steppes, winds through the Altai foothills, and by cyclopean cuts and tunnels girdles Lake Baikal. From Verhneudinsk southward, it has remained as an ancient post-road leading through the Trans-Baikal highlands to the frontier garrison town of Kiahta. Over the Mongolian border at Maimachen, it has narrowed into a camel-trail threading the barren hills to the encampment of the Tatar hordes at holy Urga. Thence it strikes across the sandy wastes of Gobi, and passes the ramparts of the Great Wall of China, on its way toward Peking and the Pacific.

Through five centuries this road has been building. Cossacks blazed its way; musketoon-armed Strelitz, adventuring traders, convicts condemned for sins or sincerity, land-seeking peasants, exiled dissenters, voyaging officials--all have trampled it. Hiving workmen under far-brought engineers have pushed the rails onward, bridging the chasms and heaping the defiles. Following it eastward, unpeopled wastes have been sown to homesteads, hamlets have grown into cities. To the very gateway of China it has led the Muscovite. It is the path of Slavic advance.

The way scarcely passed Novgorod in the early sixteenth century when the great family of the Stroganovs, a "kindred in Moscovie called the sonnes of Anika living neare the Castle of Saint Michael the Archangel," began the fur-trade with the Samoied tribesmen from Siberia, who paddled down the Wichida River to barter peltries with the Russians. The prudent merchant Anika, looking to a more permanent source for those valued furs than the irregular visits of the aborigines, planned to anticipate his brother traders in their purchases. He sent east with a band of returning Samoieds some of his own henchmen carrying, for traffic with the inhabitants, "divers base merchandise, as small bels, and other like Dutch small wares." The agents returned to report what impressed them most. There were no cities. The Samoieds were "lothsome in feeding,"--even a Russian frontiersman might shrink from the cud of a reindeer's stomach as food,--and knew neither corn nor bread. They were cunning archers, whose arrows were headed with sharpened stones and fishbones. They were clad in skins, wearing in summer the furry side outward and in winter inward. They willingly gave sable-skins for Dutch bells.

A series of trading expeditions began, which made the Stroganovs so enormously wealthy that "the kindred of Anika knew no ends of their goods." Indeed, they gained so much by this exploitation that they began to fear the application by the Czar's agent of a monetary test of patriotism. So, by a stroke of finance not unknown in modern days, there was arranged the Russian equivalent for carrying five thousand shares of Metropolitan. A block of small wares for the account of the Czar's brother-in-law, Boris, was added to the stock in an especially important expedition among the Samoieds and Ostiaks. The adventurers got far inland. They saw men riding on elks, and sledges drawn by dogs. They returned with wonderful tales of marksmanship, and, more important, brought back enough furs to give Boris a dividend, in gratitude for which he secured to the Stroganovs the grant of an enormous tract of land along the Kama River and a monopoly of the trade with the aborigines.

The Stroganovs grew and thrived. They scattered trading-posts and factories along the river-highways and sent many parties into the interior to barter. In the half-century following old Anika's expedition, they had carried the Slavic way to the Urals.

In the summer of 1578, when Maxim Stroganov was ruling over the family estates along the Kama, one Yermak, heading a fugitive band of Cossacks, tattered and spent, with dented armor and drooping ponies, straggled into camp and offered service. With great delicacy Maxim forbore pressing too closely his inquiry into their antecedents. It might have wounded Yermak's susceptibilities to avow that his chief lieutenant, Ivan Koltso, was under sentence of death for capturing and sacking a town of the Nogoy, and that the immediate cause of his advent was an army of Imperial Strelitz, which had driven his band from the Volga District for piracy and highway robbery.

The situation on the far side of the Urals, where the skin-hunting tribes had been conquered by a roving horde of Tatars under Kutchum Khan, was at this time interfering sadly with the Stroganovs' fur business. Eight hundred Cossacks, furthermore, of shady character and urgent needs were undesirable neighbors. So the prudent Maxim, not particularly solicitous as to which of the two might be eliminated, offered Yermak a supply of new muskets if he would go away and fight the Tatars. They were not pleasant people for the Cossacks to meet, these former masters of Moscow. But behind were the soldiers of Ivan the Terrible. With a possible conquest before, and the Strelitz behind, Yermak gladly chose to invade the Tatar territory, which is now western Siberia.

Up the Chusovaya River the little expedition started in 1579, damming the stream with sails to get the boats across its shallows. Penetrating far into the mountains, the band reached a point where a portage could be made across the Ural water-shed. Then they headed down the Tura River into Siberia. Here the invaders met the first army of the Tatars under Prince Yepancha, and with small loss drove them back. Yermak made his winter camp on the site of the present city of Tiumen.

Next year the advance began once more. The Khan of the Tatars, Kutchum, was alive to the seriousness of the incursion, and prepared to ambush the Cossack flotilla as it descended the Tura. At a chosen spot chains were stretched across the stream, and bowmen were stationed on the banks to await the coming of Yermak and overwhelm with arrows his impeded forces. The Tatar sentries above the ambuscade signaled the coming of the boats; all eyes were turned intently upstream. Then Yermak's soldiers fell upon them from the rear, to their total surprise and his complete victory. Straw-stuffed figures in Cossack garments had come down in the boats; the men themselves had made a land-circuit and had struck the enemy unprepared.

In defense of his threatened capital, Sibir, the old Khan rallied once more. He assembled a great army, thirty times that of the Cossacks. For the invaders, however, retreat was more perilous than advance. Yermak went on, and in a great fight on the banks of the Irtish, again prevailed. With his forces reduced by battle and disease to some three hundred effectives, he entered Sibir on October 25, 1581. A few days later the Ostiak tribes, glad to escape their Koran-coercing masters, proffered their allegiance, and the Cossack saddle was on Siberia.

But how precarious was their seat! Southward were the myriads of the unconquered hordes of Tatary; only one of the score of their khans had been vanquished. As thistledown is blown before the wind, so could Yermak's oft-decimated band have been swept away had once the march of the Mongols' main division turned northward. Girding him round were the self-submitting Ostiaks, loyal for the moment to those who had won them freedom from the old proselyting overlord, but not long to be relied upon once the weight of Cossack tribute--the fur-yassak--began to be felt.

But what the Tatar hordes had not, what the Ostiak hunters had not, the three hundred Cossacks had--a man. This man, starting his march as the hunted captain of a band of outlaws, could conquer half a continent. Then over the heads of his employers, the mighty family of Stroganov, over the heads of governors of provinces, of boyars, of ministers to the throne, he could send by his outlaw lieutenant, Ivan Koltso, loftily, imperially, as a prince to a king, his offer of the realm of Siberia to Ivan Vasilevich.

Ivan the Terrible, Czar of all the Russias, he who had blinded the architect of St. Basil, lest he plan a second masterpiece; he who had tortured and slain a son, hated less for his intrigues than for his unroyal weakness, responded imperially. Over the long versts Ivan's courier carried to Yermak a pardon, confirmation as ruler of the newly-won realm and the Czar's own mantle, an honor accorded only to the greatest, the boyars of Muscovy. Following the messenger eastward there plodded three hundred musket-armed Strelitz to bear aid to the Cossack garrison. Sorely now were these reinforcements needed, for the Ostiak tribes flamed into rebellion against King Stork. With Kutchum's Tatars, they returned to the attack and besieged Sibir. Once again, though hemmed about by the multitude of his enemies, the valor of Yermak saved his cause. In a totally unexpected sally, in June, 1584, the Tatar camp was surprised, a great number massacred, and the besiegers scattered.

The whole country, however, save only the city of Sibir, was still in arms. Engagements between small parties were constant. Ivan Koltso, striving to open a way for a trader's caravan, fell with his fifty, cut down to the last man. Yermak, marching out to avenge him, was himself surprised near the Irtish. With Ulysses-like adroitness, he and two followers escaped the massacre and reached the river-bank, where a small skiff promised safety. Leaping last for the boat, Yermak fell short, and, weighted with his armor, sank in the river that he had given to Russia. The two Cossack soldiers alone floated down to their comrades.

One hundred and fifty, all that were left of them, started their long homeward retreat. Far from Sibir, they met a hundred armed men sent by the Czar. Great was the spirit, not unworthy of the dead leader, that turned them back, to march to a site twelve miles from Sibir, where they built their own town, now the city of Tobolsk.

In the years that followed, their nomad enemies drifted south, leaving those behind who cared not for their old khan's quarrels. The phlegmatic Ostiaks returned to their hunting and to their feasts of uncooked fox-entrails. The long fight had rolled past, leaving the Slavic way undisputed to the Irtish.

Well it was, for no more of the Strelitz marched to the aid of the garrisons. Russia was in the throes of civil war and invasion,--the long-remembered "Smutnoe Vremya," time of troubles. Boris Godunov, once favorite of Ivan the Terrible, became the real ruler in the reign of the weak Feodor. On the death of this prince, with the heir-apparent Dimitri suspiciously slain, he had mounted the empty throne, and a pretender, claiming to be Dimitri miraculously escaped, had risen up in Poland, gained the support of the king, and marched against Boris. Though the Polish army was routed, Boris succumbed shortly after to a poison-hastened demise.

[Illustration: YERMAK'S EXPEDITION TO SIBIR ATTACKED BY THE TATARS (From a painting by Surikova)]

Dimitri attacked the new czar, captured Moscow, and was crowned in the Kremlin by the Poles. A revolution followed within a year, in which the pseudo-Dimitri was slain. Meanwhile the Poles were devastating Russia more cruelly than had the old Tatar conquerors. At length Minim the butcher of Novgorod led a popular revolt, which in 1613 carried to the throne Michael, the first of the Romanovs.

Through all these years, despite the fact that anarchy and chaos rioted over Muscovy, despite the fact that no troops came to aid in the advance, the Cossacks still pressed their way, contested by the scattered bands of Tatars, and farther on by the Buriats, the Yakuts, the Koriats. After these fighters and conquerors came the traders and colonists, with their families, following along the road that had been won. The valleys of the great Siberian rivers, which so short a time before had been the grazing-grounds of the Tatars, became dotted now with the farms of the new-come settlers. The advance guards of the fur-traders, with blockhouses guarding the portages, and clustering wooden huts and churches, pushed south and east as far as Kuznetz, at the head of navigation on the River Tom, and to the foot of the Altai Mountains. North and east the trade-route was advanced to the Yenesei, twenty-two hundred miles inland. As many as sixty-eight hundred sables went back to Russia in 1640, together with great quantities of fox, ermine, and squirrel-skins.

The quaint volumes of "Purchas his Pilgrimes," published in 1625, tell of some of the early explorations. A band of Cossacks dared the upper Yenesei, which "hath high mountains to the east, among which are some that cast out fire and brimstone." They made friends of the cave-dwelling Tunguses in this region, who were themselves stirred to explore, and went on far eastward to another river, less than the Yenesei but as rapid. By faster running the Tunguses caught some of the inhabitants, who pointed across the river and said "Om! Om!" The old chronicler diligently records the speculation as to what "Om! Om!" could mean. Some thought that it signified thunder, others held it a warning that the great beyond teemed with devils. These unfortunate slow-running natives died, "probably of fright," when the Tunguses, in a spirit as naïvely unfeeling as if they were collecting curios, were taking them back to be exhibited to their friends the Cossacks. How far these Tunguses had pierced cannot be told. In one of the dialects of the Yakuts who live beyond Baikal, "ta-oom" or "tanak-hoom" means "greetings." Had the Tunguses and the Cossacks who followed them arrived at the Yakuts' country? Or was the river on which passed "ships with sails" and beyond which was heard the booming of brazen bells the Amur? Were those the junks and temple-gongs of the Manchus? _Ni snaia_,--who knows?

In 1637 the Cossacks reached and established themselves in Yakutsk. In 1639 by the far northern route they pierced to the Sea of Okhotsk. In 1644 a party reached the delta of the Kalyma, and curiously speculated upon the mammoth tusks which they found. In 1648, on the Cellinga River beyond Lake Baikal they built Fort Verhneudinsk. Had their tide of conquest now rolled southward, up the Cellinga Valley, the Russian Eagles might to-day be flying over Peking. Only the Kentai Mountains were between them and prostrate Mongolia, enfeebled by the internecine warfare of her rival khans. From Mongolia, the road, worn by so many conquerors of old, leads fair and clear to the Chi-li Province and the heart of China.

But they passed this gateway by, those old Cossack heroes, as the railway builders have passed it by, to press with Poyarkov to the Pacific; to conquer, with Khabarov, the Amur; to meet in desperate conflict the whale-skin cuirassed Koriats of the coast; to battle with the Manchu in conflicts where "by the Grace of God and the Imperial good fortune, and our efforts, many of those dogs were slain"; to fight until but an unvanquished sixty-eight were left of the garrison of eight hundred in beleaguered Albazin.

The current of conquest passed by this door to China, but the swelling stream of commerce searched it out. In 1638, the Boyar Pochabov, crossing Baikal on the ice, broke the first way to Urga, the capital of the Mongolian Great Khan, and gained the friendship of the monarch. In the interests of trade, the deputies of the Czar Alexei Michailovitch followed up the opening with an embassy in 1654 to the Chinese Emperor himself. Over steppe and mountain and desert the mission wound its weary way to Kalgan, the outpost city beside the Chinese Wall, and then on to Peking, bearing to the Bogdo Khan, the Yellow Czar, the presents of Chagan Khan, the White Czar.

From the Forbidden Palace at Peking were started back, four years later, return presents, including ten _puds_ of the first tea that reached Russia. With the presents came a message that drove flame into the bearded cheeks of the Czar and set his Muscovite boyars to grasping their sword-hilts. "In token of our especial good-will we send gifts in return for your tribute." Thus, the Chinese Emperor.

The answer of the Czar started another legation plodding across a continent, and the retort was thrown at the feet of his Yellow Majesty. It was a summons forthwith to tender his vassalage to Russia. The Czar's gauntlet had been hurled across Asia. But all it brought was beggary to the traders who had begun to press along the newly-opened route to a commercial conquest of the East.

Soon Russia regretted the fruitage of her challenge. In 1685 Golovin's embassy left Moscow, and, arriving two years later at Verhneudinsk, opened negotiations with Peking. A Chinese commission then made its way north, and at Nerchinsk, August 27, 1689, was signed the famous treaty closing to Russia her Amur outlet to the Pacific, purchased with such desperate valor at Albazin, but granting to a limited number of Russian merchants trading privileges into China.

A lively traffic at once sprang up. Long caravans, silk- and tea-laden, crossed the Mongolian deserts, the Siberian steppes and hills, and the forested Urals, taking the road to Europe. A little Russian settlement was founded at Peking, and a traders' caravansary was built. The church constructed by the prisoners of Albazin, who had been so kindly treated by the Manchus that they at first refused the release which the treaty brought, gave place to a larger edifice erected by popes from Russia.

Soon, however, the Russians again offended the Celestial Emperor. In their riotous living, the quickly enriched merchants disquieted the sober Chinese. The Siberians over the frontier gave asylum to a band of seven hundred Mongol free-booters, whom it was urgently desired to present to a Chinese headsman. So commerce was forbidden anew, and most of the reluctant merchants left their compound. Some stayed and assimilated with the Chinese, retaining, however, their religion; and for years a mixed race observed in Peking the rites of Greek Orthodox Christianity.

It may seem strange that rulers so energetic as Peter the Great and some of his successors took no steps to resent by force of arms the arbitrary acts of the Chinese Emperor. But much was going on in Russia; Peter was occupied with his invasion of Persia, and Catherine was without taste for a distant and doubtful campaign. The garrisons scattered over the enormous area of Siberia were numerically too weak and too poorly equipped to do more than hold their own. So, when commerce was once more interdicted and the merchants banished, recourse was had to diplomacy. In 1725 the Bogdo Khan relented enough to receive Count Ragusinsky with a special embassy from Catherine the First, which arranged the second great agreement with China, called the Treaty of Kiahta.

By it the frontier cities of Kiahta in Siberia, and Maimachen, facing it just across the line in Mongolia, were established as the gateway to Chinese trade. The treaty provided for the extradition of bandits and for a perpetual peace and friendship between the high contracting parties. Ever since, the citizens of Kiahta have alternately blessed and blamed Ragusinsky,--blamed him because, in the fear lest any stream flowing out of Chinese into Russian territory should be poisoned, he settled the boundary city beside a Siberian brook so inadequate that Kiahtans have suffered ever since for lack of water, with the river Bura only nine versts away in China; blessed him because of the great prosperity the treaty brought to their doors.

The tea carried by this highway became Russia's national drink. Great warehouses arose, built caravansary-wise around courts. Endless files of two-wheeled carts rolled northward, bearing each its ten square bales of tea, or its well-packed bolts of silk. The merchants grew wealthy in the rapidly swelling trade.

A great Chinese embassy, headed by the third ranking official of the Peking Foreign Office, made its way to Moscow to keep permanent the relations of the two empires. Similarly, a Russian embassy was established in the rebuilt compound in Peking, where a new church arose, whose archimandrite gained a comfortable revenue by selling ikons and crucifixes to the many Chinese converts he had baptized.

Catherine the Second's edict opened to all Russians the freedom of Chinese trade. Its volume, large before, became now even greater. In 1780 the registered commerce at Kiahta had risen to 2,868,333 roubles, not to mention the large value of the goods taken in unregistered.

Tea, a pound of which, if of best quality, cost two roubles in those days, silks, porcelains, cottons, and tobacco, went north, exchanged for Russian peltries, for cloth, hardware, and, curiously enough, hunting-dogs.

An English merchant, who had penetrated to Kiahta in that year, gives an amusing account of the mutual distrust with which the barter was conducted. The Russian going over the frontier to Maimachen would examine the goods in the Chinese warehouse, seal up what he desired, and leave two men on guard. The Chinese merchant would then come to Kiahta, and do the same with the Russian's wares. When the bargain was struck, both together carried one shipment over the border with guards and brought back the exchange.

In growing prosperity, undisturbed, the Kiahta caravans came and went, while elsewhere history was warm in the making.

Napoleon marched to Moscow, to Leipsic, to Waterloo. The Kiahta caravans came and went. The St. Petersburg Dekabrists rose for Constantine and the Constitution. The Kiahta caravans came and went. The Crimean War saw the Russian flag flutter down at Sevastopol. Even as the Malakoff was stormed, a Russian army marched into Central Asia to seize the Zailust Altai slope, which points as a spear toward Turkestan and India, and a Russian navy sailed under Muraviev to occupy the forbidden Amur. The Kiahta caravans came and went.

At length a railroad, pushed year by year, reached the Pacific. One branch cut across the reluctantly-accorded Manchurian domain to Vladivostok; another struck southward to Dalny and Niu-chwang. The Russian Eagles perched at Port Arthur and nested by the far Pacific.

The camel-commerce of the old overland road across Mongolia shrank now as shrinks a Gobi snow-rivulet under the burning desert sun. The meagre Kiahta caravans became but a gaunt shadow of the mighty past. Only an intermittent wool-export and a dwindling traffic in tea to the border cities remained of the great tribute of the Urga Road. As trade vanished from their once busy warehouses, the Chinese merchants were troubled. Perhaps to prayer and sacrifice the God of Commerce would relent? So a scarlet temple rose on the hill by Maimachen. Prosperity came suddenly once again, a new trade rolled north over the historic way. The Mongol cart-drivers returned from far Ulasati. The camel-trains, that had scattered south to the trails beyond Shama, gathered back as antelopes herd to a new spring in the desert.

The God of the Red Temple, the God of the Caravan, had sent the Japanese. As the Amban's executioner strikes off a victim's hand, so had the Nipponese lopped away the railroad reaching down to Dalny and Niu-chwang--the road that was breaking the camel-trade a thousand versts beyond, on the old route by Maimachen and Kiahta. Against the Russian control of the Pacific the Japanese had hurled all their gathered might. By battle genius and efficiency the Island soldiers won, and athwart the front of Slavic empire they set their desperate legions. Far more was lost to Russia than men and squandered treasure, far more than prestige and power of place. The enormous stakes, even in the port of Dalny, in the forts of Port Arthur, in the East China Railway, were but incidents. The real tragedy of the war was that the vital terminus of her continent railroad was alienated, and that her civilization was barred back indefinitely.

The soldiers and statesmen who carried Russia's power across a savage continent had sought out many inventions. But by whatever means each successive territory was won, its maintenance had been by the warrant that the Slavs had gone not lightly, adventuring to conquest, but as an earnest host clearing a way for the homes and the hearths of their race. The colonist had followed the Cossack; cities and villages, railways and telegraphs, had risen behind the armies. The dawn of the twentieth century saw a mighty expanse of Siberia redeemed from a desolate waste to a land of farms and villages, of mines and industries; a native population, once hardly superior to the American Indian, not, like him, displaced and exterminated, but raised side by side with the settlers to a more equitable place than is held by any other subject people in Asia. The Russian advance had brought the establishment of the volunteer fleet plying from far Odessa to Vladivostok, and the completion of the greatest railway enterprise the

world has ever seen. It had opened from Europe to the Far East a land-route more important to more people than the water-route discovered by Vasco da Gama. The fruition of a nation's hope was lost when the Eagles went down at Port Arthur.

For those who feast at Russia's cost the reckoning is long. Predecessors not unfamed are worthy of remembrance: the Tatars who lorded it four hundred years, the Poles whose kings caroused in the Kremlin, the great Emperor, with his Grande Armée, whose stabled horses scarred the walls of St. Basil, the Turks, the Swedes,--all conquerors of yesterday. But long years must take their toll of life and gold before Russia can carry the entrenched lines along the Yalu, and reënter the redoubts hewn in the sterile hills around Port Arthur. The spoils to the victors for the present are unchallenged. The Russian way to China is not now through Manchuria.

But the ancient road of the Kiahta caravans is still unblocked. Here is the shortest route from Europe to the East. Here, through the defiles and the broken foothills of the Gobi Plateau, lies the future redemption of the great unfettered land-route to North China. The Chinese are themselves advancing to anticipate it. They have already built into Kalgan. To this trading-centre across the pale, a Russian railway may yet pass and her colonists make fruitful the unpeopled wilds of Mongolia.

In the cycles of progress old paths are reworn. Pharaoh's canal from the Mediterranean to the Red Sea was swallowed up under the sands of three thousand years when the Genoans won a way across the Isthmus. Their track was left unsought when the Portuguese showed the route for ships around the Cape. Yet to-day the Strait of Suez is thronged with reborn commerce.

The first American highway to the Western Reserve was superseded by the better avenue of the newly built Erie Canal, yet came to its own again beneath the tracks of the Baltimore and Ohio. So, far to the westward of Japan's outpost, the age-old caravan road, with a shadowy fantastic history dim as its dun trail across the desert, may rise to a resurrected glory as a new road to China.

Its greatness is of yesterday and of to-morrow. Unto to-day belongs the quaintness of the cavalcade that passes to and fro along its track. Over the frozen snows of winter and the rocky trails of summer there plod horse and ox and camel, sleigh and wagon and cart,--a broken line of men and beasts. Russian posts thunder past with galloping horses, three abreast. Bands of Cossacks convoy the guarded camel-trains of heavy mail for China. One meets troops of boyish recruits, singing lustily in chorus on the tramp northward, and Mongol carts and flat-featured Buriats on their little shaggy ponies, sleepy wooden villages, forests, steppes, swamps, frozen river-courses, mountain passes.

Through the kaleidoscope of races and peoples one moves in a world-forgotten life, a procession of the ages.

[Illustration: CHURCH OF ST. BASIL, MOSCOW (Ivan the Terrible blinded its architect that he might never duplicate the masterpiece)]

On the threshold of Siberia the traveler has turned back in manner, in ways of thought, in government, in everything, to the past. Go into one of these cities,--you are in the Germany of 1849, with the embers still hot of the fire lighted by the republican movement of the young men and the industrials. The seeming chance of victory has passed them by. The iron hand is over all. One hears of Siberian Carl Schurzes, fugitives to America and to Switzerland, of the month-lived Chita Republic, of the row of gallows at Verhneudinsk, of the bloody assizes at Krasnoyarsk.

It is as if one lived when citizens gathered in excited groups in the Forum to discuss the news from Philippi; or as if, from the broken masonry of the Tuileries, there stepped out into breathing actuality the five hundred Marseillaises "who know how to die," fronting the red Swiss before the palace of Louis, the King. Here is the reality of friends in hiding, of files of soldiers at each railway-station, of police-examined passports without which one cannot sleep a night in town, of arms forbidden, meetings forbidden, books forbidden,--all things forbidden. Here as there men thought that the new could come only by revolution. Yet one can see, despite all, the germs of improvement and the upward pressures of evolution.

Move further toward the frontier towns, where the relayed horses bring the weekly mail,--you have gone back a hundred and fifty years. You are among our own ancestors of the days of the Stamp Act. Did the General Howe who governs the oblast from his Irkutsk residency overhear the school-boys of Troitzkosavsk as they chant the forbidden _Marseillaise_, he, too, might say that freedom was in the air. These Siberian frontiersmen shoot the deer with their permitted flint-locks as straight as the neighbors of Israel Putnam, and with spear and gun they face the bear that the dusky Buriat hunters have tracked to its lair.

Our Puritans are there, rugged, red-bearded dissenters, "Stare' Obriachi," Old Believers, they are called, who came to Siberia rather than use Bishop Nikon's amended books of prayer. Yankee-like, outspoken, keen at a trade, are these big Siberian sons of

men who dared greatly in their long frozen march. The grants to Lord Baltimores and Padroon Van Rensselaers are in the vast "cabinetski" estates of the grand-ducal circle, engulfing domains great as European kingdoms.

Go into one of the villages of the peasants transplanted in a body by the paternal Government. Here are the patient, enduring recruits for the army, brothers to the toilers over whose fields the Grand Monarch's wars rolled back and forth. Though steeped in ignorance and overwhelmed by the incubus of communism, they are capable of real and splendid manhood, and will show it when their world has struggled through into the century in which we others live.

Go to a mining-camp in the Chickoya Valley. It is California and the days of '49. Histories as romantic as those of the Sierras are being lived out in its unsung gorges,--tales of hardships, of grub-stakes, of bonanzas in Last Chance Gulches.

When the bumping tarantass rolls across the Chinese frontier into Mongolia, it enters a kingdom of the Middle Ages flung down into the twentieth century. Feudal princes, lords of armies weaponed with spear and bow, tax and drive to the corvée their nomad serfs. A hierarchy of priests whose divine head lives in a palace at Holy Urga, sways the multitude of superstition-steeped Mongols, and receives the homage of pilgrims wending their way from Siberia, from the Volga, from Tibet, from all Mongolia, to their Canterbury of Lamaism. In prostrate devotion the penitents girdle the Sacred City before whose hovels beggars dispute with dogs their common nourishment, and in whose compounds princes of the race of Genghis Khan, with armies of retainers, live bedless, bathless, lightless, in the felt huts of their race. Squalid magnificence and good-humored kindly hospitality are linked to utter brutality. Sable-furs and silks cover sheepskins worn until they drop from the body. Here and there among the natives a Chinese trading caravansary, alien, walled, peculiar, stands as of old the Hansa-town, with merchant guilds and far-brought caravan goods.

A way of adventure and strangeness, where the years turn back, is this old road of the Golden Horde, leading down past the ancestral homes of the Turks to the Great Wall.

The Cossack sentries at Kiahta look Chinaward. They have become an anomaly, this hard-riding, fierce-fighting soldier class. The plow has metamorphosed into myriad farms the plains along the Don where once their ponies grazed. Mining-cuts score the hills in the Urals where once they hunted. Villages of Slavonic peasants rise along the Amur. The sons of the old warriors grow into peaceful farmer-folk, differing in name alone from their blue-eyed neighbors. Soon they must disappear in all save picturesquely uniformed Hussars of the Guard, and as a memory, chanted by young men and girls in the Siberian summer evenings when Yermak's song is raised. The task of the Cossack, to lead in the conquest of kindred native races and to weld these through themselves into Russia's fabric, is nearly done.

Down the ancient road lies a last avenue of advance. Eastward is Manchuria, where artillery and science grappling must decide the day with Japan. Southward is India, where England's guarded gateway among the hills can be opened only from behind. But into Mongolia Fate may decree that the yellow-capped Cossacks, drafted from Russia's Mongol Buriats, shall lead once more the nation-absorbing march of the White Czar. For another memorable ride, the Cossacks, who on their shaggy ponies led the long conquering way across the continent, may yet mount and take the road to China.

II

THE GREAT SIBERIAN RAILWAY

How long to Irkutsk? Seven days now, seven years when last I came." The bearded Russian standing in the doorway of the adjoining compartment in the corridor-car of the Siberian Express gazes thoughtfully at the fir-covered slope, whose dark green stands in sombre contrast to the winter snows. The train is slowly climbing the Ural Range, toward the granite pyramid near Zlatoust, on opposite sides of which are graven "Europe" and "Asia." Neighbors with easy sociability are conversing along the wide corridors, exchanging stories and cigarettes, asking each other's age and income in naïve Siberian style.

Regarding the burly occupant of the next stateroom one may discreetly speculate. From sable-lined paletot and massive gold chains you hazard that he voyaged with the traders' slow caravans in the days before the railway--that he was a merchant.

"A merchant? _Optovi?_ No, I did not come with the caravans."

From the triangle of red lapel-ribbon, the rank-bestowing decoration, you venture a second guess.

"Perhaps the _gaspadine_ made the great circuit to oversee the local administrations? He was a government inspector--_Revizor?_"

"_Chinovnik niet navierno_," he answers. Most decidedly he was not an official. The suggestion causes him to smile broadly. "I was with the convicts," he says.

Beside the line of rails curves the old post-road winding like a ribbon through the highlands.

"It was by that road we marched. Seven years of my life lie along it."

The train swings through a cleft hewn in the living rock, steep-sided as if the mountain had been gashed with a mighty axe. It rumbles around the base of an overhanging crag while you look clear down over the white valley, with the miles of rolling green forest beyond.

"Was not seven years a long time for the march?" you venture.

"For a traveler, yes; for convict bands not unusual. We went back and forth, now northward a thousand versts as to Archangel, now west as to Moscow, now south as to Rostov. Again and again our troop would split, and part be sent another way. New prisoners would be added, from Warsaw, Finland, Samara. New guards would take charge. Some groups would go to the West Siberian stations, some east to the Pacific and Sakhalin. I, who was written down for ten years at the Petrovski Works beyond Baikal Lake, with a third commuted for good behavior, had finished my term before I got there."

"Why did they wander so aimlessly?"

"It seems truly as a butterfly's flight, but you others do not know the way of Russia. Very slowly, very deviously she goes, but surely, none the less, to her goal. We each came at last to our place."

A match flares up and he lights another cigarette.

"Shall we not go to the 'wagon restoran' for a glass of tea?" you ask.

Along the broad aisles you walk, past the staterooms, filled with baggage, littered with bedding, kettles, novels, and fur overcoats. Everything is in direst confusion, and the owners are sandwiched precariously between their belongings. On the little tables which are raised between the seats, they are playing endless games of cards, sipping tea and nonchalantly smoking cigarettes the while. You pass the stove-niches at the car entrances, heaped to the ceiling with cut wood. The fire-tenders as you pass give the military salute. You cross the covered bridges between the cars, where are little mounds of the snow that has sifted in around the crevices; and a belt of cold air tells of the zero temperature outside. At length the double doors of the foremost car appear ahead, and crossing one more arctic zone over the couplings, you can hang your fur cap by the door and salute the ikon that with ever-burning lamp looks down over the parlor-car. Now you can sit on the broad sofa set along the wall, or doze in the corner-rocker under the bookcase, or sit tête-à-tête in armchairs over a miniature table. Ladies here, as well as men, are chatting, reading, and smoking, for this combination parlor, _fumoir_, and dining-room is for all, not a resort to which the masculine element shamefacedly steals for unshared indulgences.

"_Dva stakan chai, pajolst_" (two glasses of tea, please), your friend says to the aproned _chelaviek_, a Tatar from Kazan.

"_Stakan vodka_," you add; for you are willing to contribute twenty kopecks to the government revenues if this beverage will help out the memoirs of your friend, the convict.

"_Say chass_," replies the waiter, which means, literally, "this hour," figuratively, "at once," actually, whenever he chances to recall that your party wants a glass of tea and another of vodka. When at length the refreshments have come, your companion gets gradually back to the reminiscences.

"Were your comrades many on that march?"

"Twenty-six from my school in Odessa," he says. He tells of the tumult in the Polytechnic Academy, when he was a boy of sixteen studying engineering; of the barricade which the students threw up; of the soldiers sent against it; of an officer wounded with a stone, and the sentence to the mines. He tells of the journey, day after day, the miserable company trudging under the burning suns of summer and shivering under the biting cold of winter, ill-fed and in rags. He recalls how this friend and that friend sickened and died; how a peasant-woman gave him a dried fish; how one of the criminals tried to escape and was lashed with the _plet_ until he fainted beneath its strokes.

"We were a sad procession. First came the Cossacks on their ponies, with their carbines and sabres. Then the murderers for Sakhalin, and the dangerous criminals in fetters; a few women next; then we, the politicals; last, more soldiers marching behind. Far to the rear came carts and wagons with the wives and families of the prisoners, following their men into exile. Slowly we went, scarcely more than fifteen versts a day, with a rest one day out of three, for the women. In winter we camped in stations along the road."

From the comfortable leather armchairs they seem infinitely distant and dream-like, these tales from the dark ages of Siberia. The speaker seems to have forgotten his auditor and to be talking to himself, and soon he relapses into silence. He sits holding his glass of lemon-garnished tea, like a resting giant with his shaggy beard and mighty chest. The drag of the brakes is felt through the train. "_Desiet minute stoit_" (ten minutes' stop), somebody calls out. Suddenly, with an effort, the man across the table rouses from his reverie, and looks about the car, when the broad smile comes back and he says earnestly:--

"You must not think of that as the true Siberia. It was all long ago--thirty-five years. And you see I who became a _kayoshnik_, a gold-seeker, have prospered, and work many mines. I am glad now that they sent me to Siberia. And many others prosper who came with the convicts. The old dark Siberia dies, but our new Siberia of the railroad lives, and grows great."

He rises resolutely and shakes your hand with a vise-like grip.

"_De svidania!_" (Till we meet again.)

You rise with the rest, draw on your fur cap and gloves, work into the heavy fur-lined overcoat, and clamber down to the platform. A little wooden station-house painted white is opposite the carriage door. It has projecting eaves and quaint many-paned windows. In front of it is a post with a large brazen bell. On the big signboard you can spell out from the Russian letters "Zlatoust." This is the summit station of the pass that crosses the Urals. Around are standing stolid sheep-skinned figures, bearded peasants just in from their sledges, which are ranked outside the fence. Fur-capped mechanics, carrying wrenches and hammers, move from car to car to tighten bolts and test wheels for the long eastward pull. Uniformed station attendants are here and there, some with files of bills of lading. As you walk down the platform among the crowd, you come upon a soldier, duffle-coated and muffled in his capote, standing stoically with fixed bayonet. Forty paces further there is another, and beyond still another, all the length of the platform, and far up the line. What a symbol of Russian rule are these silent sentries! And what a mute tale is told in the necessity for a guard at every railroad halting-place in the Empire!

You stroll along toward the engine. Huge and box-like are the big steel cars, five of which compose the train. Two second-class wagons painted in mustard yellow are rearmost, then come the first-class, painted black, next the "wagon restoran" and the luggage-van, where the much advertised and little used bath-room and gymnasium are located. The engine is a big machine, but of low power, unable to make much speed; and the high grades and the road-bed, poor in many places, additionally limit progress. It is apparent why the train rarely moves at a rate greater than twenty miles an hour.

At first you do not notice the cold. But now that you have walked for a few minutes along the platform, it seems to gather itself for an attack, as if it had a personality. You draw erect with tense muscles, for the system sets itself instinctively on guard. The light breeze that stirs begins to smart and sting like lashes across the face. The hand drawn for a moment from the fleece-lined glove, stiffens into numbed uselessness. As you march rapidly up and down the platform, an involuntary shiver shakes you from head to foot. A fellow passenger, remarking it, observes:--

"It is not cold to-day, in fact, quite warm. _Ochen jarko._"

You walk together to the big thermometer that hangs by the station-door. It is marked with the Réaumur Scale, and your brain is too torpid for multiplications. But the slightly built official, known as a government engineer by green-bordered uniform and crossed hammers on his cap, is inspecting the mercury also.

"Eight degrees below zero Fahrenheit," he says. "Quite warm for January. It is often thirty-five degrees below zero here in the Uralsk."

It gets colder at the suggestion. The three starting-bells ring, and everybody scrambles into the compartments.

The express rolls onward down the Urals. You stroll back to the warm dining-room and idly watch the groups around. Across the way is an elderly mild-looking officer, whose gold epaulettes, zig-zagged with silver furrows, are the insignia of a major-general. He smokes endless cigarettes in company with another officer lesser in degree, a major, decorated with the Russo-Japanese

service-medal, smart of carriage and alert of look. By the window beyond is a young German, gazing meditatively at the hills and the snow through the bottom of a glass of Riga beer. A rather bright-mannered dame, with rings on her fingers and long pendants in her ears, chats vivaciously in French with a phlegmatic-looking personage in a tight-fitting blue coat which buttons up to his throat like a fencer's jacket. A quietly-dressed gentleman, evidently in civil life, is reading one of the library copies of de Maupassant.

Outside, cut and tunnel, hill, slope, and valley, green forest, white drifted snow, and bare craggy rocks, the Urals glide past. The little track-wardens' stations beside the way snap back as if jerked by a sudden hand, and the telegraph-poles catch up in endless monotony the sagging wires.

The Tatar waiter goes from place to place, clearing off the ashes and the glasses, and getting ready for dinner. There is a table-d'hôte repast, the Russian _obeid_, a meal which starts with a fiery vodka gulp any time after noon, and tails off in the falling shadows of the winter sunset with tea and cigarettes. Or, if one wishes, he may press the bell, labeled in the Græco-Slavonic lettering, "Buffet," and dine à la carte.

"Il vaut mieux essayer le repas Russe," says the quiet reader of de Maupassant, joining you.

He is duly thanked for the advice, and we beckon to the aproned waiter. At once the latter passes the countersign kitchenward to set the meal in motion, and puts before us the little liqueur-glasses and the bottle of vodka. While we still gasp and blink over this, he has gotten the cold _zakuska_ of black rye-bread and butter, _sardinka_, salty _beluga_, and cold ham, and has started us on the first course. Then comes in, after the omni-inclusive _zakuska_, a big pot of cabbage-soup which we are to season with a swimming spoonful of thick sour cream. The chunky pieces of half-boiled meat floating in it are left high and dry by the consumption of the liquid. The meat becomes the third course, which we garnish with mustard and taste.

"Voyons!" the Frenchman observes. "Of the Russian cuisine and its method of preparing certain food-substances one may not approve. Frankly it calls for the sauce of a prodigious appetite. But contemplating the _obeid_ as an institution so evolved as to fit into the general scheme of life, it finds merit. The Russian meal is a guide to Russian character."

"What signifies this mélange of raw fish, eggs, and great slices of flesh, and mush of cabbage-soup?"

"Not that the Russian has no taste. It is that he sacrifices his finer susceptibilities to his love of freedom. A regular hour for meals would seem to him a sacrifice of his leisure and convenience to that of the cook. The guiding principle of the national cuisine is that all dishes must be capable of being served at any time that the eater feels disposed."

This is a problem to put to any kitchen, we allow. Napoleon's chef met it by relays of roasting chickens. But one cannot keep half a dozen fowl going for each household of the one hundred and forty million inhabitants of Russia. Thus sturgeon is provided, and sterlet, parboiled so that it tastes like blotting-paper; and the filet that is called "biftek," and the oil-sodden "Hamburger," that is dubbed "filet." These can be started at nine in the morning, and be removed at any time between that hour and nine at night, without any appreciable change in taste or texture. The cook of the restaurant, like his brethren of the Empire, has laid his professional conscience sacrificially upon the national altar of unfettered meals. If the _obeid_ is not a triumph in culinary art, it is at least a signal example of domestic generalship.

We have advanced without a hitch to roast partridge, with sugared cranberries, which our friend washes down with good red wine from the Imperial Crimean estates. We get through a hard German-like apple-tart, and reach the last item of cheese.

When the mighty meal is over, we order tea, light cigarettes, and lean back in the armchairs to chat and note how our neighbors are getting through the time.

At the far end of the room a Russian has joined the French lady and her escort. They are celebrating some occasion that requires heaping bumpers of champagne. The babble of their conversation is in the air. It seems to refer to the comparative appreciation of histrionic talent in Rouen and Vladivostok!

Somebody is being treated to a dressing-down in the latest Parisian argot. "Ces sont des betteraves là-bas!" one hears scornfully above the murmurs.

Across the way some Germans are engaged with beer-schooners. One of them gets excited and brings his fist down upon the table. "Arbeit in Sibirien nimmer geendet ist; they always want more advice about their gas-plants."

In the lull that follows the explosion, a gentle English voice floats past from the seat behind us. "And so I told him that the station had nearly enough funds, but we needed workers, more workers." It is the English medical missionary on his way to Shanta-fu, discussing China with the American mining-engineer, bound for Nerchinsk.

The piano, under the corner ikon with its ever-burning lamp, tinkles out suddenly, and a man's voice starts up--

You can hear the girls declare, He must be a millionaire.

He misses a note every now and then, which does not embarrass him in the least. Caroling gayly to his own accompaniment, he forges ahead. The crowd in the armchairs around the room, consuming weak tea or strong beer, and smoking, all join with an untroubled accord and versatile accents, French, English, and Russian, in the blaring chorus, "The man that broke the bank at Monte Carlo."

The train rocks faster on the falling grade; little by little the mountains drop away; gradually the mighty forests become dwarfed into scattered clumps of straggly birches, and the great trees dwindle into bushes; lower and still lower fall the hills, until all is flat. As far as the eye can see are the snow-covered wastes, treeless, houseless, lifeless. The lowest foothills of the Urals have been passed. It is the beginning of the great steppes.

Slowly the daylight wanes. The gray darkness deepens steadily; it seems to gather in over the gliding snow, and the peculiar gloom of a Siberian winter's night closes down. At each track-guard's post flash with vivid suddenness the little twinkling lanterns of the wardens of the road. Involuntarily conversation becomes less animated and voices are lowered; the spell of the sombreness is over all.

Soon the electric lamps are lighted, and from brazen ikon and sparkling glasses flash reflections of their glitter. Curtains are drawn, which shut out the enshrouding blackness. The piano begins tinkling again; the waiters come and go with tea and liqueurs; the babble of conversation rises; and the idle laughter is heard anew. Darkness may be ahead, behind, and beside, but within there is light--enjoy it.

The train slows for a halt. Station-lamps shine mistily through the brooding night. Lanterns bob to and fro on the platform as fur-capped train-hands pass, tapping wheels and opening journal-boxes. At each door a fire-tender is catching and stowing away the wood which a peasant in padded sheepskins is tossing up from his hand-sled below. It is Chelliabinsk, whose old importance as the clearing-house of the convicts has been passed on to the new city of the railroad. Here the just completed northern branch, linking Perm to Petersburg, meets the old southern line from Samara and Moscow.

A short stop and the train moves on again. The day is done and gradually each saunters into his own warm compartment, which the width of the Russian gauge makes as large as a real room. One can read at the table by the window, under the electric drop-light, or, propped in pillows, one can stretch out luxuriously on the easy couch that is nightly manoeuvred into an upper and lower berth. Practically always after crossing the Urals, the number of passengers has so thinned out that each may have a stateroom to himself.

Presently you push the bell labeled, "Konduktor." A uniformed attendant appears standing at the salute. "_Spate_" (sleep) is sufficient direction. The sheets and pillows are dug out and the transformation of the couch into a bed is effected. "_Spacoine notche_" (good-night) he says, and you fall asleep to the rhythmic throb of the engine.

During the following hours the train enters the Tobolsk Government, the oldest province of Siberia, whose 439,859 square miles of area, nearly four times as large as Prussia, extend roughly from the railroad northward to the Arctic Ocean, and from the Urals eastward so as to include the lower basin of the Ob-Irtish river system. This ancient province has seen much of Siberia's history, whose predominant features have been two, growth and graft.

[Illustration: BRIDGE OVER THE IRTISH]

[Illustration: ALONG THE TRANS-SIBERIAN RAILWAY]

Out of evil, somehow, in a marvelous way has been coming good. In the earliest days, with what smug satisfaction did the Stroganovs find that the native inhabitants would trade ermine for glass beads! Yet the fruit of their sharp dealing and purchased protection and special privilege was the expedition that won Sibir, founded Tobolsk, and opened to Russia the way into northern Asia. The imperial commissioner who came to Tobolsk shortly after Kutchum Khan's overthrow, to collect the yassak tribute of ten

sable-skins for each married man and five for each bachelor, was detected culling the choice skins for himself, and substituting cheap ones for his master. But his agents had sought out the paths and extended the Russian Empire far into the northern forests.

By despotic oppression the inhabitants of Uglitch town, condemned for testifying to the murder of Dimitri, the Czarevitch, came here into exile in 1593, carrying with them the tocsin-bell that had tolled alarm when the Czar wished silence. But they, together with the deported laborers settled by the same arbitrary will along the Tobol River, started the permanent settlement of the new realm.

A succeeding functionary called on the natives for a special tribute of ermine for the Czarina's mantle. He collected so many bales of it that the taxed began to wonder at the stature of the "Little Mother," and sent a special deputy to Petersburg. The legate discovered that the Empress was as other women, and on his disclosures the official was unable to save his own, let alone the ermines' skins. Yet while the governor was plundering the fur-merchants of Tobolsk, the frontiers were extending, until by 1700 they reached eastward to Kamchatka and Lake Baikal, southeast to the Altai foothills at Kuznetz, and north to the Arctic Ocean.

At Tobolsk in 1710 Peter the Great established the capital of his reorganized province of Siberia. Prince Gagarin, whom he appointed its first governor, found here a systemless extortion unworthy of an efficient statesman. With the thoroughness of genius he built up in the unhappy province a regular organization of rascality. His pickets patrolled the roads into Russia, to prevent the escape of those who might carry the tale of his oppression. He arranged with high officials at Court that any petitioners who evaded this frontier net should be handed over to an appropriate committee. Thus fortified, he began collections of as much as could be wrung from his luckless subjects. Every traveler paid Gagarin's tariff, every farmer sent him presents of stock, every trapper forwarded the best of his catch. The fur-trader's donations and the merchants' loans were assisted into Gagarin's warehouses by thumbscrew and thonged knout.

While these things passed in Tobolsk there came periodically to Petersburg delegations of outwardly contented citizens attesting the wisdom of their governor. They brought to the Czar and the Grand Dukes, in addition to the punctiliously rendered tax yassak, gifts of especially fine furs. Such was the completeness of Gagarin's control that not an echo of the true state of affairs reached the ears of the astute Peter.

At length, in 1719, Nesterov, the Minister of Finance, was privately approached by some Tobolsk merchants and was supplied with evidence sufficient to hang half the officials in Siberia. In a dramatic presentation the Minister furnished this to the Imperial Senate, showing so bad a case that Gagarin's own agents in the ducal circle rose up against him. The Czar sent Licharev, a major of the Guard, to Siberia, to proclaim in every town and hamlet that Gagarin was a criminal in the eyes of the Emperor. As this messenger approached Tobolsk, official after official came out to turn state's evidence, trying to assure his personal safety. The highways to Russia were guarded by Peter's own troops, with orders to seize all outgoing travelers who might be transporting Gagarin's accumulated spoil, which with commendable prudence the Czar had allocated to himself.

When Peter was in England he had remarked casually to an acquaintance, "In my realm I have only two lawyers, and one of these I intend to hang as soon as I get back." It was particularly unfortunate for this ex-governor that the remainder of the legal profession did not feel himself called upon to explain to Peter the Gagarin campaign contributions. No one ever needed an attorney more. He was under trial before an imperial judge who did not know a technicality from a tort, and whose preliminary procedure was to order a reliable gallows.

For some score of years subsequent to Gagarin, the governors of Siberia were, in any event, moderate. The province grew apace, increased by exiles, by land-seeking colonists, by raskalniks,--nonconformists of the Greek Church, self-called "Old Believers,"--who preferred to come to Siberia rather than follow Peter's orders and shave off their beards.

Then Chicherin the Magnificent came. His life was a round of celebrations. Wonderful stews he concocted for his sybaritic revels. At _obeid_ an orchestra of thirty pieces supplied the music. Artillery in front of the residency saluted him with salvos when he drove out. In Butter-Week all Tobolsk drank the spirits which their governor bountifully provided. It is hardly necessary to say that the money for these entertainments did not come from Chicherin's private purse: the city merchants groaned over forced loans and benevolences; and at last their cry reached the throne, and Chicherin too was removed.

With his passing, the Tobolsk Province fell to less spectacular rulers, but under good and bad it grew steadily, until in 1860 there were a million inhabitants within its borders, a population which at the present time has risen to a million and a half. Some forty thousand of these are exiles; some eighty thousand raskalniks; and forty thousand Tatars, who feed the flocks where their ancestors once bore sway, living peacefully side by side with the Russians. Some fifteen thousand are descendants of the

Samoieds and Voguls with whom the first Stroganov from the adjoining Russian province of Archangel traded his wares. Some twenty thousand are Ostiaks whose forebears were alternately allies and enemies of Yermak.

The capital city, Tobolsk, on the Tobol River hard-by its junction with the Irtish, has grown from a precariously held camp of two hundred and fifty fugitive Cossack soldiers to a city of thirty thousand. Tiumen, the easterly city on the Tura River, another of Yermak's camps, has grown into a great distributing-centre for produce brought by the river-highways. From the railway line northward as far as the city of Tobolsk extends a farm-belt, a continuation of the black-earth region of great Russia. The fertility of the land may be judged by the number of villages met as the train speeds on, and the large proportion of enclosed fields on both sides of the track. Some of the finest agricultural soil in the world lies here, such soil as composes the prairies of Minnesota and Dakota. Three million head of live stock graze in the district, which has a yearly production of ten million hundredweight of wheat alone, four million of rye, and nine million of oats. Five million more settlers may live and thrive, and the harvest will feed the ever-growing cities of Europe when Siberia comes to be the new granary of the old world. The stress and turmoil of Tobolsk are passed. Happy the people who have no annals!

Gradually, as the train rolls eastward beyond the Ishim River Valley, the farm country opens out into the unfenced prairie of the Great Steppe. The clustered wooden villages that flanked the line through Tobolsk appear less and less frequently, till at last we seem to glide over an immense white sea, frozen into perpetual calm and silence. Here and there a gray thicket of stunted trees and bushes, here and there a grove of naked-limbed birches, mutely exhibit Nature's desolation.

As the sullen landscape bares itself, one thinks of the prison caravans tramping these wastes; of the early neglected garrisons which Elizabeth's favorite General Kinderman proposed to victual on crushed birch-bark and relieve the Crown of their expense; of all the misery and the wrong that the steppes of Siberia have symbolized. No sign of man's handiwork or of Nature's kindliness is seen,--only the cold snow and the bare birches, while regularly as the ticking of a clock the telegraph-poles and the verst-spaced stations snap back into the wastes. The dominant reflection is not, how great is the achievement which has mastered these steppes! but, how infinitesimal is all that man has done in this ocean of untrodden snow! Hour after hour we are driving on. Yet never is there passed a landmark to conjure into imagination a picture of progress. One moves as in a nightmare, where he runs for seeming ages, hunted forward, yet can never stir from the spot. The horizon-bounded circle of vision is as the ever-receding rim of a giant dome, the rails ahead and behind bisecting its white immensity. Above, the vast bowl of the blue sky dips and meets it, imprisoning us. Where are the fields and villages; the bustling activity of human life that tells of man's mastership? Hour after hour passes without a change in the drear monotony of the landscape; for miles on miles not a trace is seen of human dominion. Grim Nature spreading her shroud over plain and pasture is despot here, and Winter is ruler of the Siberian Steppe.

One could ride due south a thousand versts, through Golodnia the "hunger steppe" to the borders of Turkestan, and find the same monotonous plain, snow-covered save where the dryness of the south has thinned its fall. One could ride from the Caspian Sea due east to China, with each day's march a counterpart of the rest. Five hundred thousand square miles of area are covered with grass and gaudy flowers in the spring, with low brush and green reeds where the salt swamp-lakes receive the tribute of snow-fed streams. In midsummer the growing grass scorches under a heat of 104°. In winter snow is everywhere,--in feathery flakes that the midday sun does not soften during whole months of a cold which is a ferocity. Thirty to forty degrees below zero is not unusual, and the land is swept by bitter winds that pierce like daggers through doubled furs and felts. Yet there dwell on the central plateau of Asia a million people, and one million cattle and three million sheep are scattered over the tremendous range. As the herds have become hardened through the centuries and survive in measure despite the severity, so also have the men. From the train-windows now one may chance to see infrequent straggling herds of long-horned cattle, lean and gaunt, scratching away the snow in search of food. Mounted on little shaggy ponies are figures buried in skins, who keep guard over them.

One detects a new type among the crowds at the stations,--flat faces, round eyes, square thickset bodies. Here on the borderland, the old race has fused with the Slav and has become metamorphosed. The sons of the Tatars, whose very name was distorted into that of a dweller in Tartarus by those who feared their fierce valor, have become shopkeepers, train-hands, waiters, and butchers, who come to sell meat and milk to the chef of the wagon restoran. Sometimes, at the stops, figures, gnome-like in enveloping red capote and grotesquely padded furs, hold their ponies with jealous rein, staring curiously at the locomotive and passengers.

[Illustration: DINING-CAR SALOON, VIEW OF THE LIBRARY]

Looking long from the windows at this steppe, a drowsy hypnotism steals over the mind--a dull stupor of unbroken monotony. It is better to do as the Russians--pay no attention whatever to the landscape outside, but make the most of the life within the moving

caravansary,--cards and cigarettes and liqueurs, tea and endless talk, with yarns that take days for the spinning.

The uniformed judge, passing by, joins you. He is traveling to a new appointment with his swarming family of children, shawl-decked females of unknown quality and quantity, the household bedding, and the ancestral samovar, all crowded into one stifling compartment. He discusses volubly the confusions of the Code, and propounds a unique theory of his own as to Russian jurisprudence, to the effect that all the best laws of other nations have been adopted, with none of the old or conflicting enactments repealed. The general drops into the circle. He is interesting when one has pierced the crust, but dogmatic. At every station the soldiers of the garrison, not on sentry-duty, jump to one side, swing half-around, and stand at the salute until he passes, to the huge inconvenience of the porters. He would undoubtedly vote the Democratic ticket to repay Mr. Roosevelt for putting Russia under the alternative of stopping the war perforce, or forfeiting sympathy, when Japan was said to be breaking under the strain.

"Russia was beaten this time. What of it? _Nietchevo!_" says the general.

"_Nietchevo_," we echo, as we sip our tea.

"But the Japanese are wily insects," observes his companion, the young service-medaled major. "I was in Vladivostok when our prisoners came back. They tried to get money for the checks the Japanese had given them. That was how the big mutiny began. You know, when our men were taken captive, the Japanese treated them very well, much good food, vodka, let them write home all about it, and gave them enormous pay, six yen, three dollars a month, charging the expense all up to the Czar for after the war. When at last the prisoners were to be released, the Japanese promised every man double pay, twelve roubles. But they gave them the money? No, the insects gave them each an order payable by the Russian commander in Vladivostok. So the transports came, and these men were sent ashore with these checks in their hands, and they went up to the commandant of the city, and asked for their cash that the Japanese had promised. What money did the commandant have for them? What could he do? He ordered them to go away. So they stood and discussed on the street-corners. And more men still came from the transports. Then they said, 'We will ask the general of the forts.' So they marched to the forts in a big crowd, and the general he also told them to go away. For a long time they talked and they persuaded the sailors to help them. So they went again to the forts, and the sailors shot at the forts, and the general ordered the artillery to shoot. But the artillery would not, so the men broke in and killed the officers and got arms and went back to the city commander. Him, too, they killed, and all Vladivostok was in mutiny for two weeks. Not an officer dared show himself. General Orlov persuaded them to let him into the town. Then many were shot, but at last the city was quiet. The Japanese are very sly insects."

His story ends and the two officers go back to join their families. The train throbs on across the steppe.

The German gas-plant drummer, with his new Far Eastern outfit, is gathering from the missionary doctor details of treaty-port life, which are being treasured up as valuable reference data. The French fur-merchant dips back into his library copy of de Maupassant.

The rigor of the outside scene seems at length to be changing. A few scattered houses appear, and trees and fenced fields, and villages, with curling smoke rising from the chimneys. Men and children are walking about, and finally we come to the Irtish River, over which the train rumbles on a half-mile bridge. Spires and gilt domes are visible, dark wooden houses, and bright white-painted churches with green roofs. Droshkies and carts are passing in the streets, and presently we draw up to the station of Omsk, the second city of Siberia.

The junction of the Trans-Siberian Railway with the Irtish River, which is 2520 miles long and open from April to October, would of itself make Omsk a centre of great strategic importance. But in addition to this main river-highway, which is navigated by some hundred and fifty steamers, there are affluents by which one can sail from the Urals to the Altai, from the Arctic Ocean to China, and these lines of communication centre here.

From Omsk, following the Irtish down past Tobolsk, one can steam by the Obi to Obdorsk, within the Arctic Circle. Indeed, a regular grain-export service was planned via the Kara Sea to London by an ambitious Englishman. It failed after some promise of success, because of the ice-packs in the Gulf of Obi. From Omsk, following the Irtish upstream, steamer navigation extends as far as Semipalatinsk, in the Altai foothills. Smaller craft may go nearly to the Chinese frontier.

By the Tobol and Tura rivers, Tiumen, in the Ural foothills, may be reached, four hundred and twenty miles from Semipalatinsk. By ascending the Obi, a boat may go fourteen hundred and eighty miles east from Tiumen to Kuznetz on the Tom; through a canal from an Obi confluent the Yenesei River System may be entered, and from it by a short portage the Lena System. In all

twenty-eight thousand miles are navigable by small craft, and seven thousand miles by steamer. Omsk is the pulsing heart of this mighty interior waterway system.

[Illustration: TIUMEN TOMSK PERM CITIES OF NEW RUSSIA]

The train leaves the station, which is at a distance from the town, and once more we are en route. The eye rests gratefully upon the ribbon of cultivated fields which follow the Irtish down. But we reënter the steppe, and again the desolation settles over all. In hours of looking, not a habitation is seen, not an animal, not a tree,--only the same white billows. This Barbara district in the Tomsk Government has an area of fifty thousand square miles. Kainsk, some seven hundred versts from Chelliabinsk, is the centre. The section, though covered with the fertile black earth of the adjoining regions, is, owing to lack of drainage and adequate rainfall, arid and almost untilled.

The round-faced civilian from the compartment further up, whose familiarity with the country has made him a welcome accession, joins us at the window. He looks out over the level plain of the Barbara Steppe with manifest satisfaction.

"You admire the landscape?" we ask satirically.

He smiles. "We got big money when the line went through here. I made my first fortune then."

He sighs at the memory of old times, and tells of the railway-building days when the Czar had given the order for a road across the continent, and the soldiers of fortune, of whom he was one, had gathered to the task.

"Not a kopeck had I when the Dreyfus brothers made their big speculation in Argentine wheat and went down, leaving us young clerks stranded in Kiev. You know Kiev? Great pilgrimages come there to see the bodies of Joseph and his brethren, all preserved just as when they died. We heard by accident of a grading job under a big contractor out here. None of us knew anything about construction, but three of us grain-clerks wrote a letter saying we would put the work through, and started. We had just enough money to get to Samara. In Samara was a merchant much esteemed, whom I went to see. He went on our bond, never having seen us before, and gave us enough money to come. So it was in the old days. The country was flat as a board. We had but to lay down the ties and spike the rails. Thirty versts we made of this line. It cost us thirty thousand roubles a verst, but we got fifty thousand. Would that we might do that now again."

The contractor, his round jolly face glowing with the recital and his eyes shining through gold-rimmed glasses, is entertaining a growing company, for the judge has stopped to gossip, and the railroad official.

"I took my money and bought an estate in the country of the Don Cossacks," the contractor is saying. "I paid ten per cent to the Government for taxes when I bought the land. I had to pay no more taxes then all my life, but my heir would pay taxes, or, if I sold, he who bought would pay. So it was done in the Hataman Government."

"It is just," says the judge. "Why should they, who get the property, not pay taxes?"

The contractor shrugs his shoulder and continues: "For five years I farmed, and though I had a German overseer, I did not prosper. So I went to one of the cities of Russia and thought to put in a tramway. The men of the city said, 'Are all the horses dead? He of the spectacles is mad.' Yet by importunity I got them to give me the right to make a tramway. There were in Petersburg then many Belgians, with much money, wishing to give it away. So I went to them and said, 'Here is a great franchise, but who will build the line and gain the riches?'

"'We will, we will,' said the Belgians.

"From them I got a hundred and eighty thousand roubles clear, and an interest. I sold the interest quickly to other foreigners, Frenchmen, and went away. Yes, the tramway was built, and the people crowded to ride on it as I had said. But when it was going well, and the profits were yet to come, the people said, 'Shall foreigners oppress our city?' So the town bought the tramways for what they said was the cost, and the Belgians went away. And they did not come back to Russia. Thus were many railways and tramways built and taken. The foreigners will not come back now, and Russians too do not enter these pursuits, lest the Government come after them later. It is _hudoo_ (bad)."

"But is it not worse that these men should make a tramway and draw vast money from the people?" says the railroad official. "For me, I think the Government should do it all."

"_Ni snaia_, I don't know," says the contractor. "But I who bought stocks with the Belgians' money (foolishly thinking that the business which I knew not was safe, while that which I knew was shaky), I will not give again to the stock-people the money I shall make from the oil-fields of Sakhalin, where I go now."

"But," says the railway chinovnik, "does not the State do these things better? Look you at this very railway. For years any who wished might have built into Siberia. An Amerikanski, and Collins, an Angleski, came proposing railroads, but all things slumbered. Then in 1891 the Czar ordered the road to be built, and in ten years we had laid the eight thousand versts to Vladivostok. I read that the line of Canada, where too there are steppes and highlands as ours, took ten years for but half the distance. We made two versts a day for all the years, and they but one. Who other than the Government could spend a billion roubles for a line that will bring money returns only in the far future?"

"Ah, you chinovniks, you say, lo, we do all this! But it was such as I built that road, and because you gave us big money. And is not the money to support it now got from the peasants' taxes while so many clerks and operators waste time in the offices? I have seen a third as many men as at Omsk do the same work. And your trains go as the water-snails, twelve versts an hour for freight, twenty versts an hour for the mail-trains, thirty-five versts for the express. One can go eighty versts in Europe."

"Truly, truly, but why go so fast? It costs more for fuel, and the track has to be made straight. What good does it do you to come in sooner? If a man is in a hurry to get somewhere, can he not take an earlier train?"

The group mulls over this knotty point of logic, which is complicated by the fact that our own train is twelve hours late. They cite hypothetical men with varying sorts of engagements, and then lightly switch to talk of the nourishing properties of beer, the utility of agricultural machinery, and the old tiger battue of Vladivostok.

The birch groves become more frequent now, pines begin to appear, and at last the country has become forested. Several of the passengers bestir themselves for departure, gathering multitudinous bundles, and making the circuit in demonstrative hand-shaking farewells.

"We come to Taiga, whence they go to the stingy town of Tomsk," the government engineer observes.

"Why do you call it the stingy town of Tomsk?"

"I will tell you. Tomsk, before the railroad came, was the biggest, finest, and wealthiest of our cities. She was the capital of the great Tomsk Gobernia, with three hundred and thirty thousand square miles of area, and a million and a half people. The Tom brought the big river steamers to her wharves. In the city she had sixty thousand inhabitants, increasing every year; a university, Stroganov's Library, a cathedral, fine public buildings. The merchants were rich; the miners came down from the Altai; all things were prospering. When the railway was ordered, the engineers came through to locate the line. All they asked was a hundred thousand roubles. But how stingy were the people of Tomsk! They had given two million roubles for their university, where the students made speeches and got sent to the Yakutski Oblast, yet they would not give a hundred thousand roubles to the engineers. 'Give fifty, give even forty thousand,' said the engineers. But the people of Tomsk said, 'Are we not the seat of government for all western Siberia? Have we not Yermak's banner in the cathedral? Are we not Tomsk? You must bring the railway here anyway.' But if the engineers had done that, who could say where it would have ended? All the other cities would begin to make excuses. So the grades to Tomsk became suddenly so bad that the line had to be run away south here, eighty-two versts. The station where one changes was named, in mockery, Taiga, 'in the woods.' The merchants flocked out begging the engineers to come back to Tomsk. They offered all that had been asked and much more. They hung around the office and wept over the blue-prints. But how can a professional man change his plans and sacrifice his reputation? One cannot do such things. So Tomsk was left, and her trade now falls far behind that of the other cities, Omsk and Irkutsk. We in Siberia smile at her and call her the stingy city of Tomsk."

"We have, too, another jest, of the Tomsk Czar," chimes in the judge. "There appeared one day there a stranger calling himself Theodore Kuzmilch, who bought a little house which he never left save to do some act of charity. For years he lived; then, when he died, the house was turned into a chapel because of his good deeds. Many years after his death, a merchant started the tale that this was the Czar Alexander I, who did not die in the Crimea, but left a false body to be carried to Petersburg and entombed in state. He had, it was told, not really died, and, disappointed at his powerlessness to help his people, had come, self-exiled, to Siberia. But we others laugh at this tale of Tomsk as an imperial residence."

The twenty minutes' stop at Taiga ends, and the train renews its journey through the forests.

With rolling hill and long-stretching forests, the watershed bounding the eastern limits of the Obi Basin is crossed near Achinsk, and the drainage-basin of the mighty Yenesei River, one million three hundred and eighty thousand square miles in area, is entered. It just fails to equal in length the Mississippi-Missouri System. Including the administrative territory "Yeneseik" of the East Siberian Gobernia, the river sweeps from the Chinese borderland north beyond the Arctic Circle. In the far south, where it rises among the Minusink Mountains, the valley country is like the Italian Alps, mild and very fertile. Iron-mines of prehistoric antiquity are found in these valleys, relics of the old Han Dynasty of China.

Of the twenty million bushels of grain produced throughout the Yeneseik territory, nearly a third comes from the Minusink oasis. The railroad pierces the central plains, farmed in the most favorable spots only, and capable of enormously extended cultivation.

Through alternating forest, field, and plain the train moves on, and crossing the three thousand-foot Yenesei bridge, enters the city of Krasnoyarsk. When we pull out, the engineer, who has been chatting with the erstwhile contractor, observes, "This town was a main hotbed of the great strike. They are well in hand now, but we had our time with them in 1905. Even I knew nothing of what had been prepared."

He goes on to tell the most curious tale of the organized strike movement which introduced the disturbances subsequent to the Russo-Japanese War.

"On September 15 at noon, no one knows by whom or from what station, a signal of dots and dashes was tapped off. Each telegraph-operator answered the message and passed the word to the next, standing by until it was repeated back. Then, leaving all things in order, he stepped from the operating-room into the railway-station. With a motion he gave the countersign to the ticket-sellers, and each, as he received it, shut his desk, and walked out. The word went to the engineers, and each, at the signal, drew his fires and left the engine and its train forsaken on its tracks. Every postman put away his mail, closed the safe, and left his office; every diligence-agent locked his doors. From Astrakan to Archangel, from Warsaw to Vladivostok, the electric summons went, and the whole realm of Russia was paralyzed.

"With two thousand roubles, offered by the Governor-General of Poland, before them, and ten bayonets on the tender behind, an engineer and a fireman were secured to run one coach, containing a terrified prince, from Warsaw to the frontier. In the south, a few cars were started by soldiers, but beyond such rare instances, for three weeks not a train was moved. More than this, not a telegram was transmitted, not a letter delivered. Everywhere was black silence, as if all the Russias had been swept from the face of the world.

"'More wages, and the constitution,' was the slogan of the strikers. The official cohorts met the issue courageously, with bribes and bayonets, and little by little got the upper hand. Force and money were used unstintingly to win the operators needed and break the front of the strike. A few, who, contrary to the expectations of their mates, had remained loyal to the officials, were finally secured and protected by the soldiery. As in time one train after another was manned and moved, the men who had stayed away lost heart, knowing but too well what would be the fate of those who were left outside the breastworks. First singly, then in crowds, they returned, and the great strike was broken."

"Here in Krasnoyarsk there was revolutionist rule for a while as well," the manager remarks. "The troops were driven out, and we had to wait for reinforcements. Yet when I came to my office there were sixty thousand roubles in the safe, not a kopeck of which had been touched. Some of the best employees were condemned. I was very sad, and the service was very poor when they marched away."

"What became of them?" we ask.

In a low voice he answers, "They went to the Yakutsk."

Everybody is silent for a moment.

"Where did you say?" inquires the missionary.

"The Yakutski Oblast," answered the chinovnik.

In Europe people talk of the rigors of Russia's winter. In Russia of the cold of Siberia. In Siberia, along the railway, when the thermometer gets down into the forties and the sentries pick up sparrows too numb to fly, they say, "It's as cold as the Yakutsk."

"One starts to the Yakutsk by the steamer-towed prison barge, following down the Yenesei from Krasnoyarsk," the engineer continues. "For the first thousand versts northward the way is through a mighty forest region. The interior is almost as unknown as when the Samoieds were its sole inhabitants. Marshes covered with trembling soil, to be crossed only on snowshoes, alternate with thickets, called _urmans_, of larches, cedars, firs, pines, and beeches."

"It is not alluring," we observe.

"The cold of the winter seems largely to arrest decay, and the fallen trees, remaining unrotted, form a nature-made _cheval de frise_, impossible to traverse save along the hunters' trails. Another thousand versts up the Upper Tunguska River, at whose limit of navigation is a crossing into the Lena System, and the Yakutsk Province begins; eastward to the coastal range overlooking Behring Sea, and northward to the Arctic Ocean, a million and a half square miles of desolation, extends this exiles' oblast. Prison-stations are located in the forsaken tundra country beyond the Arctic Circle, where scattered clumps of creeping birches and dwarf willows struggle to maintain existence in the few unfrozen upper inches of ground, congealed perpetually beneath to unmeasured depths. Here, where the average winter temperature is eighty below zero, come the exiles deemed most formidable."

"How long do men last in the Yakutski cold?" we ask the engineer.

"Oh, sometimes a strong man will outlive his sentence and return. The friends of our strikers ask me sometimes about one or another, but we have heard nothing of them since they marched away in chains. May fate keep us from that road!"

The theme is not enlivening, and soon we go forward into the observation-car.

After crossing the Kan River at Kansk, the railroad turns abruptly southwest, through the hilly country of the Irkutsk Gobernia, and climbing into the highlands of the Altai, enters the watershed of the Angara. The drainage-basin of this river equals the combined areas of Iowa, Illinois, Indiana, Ohio, Pennsylvania, and New York. It is as well adapted to agriculture as parts of the best provinces of Central Russia in the same latitude.

The train pulls next into the station of Nishneudinsk. A booted peddler is making his way down the platform, with knives, combs, caps, and cheap knick-knacks. He stops to show us something special, a miniature of multicolored minerals, glittering from a hundred crystal facets. The Russian engineer picks out the flaky quartz, the iron pyrites,--"fools' gold," as they called it in old Nevada times,--green porphyry, iridescent peacock ore of copper, and some black crystals like antimony, which show here and there. Malachite, serpentine, topaz, and numberless other minerals are in the mass, which glitters in kaleidoscopic changes. A small piece of gold ore tops the pile.

"Cabinetski?" asks the engineer.

"Da, da," assents the peddler. "Cabinetski."

"It comes from one of the domains of his Imperial Majesty's Cabinet," explains the engineer. "Stretches of forest, belts of fertile river valley, fur districts, hundreds of thousands of square versts, the best mines in these Urals which produce sometimes yearly seven million roubles, the entire Nerchinsk region, producing six million roubles, are 'cabinetski,'" he remarks. "Even I, Ivan Vasilovich Poyarkov, am 'cabinetski'!"

He explains the origin of the term, going back to the old days when princedoms went to the courtiers of Catherine. Always for a great enterprise it was necessary to have a friend at Court. So the rich merchants and miners would form, with powerful members of the inner circle at St. Petersburg, alliances such as that made by the Stroganovs with Boris. Gradually, as time went on, the protected were swallowed by the protectors, until one by one the various estates had passed into the hands of the nobles of the Imperial Court. The mines in the Altai, which Demidov had opened up, were taken over in 1747 by the Emperor, those in the Zabaikalskaia Oblast at about the same time. With the passing of the years, what had been graft and expropriation was transmuted into vested interest, until now it is the established right of the Imperial Cabinet, or the Grand Dukes, to receive the revenues of these vast domains. In the mining regions their perquisite is from five to fifteen per cent. Save for the tax, however, miners are free to operate upon the ducal estates, and many are thus engaged.

A fur-capped station-agent clangs the big bronze bell, waits a moment, and then clangs twice. The passengers climb back into the box-like steel cars of the express. The third bell sounds, and the train starts. We sit down beside the engineer and the conversation takes up the "cabinetski" again.

"We have great traditions. One Governor, Neryschkin, of the 'cabinetski' mines at Nerchinsk, marched to fight the Czar. In 1775 he was appointed chief of the mineral belt in the Zabaikalskaia Oblast. He sat for eleven months at home with closed shutters. Then, on Easter Sunday, singing a devil's hymn, and with a fat female on either side, he drove to church and ordered the service amended to suit a rather bizarre taste. He organized a series of glittering shows at the Crown's cost, gave free drink to the populace, and throwing out many of his subordinates, appointed convicts in their stead. When he had used up all the tax-money in his keeping, he drew up cannon before the house of the rich merchant Sibirayakov, the operator of the mines, and made him hand out five thousand roubles. Finally he got together an army of Tunguses and the peasants, to march against the Czar. He was caught on the way and sent to Russia for punishment. It is the great honor of our service to be governor over the 'cabinetski' mines. Perhaps I shall rise there some day. Perhaps not. But I shall not march against the Czar."

The forests of birch and pine and fir, and the hills, as the car drives eastward, close in again. The crests of mid-Siberian mountains lift their snowy heads, and the train climbs up and up toward the great central Lake Baikal, and the city of Irkutsk, 3378 miles from Moscow, and further east than Mandalay.

When, on this seventh day, the train is winding up the Angara Valley toward Irkutsk, one may mentally look back over the country that has been traversed and estimate somewhat the meaning of the railway. The Urals formed the first landmark. As in the dominion of the blind the one-eyed man is king, so after the monotony of the plains, the Ural Mountains seem great and worthy of the name given by the old Muscovite geographer, the "Girdle of the World." By actual measurements, however, in their seventeen hundred miles of length, no peak rises over six thousand feet. Coming eastward from the Urals the line has cut through the southwestern corner of the old Tobolsk Government, has skirted the northern border of the steppe, has bisected the Tomsk Province, and after crossing the Yenesei River in Yeneseik has entered Irkutsk Province, and traversed the central highland region nearly to Lake Baikal.

Many who journey this way will have as their first impression, when the long winter ride draws to its close, a feeling of depression, almost of discouragement, so few are the settlements, so desolate seems all Nature. They see the single line of rails, without a branch or feeder in the mighty expanse from Chelliabinsk to Irkutsk, save for the stub put in for the ungenerous outlanders of unlucky Tomsk. They calculate that for a territory forty times the size of the British Isles, and one and a half times as large as all Europe, the inadequacy of a railroad less in total mileage than the Chicago, Milwaukee and St. Paul, is manifest. Statistically-informed bankers sometimes shrug their shoulders at the mention of the Trans-Siberian. "Every year a deficit," they say. "Gross earnings but twenty-four million roubles,--one sixth of the Canadian Pacific Railway; one tenth of the Southern Railway. _Hudoo_ (bad)!" One hears expressed not infrequently in Russia the opinion that the railway is a sacrifice justified politically by Russia's need for a link to the Pacific, but ineffectual to secure prosperity and advancement to the isolated land of mid-Siberia. It is deemed, like the Pyramids, a monument to colossal effort and achievement but of little service to mankind.

Their statistics are correct. But it is to the greater honor of the road that much which it has accomplished will never appear in credits on the account-sheets. Where the white stations of the Siberian Railway stand now were once the wooden prison-pens with their guarded stockades. Murderers and priests, forgers, profligates, and university professors, highway robbers and privy councilors, all together have tramped this way. It is its past from which the railroad has raised Siberia, the past of neglect and exile that this steam civilizer has banished to the far Yakutsk.

Closer study gives, too, a better appreciation of the railroad's economic significance. The line holds a strategic position as truly as does the Panama Canal. Though in Siberia proper there is the enormous area of nearly five million square miles, so much of this is in Arctic tundra, impassable swamp, forest, or barren steppe, that the really habitable and arable land narrows down to a tenth of this, which lies in general between the parallels of 55° and 58° 30' north, and is contained within a belt some thirty-five hundred miles long and two hundred to two hundred and fifty miles broad.

When it is noted that the tillable area of one hundred and ninety-two thousand square miles in Tobolsk and Tomsk, mostly along the Obi System, the stretch of twenty thousand miles in the steppe, and that of one hundred thousand in the Yeneseik and Irkutsk governments of eastern Siberia, are all in immediate proximity to the railroad, whose course is generally along the 55th parallel, the economic value of Russia's great enterprise takes a different perspective.

Its vantage is still more emphasized when the element of the north and south watercourses is considered. One after another the great Siberian rivers are crossed,--in the Tobolsk Gobernia, the Tobol, the Ishim, the Irtish; in the Tomsk Gobernia, the Obi and the Tom; in Yeneseik, the Yenesei; in Irkutsk, the Angara. Each of these reaches far up into the agricultural zone that lies north of the

railroad, bringing the harvests to its cars by the cheap unfettered water-avenues. Thus, to the part of Siberia that is capable of extensive development, the railroad is even now in a position to give great aid.

It is from such natural factors as these, not from financiers' figures, that one must weigh the potentiality of this great line. Its direct value is enormous, its indirect commercial services greater yet. It may best be compared to a mighty river system such as that of the Mississippi. The latter's traffic has never directly returned a dollar of the millions that have gone to maintaining its levees and training-walls and channels. Yet indirectly the return and the value, as an asset to the American people, are so great as to be incalculable. From its controlling position in relation to the cultivatable land and the interior watercourses of Central Siberia, as well as in relation to the far eastern artery, the Russian railway is an empire-builder as important as has been the Nile.

The results already achieved are noteworthy. The city of Omsk, where the railroad and the Irtish River lines meet, has risen from a population of thirty-seven thousand in 1897 to seventy thousand in 1908. Further east, Stretensk has sprung from a town of two thousand people ten years ago to over twelve thousand to-day. Irkutsk has climbed from sixty to over eighty thousand since the railroad opened.

[Illustration: ISLAND OF KALTIGEI VILLAGE OF LISTVIANITCHNOE LAKE BAIKAL]

The rural population has increased even as that of the cities. At the beginning of the seventeenth century, all Siberia contained but two hundred and thirty thousand souls; at the end of the eighteenth, one million five hundred thousand; at the end of the nineteenth, five million. Now, with the railroad-induced immigration, it approaches the seven million mark. The Steppe Government alone has risen in fifty years from five hundred thousand to one million five hundred thousand, and the Tomsk from seven hundred thousand to two million five hundred thousand.

More in importance than its present utility is the fact that the railway holds the key to Siberia's future. The arable territory of the belt is equal to that of Michigan, Wisconsin, Minnesota, Ohio, Indiana, Illinois, Iowa, Missouri, Kansas, Nebraska, and the Dakotas combined. This land is generally well-watered, in a climate suitable to grain-raising, and it is, as has been shown, in its whole extent, adjacent to river and rail transportation.

While such farming districts of the United States have some fifty inhabitants to the square mile, the most densely populated gobernia, Tomsk, has but six, and the Yeneseik but six tenths of one.

An immense further area will yield to clearing and to irrigation, as has been demonstrated in the great results secured from five hundred versts of canals in the Barbara Steppe. Coal and iron are available in many places, and timber in the greatest abundance grows in the northern district.

From a summary of these elements one may glean an idea of the Colossus sleeping beneath these snows. At a normal rate of increase, fifty million souls should populate Siberia at the close of the twentieth century. The agency of their coming and existing will be primarily the line of rails across the continent. Despite the eight hundred million roubles expended, with only far-off hopes of profit, the faulty road-bed, the light rails, the steep grades, and crawling trains, the glory of Russia is still "The Great Siberian Railway."

III

IN IRKUTSK

The train pulls slowly up to the white station-house at Irkutsk. A swarm of porters, _nasilchiks_, white-aproned, with peaked hats, and big, numbered arm-tags, invade the carriage. They seize each piece of luggage and run with it somewhere into the crowd outside. You, encumbered with your heavy coat, laboriously follow. Irkutsk station, more than any previous one, is crowded with passengers and Cossack guards. Train officials are shouting instructions, and every few paces a sentry is standing his silent watch. This is the transfer entrepôt for all through traffic, as well as the depôt for the largest and most important city of Siberia.

Threading the press on the platform, you struggle with the outgoing human current, and in time reach the big waiting-room of the first class. It likewise is crowded with a mass of people, and its floor is cumbered with heaping mounds of baggage. One of these hillocks is constructed from your impedimenta, which are being guarded now by a porter, apparently the residuary legatee of the half-dozen original competitors within the car. The man takes the long document that witnesses your claim to two trunks, and departs. Upon you in turn devolves sentry duty for the interminable time during which those trunks are being culled out from the

baggage-car.

It is an exasperating wait, but the fundamental rule for Russian traveling is, "never separate from the baggage." The parcel-room here at Irkutsk held for six months a suit-case left by a friend to be sent to this traveler. The officials would not give it up to its owner or to any person save the forwarder, though he, oblivious to sequels, had gone on to San Francisco.

Like the rest, now, you camp, with the baggage in front of you, on the waiting-room floor. It is a very country fair, this station. At the far end is a big stand crowded with dishes, on which are cold meats, potato salad, heaps of fruit and cakes, sections of fish from which one may cut his own slices, boxes of chocolates, and cigarettes. All are piled up in heaping profusion. One can get a glass of vodka and eat of the _zakuska_ dishes free, or while waiting he may buy a meal of surprisingly ample quantity and good quality at the long tables that run down the centre of the room. Most of the Russians order a glass of tea, and with it in hand sit down till such indefinite future time as the luggage situation shall unroll itself.

We move our baggage and join the tea caravan. Across the table is a slight, brown-faced man, with an enormous black astrakan cape falling to his ankles, and wearing a jauntily perched astrakan cap on his head. "One of the Cossack settlers," a friend from the train remarks. Beyond are half a dozen tired-looking women, with dark-gray shawls over their heads. Near them are men with close-fitting _shubas_, or snugly-belted sheepskin coats, fur inside, and rough-tanned black leather outside. Beside the lunch-stand are a couple of young men with huge bearskin caps, short coats, and high leather boots tucked into fleece-lined overshoes.

A general at one of the little side tables is talking volubly to a plump dame with furs, which are attracting envy from many sides. The lady merely nods between puffs of her cigarette, and sips her tea. A large fat merchant waddles past, wrapped in a paletot made of the glistening silvery skin of the Baikal seal. The room is stifling, full of smoke, and crowded with people. Yet no one seems to feel the discomfort, even to the extent of taking off the heavy outer coats, which, with the thermometer at twenty degrees below zero, they have worn on the sleigh-ride in, from across the river.

Your friends of the train, save those whose possessions were comprised in their multitudinous valises, are all here, fur-coated likewise and sipping tea, waiting, without a thought of impatience, for the baggage to be brought out.

At last appears your _nasilchik_. "They are got," he cries, and balances about himself, one by one, your half-dozen pieces of luggage. Through the noisy, gesticulating, thronging passengers and heaped belongings, he shoulders and squirms a way to the door and into the anteroom.

A couple of soldiers are good-naturedly hustling out, from the third-class waiting-room opposite, a little leather-jacketed and very dirty mujik.

"I did not owe seven kopecks. I cross myself. I am not a Jew," he loudly proclaims.

"_Nietchevo_," says the soldier. "Out with him just the same!" The peasants and crowd loafing alongside grin appreciatingly, as the mujik is escorted, collar-held, through the great doors.

The porter and yourself follow. A plunging line of sleighs, backed up against the outer platform of the station, extends far up and down the road. Their _isvoschiks_, leaning back, are shouting for fares. In sight are your two trunks. "How much to the Métropole?" you call. The legal fare across the river to the hotel is a rouble, but the Governor-General of eastern Siberia couldn't tell how much it would be if you didn't bargain beforehand. "_Piat rubla!_" "_tree rubla!_" come hurtling from all sides.

It is for you to walk down the line calling in the vernacular, "fifty, seventy kopecks!" One of the drivers will eventually shout a fare which you feel able to allow, and the porter, who has been watching the bargaining process with keen interest, gives him the two trunks. The _isvoschik_ retires then behind the stormy hiring-line, and you renew the process for a second vehicle. The sleighs are just big enough for one person to occupy comfortably. Two can squeeze in if they be thin enough or economically minded. But a second sleigh is needed now for the hand-baggage, and a third for one's self. At length the arrangement is completed. The porter bows low at the donation of fifty kopecks, "for vodka"; then, "Go ahead! all ready!" you call, and with a flourish the procession of sleighs dashes out of the station purlieus.

The road to the town mounts first a low hill parallel to the river. As the horses climb toward its crest the panorama of the city and stream, hidden previously by the railroad structures, unrolls. Like a great band of white, the frozen Angara sweeps to the left and right. Beyond it stand out boldly the clustered domes of the cathedral, their surmounting crucifixes glittering in the sunlight. At your feet are the sections of the pontoon bridge, which in summer spans the river but in autumn is disconnected, the parts being moored

to the shore, lest the drifting ice from partly frozen Baikal cut and destroy their woodwork.

A dark streak crosses the frozen river, with dots moving, as small apparently as running ants. The deceptive snow has made the distance seem much less than it is in reality. The streak is a road, and the seeming insects are the sleighs that pass and repass on the frozen river-trail. Between scattered wooden houses our cavalcade rides down to the bank, and at length onto the smooth white sheet. It is like skating. The big horses on our sleigh are imported from Russia, and trot splendidly, overtaking one after another of the citizens with their little shaggy Siberian ponies. The heaped snow is on either side. The cold air is bracing, almost welcome, until it begins to eat its way in.

It is a fair drive, this, across the river--a full verst to the northern bank. We mount the incline that leads up the slope, and come to the first log houses of the poorer quarter of Irkutsk town. Gaunt dogs bark feebly, and slink away on either side. The street is almost deserted; the houses give no sign of life.

Suddenly we come into a square crowded with people, gay with life and motion, and motley in colors. It fairly buzzes with talk and cries and chaffering. Low-built booths face every side of the open _piazza_. We catch a glimpse of one stocked with hardware. Opposite it stands a little shrine within which are dimly visible pictured saints and the Madonna, before which are scores of burning tapers. Our _isvoschik_ takes off his hat as he drives past, and reverently makes the sign of the cross. He crosses himself also as he passes the white church of St. Nicholas with its green roofs and gilded crosses, and he removes his cap to the long-haired and dark-robed pope that he meets, for the Siberian pays much reverence to his Church.

[Illustration: THE ANGARA RIVER THE CATHEDRAL IRKUTSK]

The residences improve from the log cabins of the outskirts, and grow into the two-storied whitewashed structures of the main thoroughfares. The streets also have an interesting procession of people. The big troika of some high official glides past, with coal-black horses and a coachman padded out into a liveried Santa Claus, after the style of St. Petersburg. Officers of the garrison sweep by in their light-gray overcoats. Shoals of sleighs and sledges are going to and fro. At almost every corner, armed with a sabre and revolver, stands a police officer.

As one drives along he reads the Russian letters on the placards and the names on the stores. Many here are Hebrew, for the Siberians of the cities are more tolerant than their European cousins. Irkutsk has a very large and prosperous Jewish merchant community, and sent her Dr. Mendelberg to the Duma. Irkutsk has had its representation cut down, they say, _post hoc_,--perhaps _propter hoc_.

The driver, who has kept his horses at a moderate trot from the station through the town, suddenly cries out to them, and swings and snaps his lash till they break into a gallop. “We always come in handsomely,” says the city native who is with you, as the sleigh pulls up triumphantly at the door of the Hôtel Métropole.

A swarm of attendants greet you at the portal, a tall uniformed concierge, half a dozen aproned porters, a waiter or two, a page, and behind them the Hebraic Hazan, our host. Each porter seizes a parcel and the concierge leaves his post by the front door to lead the procession up the broad red-carpeted stairway. With a rattle of keys he swings open the door to a salon big enough to give a ball in, and whose ceiling is six good feet above one’s head. The average New York flat would rattle around in it. The concierge advances to its centre and bows. Then he goes on through to another room, almost its duplicate in size, with a forlorn-looking washstand and a screen across one corner.

“But the bedroom, where do we sleep?” you ask.

“_Sdiece, gaspadine_,” he says, “right here”; and he conducts you to the screen.

Raised about eighteen inches above the floor is a little wooden platform-like structure, about the size of a cigar-shop showcase. A dingy mattress is rolled up at one end of it. As you ruefully feel its straw texture and survey the planks which it is to cover, the hotel-keeper pushes in to tell you that sheets will be put on at once if the _gaspadine_ has not his own. “_Chass! Chass!_ If only the rooms suit the _gaspadine_, everything will be arranged.”

The porters silently deposit their loads and depart with their twenty kopecks each. The manager goes out, doubtless to gather his sheets. Only the concierge stays expectant after he has received his tribute. You throw your heavy overcoat over one of the armchairs and begin to open some of the bags. The concierge still stays and looks on. You begin to segregate laundry, and locate brushes and tooth-powder. The concierge still stays and looks on. You get out some slippers which are an improvement upon the

heavy snow-boots. The concierge still lingers.

"The room is accepted," you say finally.

"Yes, yes," he answers. "_Haracho_, but for the police, I want, please, your passport."

To show your passport, true enough, is no more of an incident than to take out your handkerchief. But to be obliged before you have been ten minutes in a place to produce a paper for the police telling of your age and infirmities, the color of your eyes, the number of your arms and legs and children, seems tiresome.

"Must all give in their passports?" you inquire.

"All, all," he answers. "I am punished if one person stays here overnight without showing it."

He takes the document, visibly impressed with its flying eagle and the big red seal, and bows his way out.

Now one can stroll around one's suite and take in some of the details. There are electric lights with clusters of globes in the big pendant electrolier of the parlor, and drop-lamps for the massive writing-desk in the corner! The armchair by the high-silled window is a good place to read in. Too bad one cannot look out on the shuttling sleighs of the street below, but the cold has thickly frosted the double windows. Here is a big sofa, plush-covered, and half a dozen armchairs surround the polished table, whose top is scarred with a multitude of rings--from the hot tea-glasses, one deduces.

Mentioning tea, why not have some? There ought to be a bell somewhere. Unfortunately there is not a bell. In looking for it one finds that Siberian housekeeping does not include any dusting of the heavy red hangings which flank the doors and windows. An imperious cry resounds in the corridor. "_Chelaviek!_" It is followed by a patter of footsteps. So this then is the custom of the country. You open the door, and in the tone described in books upon elocution as "hortatory," cry out into the dim distances of the corridor, "_Samovar, chai!_" Somewhere down the line a voice answers, "_Chass, chass!_" and you retire to wait and hope.

Curiously battered the furniture looks when you inspect it closely. Here and there a flake is chipped away from the varnish, and cuts or dents show in the paint. Have sabre fights, perhaps, taken place here, or raids on assembling revolutionists? Certainly in the generations of occupants, life has been, in some fashion, tumultuous.

There is a fumbling at the door-knob, and, without any preliminary knocking, a waiter comes in with a nickel samovar, an empty teapot, and a glass. He puts them down on the battered table and walks out. The big kettle hums away pleasantly as the red charcoal in its hollow interior glows from the upward draft. The preparations seem all made, save for the tea. Perhaps the _chelaviek_ has gone to get it. You let your eye rove around to the little ikon far up in the corner, and the sleighing and wolf-shooting etchings on the walls. But after a time this becomes tiresome. Has the secret gendarmerie descended on the waiter among his teapots and trays? Has he forgotten the matter entirely, or what? The corridor-call seems to be the only recourse. Once again you go out. "_Chelaviek!_" and from some region he comes trotting up.

"Where is that tea?"

"Oh, _chai_," he says, illumined. "Has the _gaspadine_ not his own?"

"Most decidedly the _gaspadine_ has not his own," you retort. "The _gaspadine_ does not carry pillow-shams or bales with him. He is not a draper's establishment or a grocer's store."

"_Nietchevo_," says the waiter, amiably; and runs off, to return with a saucer of tea-leaves, and another containing half a dozen lumps of sugar.

"Your pardon, generally the _gaspadines_ have their own"; and he leaves you to the brew and your meditations.

Well, it is pleasant, after a long train-ride, to stretch out in a big, if battered, armchair, and sip glasses of anything hot. The little teapot, full of a very strong decoction, is perched on the top of the samovar over its chimney. For a fresh glass you pour out a half-inch of the strong essence, throw in the sugar, and from the samovar's spigot fill the glass with hot water. It is thus just the strength you personally prefer, and always hot. The samovar, by a judicious regulation of the draft, can be kept for hours exactly at the boil. It is a fine institution, but cannot be transplanted to a country where hot charcoal embers are not constantly available.

Comfortably ensconced and sipping one's tea, one can leisurely, Russian fashion, think of the most amusing method of passing the time. It is getting on toward evening; for the day fades early here. To-morrow is soon enough to look at things and distribute letters of introduction. The beverage has also blighted the appetite. Perhaps a light supper and an early couch would be wise. The latter in the far room looks singularly unpromising, but, "_Nietchevo!_" It is rather early for dinner or supper, but what of that? As an elusive New York politician used to say to each of the office-seekers who came to ask his influence for nominations, "If you want it, there is no reason why you should not have it." We will try another summons of the waiter.

Up he comes with the bill of fare printed in Russian and alleged French.

Perhaps some eggs would be good. You decide upon them to begin with, and you will have them poached.

"_Gaspadine_," he says, "the eggs to-day cannot be poached. Will you not have an omelette instead?"

On second thoughts we will not have eggs at all this time; we will have a sterlet, a small steak, and a compote. He goes off to the nether regions again. A long time passes, but at length he returns with the sterlet, its chisel-shaped nose piercing its tail in true Siberian style. White creamy butter and Franzoski kleb, white bread, round out the course. The steak is excellent and the canned fruit is satisfying, eaten beside the singing samovar in the great room of the main hotel of Irkutsk. Half a dozen letters pass the next hours until it is time to sleep. They are written on the big desk beneath the drop-light, with a glass of tea at one's elbow in warm cosy comfort.

The place is rather warm, and without any apparent source of heat, for there are no registers or gratings of obvious instrumentality. A search of elimination, like the game in which one is warm, warmer, very hot, leads at length to a rounded corner of porcelain built into the wall, of which only a curved segment shows in an angle of the room. Further inspection reveals that it is a big cylindrical stove fed by somebody in the hallway, and so arranged as to warm two adjoining rooms.

In mitigation of the fire-tender's zeal, we decide to open a window. Perhaps with an hydraulic jack this might be possible; but to manual labor it is not. A single pane of the inner window, however, swings back, and then we can open a similar pane in the outer window, leaving a hole as big as the port of a ship. It is sufficient in this weather. Some further corridor-shouting, produces, in due time, sheets and blankets, and presently we lie down on the straw mattress in the little wooden-bottomed box called a bed. "_Spacoine notche_," the attendant calls, and without trace of irony.

It is one thing to go to bed, another to sleep. Tales are told of powder-circled couches which the invaders, surmounting these ramparts by climbing walls, dropped upon from above. There is a legend that there are some people whom they do not bite. "_Nietchevo!_" Is it not Irkutsk, the Paris of Siberia? Why then complain of parasites?

Furthermore, a brass band has started up somewhere in the immediate neighborhood the tune of _Viens poupoule!_ to which there echoes a popular accompaniment of tapped glasses and stamping feet. Perhaps one had better get up and see things after all,--"Needs must when the Devil drives." We dress again. An exploring expedition reveals the big dining-room on the floor below full to the doors with uniformed officers, long-haired students, and assorted civilians. All are drinking and smoking. On a stage at one end of the room thirty short-skirted damsels are singing and dancing in chorus, to the great approval of the audience. As the curtain rolls down on an act, the _ci-devant_ dancers descend to their friends on the floor. Corks pop, and sweet champagne flows. The call goes up for "_Papirose!_" and more cigarettes and more bottles come thick and fast.

Soon there is an air of subdued expectancy, and eager looks are directed to the curtain. Somebody near by leans close and whispers for your enlightenment, "All-black man!" Out comes an old Southern Negro, who sings to the wondering Russians a Slavonic version of the "Suwanee River," between verses delivering himself, with many a flourish, of a clog-dance. Johnson is the man's name. How he drifted so far from Charleston he hardly knows himself. He followed the music-halls to 'Frisco, and somebody, for whom he "has a razor ready," told him he would make his fortune in Vladivostok. He kept getting further and further into the interior, picking up the language as he went, and turning his songs into the vernacular. Poor chap, the pathos he puts into the "Suwanee River"! He is thinking, in frozen Irkutsk, of the old Carolina homestead, and is singing and dancing his way back.

A girl in peasant dress takes the stage after "Sambo." She is singing some song that is running its course across northern Asia. The lassies at the tables and the men join in. Glasses clink and heels tap. The miners who have made their stake, the prospectors who hope to, the sable-merchants of the Yakutsk, the wool-dealers from Mongolia, all meet here as the first place where the rigors of the hinterland can be compensated. It is very gay--very, very gay.

In the years after the ukase of Paul I, ordering that all officers who had made themselves notorious for lack of education or training should be sent to the Siberian garrisons, it may be imagined what a Gomorrah grew up under the Russian banners. Modern celebrations are by comparison mild and temperate, as the cold beyond these double windows is mild and temperate to that outside the Tunguses' huts, in the Yakutsk Province. But it is fairly impressive, nevertheless.

Even in a Siberian hotel, the world goes to bed sometime. By four o'clock the music has stopped, and the traveler is tired enough to sleep on even the populous plank-bottomed bed. Thus do all things work together to weave the "web of life."

It is nearing noon when one wakes to eat a combination of breakfast and lunch, and plan for the day. The Post-Office and the Bank are the first material objectives. One must register so that mail may be delivered. We go down and join two companions of the road. With careful directions from the porter, the party prepares for the half-mile walk to the Post-Office. The preliminaries are formidable in themselves. First the felt goloshes must be pulled over the shoes; then the big fur overcoat must be swung on and carefully buttoned down its length. Finally a fur cap, like a grenadier's, with ear-flaps is tied, and great fleece-lined gloves are donned. The droshky-drivers assembled before the hotel seem to take it as an insult to their profession that we elect to walk, and two or three follow along outside the curb until the group reaches the corner and turns into the main street, Bolshoiskaia.

[Illustration: A CHAPEL BOLSHOISKAIA IN IRKUTSK]

There is an air of placid quiescence at this noon hour. The policeman at the nearest corner is ruminatingly handling his sabre-hilt, and watching the sleighs go by. Here and there a woman, with the ubiquitous gray shawl over her head, passes, with a preoccupied air. Sheepskin-clad mujiks are driving along, with sledge-loads of firewood or stiffly-frozen carcasses, on their way to the bazaar markets. The shop-windows attract our gaze. Here is one with the word "_Apteka_" over the door, which is to say, Apothecary. Benches are set in front of it, on which one may sit and watch the people pass, as in the chairs before a New England country tavern. Further along is a solidly built white department store, the Warsawski Magazine, wherein one can get all manner of apparel,--shawls of the latest Irkutsk pattern, towels and soap, and--most important--blankets for the trip into the interior. We stroll in for a moment. An individual looking like a stalwart Chinaman, with long braided queue, shoulders his way past us to buy some cloth.

"He is a Buriat of the tribe north of Irkutsk," explains one of the shop-girls, very close herself in type to those seen at Wanamaker's in Manhattan.

Near-by the imposing magazine is a low one-story booth occupied by a watchmaker. Beyond that is a walled enclosure with lofty gates, as befits a school. Still further is the yellow and green sign of a government liquor-_traktir_. The name is said to be derived from the French word _traiteur_, which was current in the days when Napoleon and Bourrienne were planning conquests in their Parisian poverty.

As we turn up a side street, the shops for the poorer people appear. Gaudy pictures, of packages of tea, vegetables, and sugar-loaves, illuminate the walls, to tell the unlettered that groceries are sold within. Saws and hammers and vises are painted on the walls of the hardware-shops. Loaves of bread, crescent rolls, and rococo wedding-cakes decorate a bakery; boots and high-heeled slippers, a shoemaker's booth. The street is an open-air gallery of rude frescoes.

Presently we come to residences, some of cement-covered brick, with high enclosing whitewashed walls and iron gates, some wooden, with their rough-hewn logs unpainted save for the brilliant white sills and window-frames.

At length, far from the town's busy district, the Post-Office is reached. The building is thronged. Two soldiers are loading their saddle-bags with the mail for the regiment. Women are collecting money-orders. A crowd waits at the window of the girl who sells stamps. In rushing industry she makes the calculating beads of her abacus fly across the wires. Everybody is far too occupied to register a voyageur's name,--excepting always the half-dozen soldiers posted in different parts of the room and leaning stolidly upon their bayonets. We venture to ask one of them which is the registry window.

"_Russisch verstehe ich nicht_," is the answer.

A Siberian post-guard knowing no Russian and answering in German seems extraordinary.

"Where are you from?" we inquire in his native tongue.

"Courland," he answers,--"Courland by the Baltic."

This city of Irkutsk gave trouble in 1905. If it gives trouble again, the garrison will be safe.

The registering at length is done and we turn to go out. A tattered figure, bearded and haggard, with rags bound on his feet, opens the outer door.

"Will the _gaspadine_ help a man get back to Russia?"

Your companion looks closely at him.

"A convict! very bad people." He adds: "There is a murder every day here, and one cannot safely go out at night. Very bad men!"

With the contradictory charity that is so typical of the Russian, he fumbles in his pocket and gives the unfortunate a fifty-kopeck piece.

We go now to the great market-place and the bazaars. Here where we enter is a row of hardware-shops. In the first booth a string of kettles hangs down, and knives, spoons, candlesticks, and hammers are suspended so as to catch the eye. The proprietor stands outside, chatting with a passer-by and the tenant of the adjoining booth. Further on are stationers, with tables of cheap-covered books. The wall of one is decked with chromos of galloping Cossacks, led by a long-haired pope with a crucifix. The soldiers are sabring fleeing Japanese, and red blood is lavishly provided. On the opposite wall are glittering brass and silver ikons, and lithographs of ancient martyrdom.

Row upon row of red felt boots hang in the next line of booths, and in still another--the wooden-ware bazaar--are bowls and spoons, and platters of high and low degree. Further on a dozen women are grouped around one of their class, who is bargaining for a huge forequarter of beef, a full _pud_ weight by the big lever scales that are balancing it.

"_Dorogo! dorogo!_" (Too dear, too dear!) she cries. "I will give eight kopecks a pound."

The market-woman protests that she will be beggared at less than eleven kopecks.

A half-_sotnia_ of little Buriat Cossacks come riding by, clad in their puffy leather _shubas_. Yellow-topped fur caps are their only uniform garment, and across their backs are hung the carbines. They make merry at the haggling women. Two swing off their shaggy ponies, and begin in turn to bargain in broken Russian for some paper-wrapped sweetmeats. They close the deal finally, tuck these away, toss themselves back into position, and ride off. Further along, half a dozen men cluster around a fur-cap seller. He is a merry fellow, and there is much noise and banter and gossiping. Such is the bazaar, the Forum of old Rome set down in a Siberian city.

[Illustration: THE BAZAAR, IRKUTSK]

A short further stroll, and the party is at your other objective, the Bank. You take leave of the rest and enter. At the door, a grandly uniformed porter helps you off with the outer husk of furs, and motions you into the outer office, with its half-dozen clerks bending over sloping desks. One of these takes your card, and returning leads the way to a capacious sitting-room, with armchairs scattered here and there, pictures on the wall, magazines of many nations on the centre table. The American typewriter, which alone betrays that this is an office, is on a little table at one side. A tall military-looking man, gray-mustached and grave in manner, is seated beside the window reading some documents. He rises as you enter, and greets you, and for some minutes the conversation in French is upon general themes. Presently you go down into a side pocket and get out letters of introduction. One is from the Petersburg headquarters. He looks at the signature--Ignatieff.

"You are his friend?" The polished worldliness falls away as a cloak that is thrown off. "Splendid!" he says. "Welcome to our city. We must have tea." He pushes a bell, and a page, red-bloused and wearing brightly polished jack-boots, appears. "_Chai_, Alexis," he orders. "And how did you leave Ignatieff?" he begins eagerly. "Does he still drive his black stallions? It is two years that I have not seen him. When I was in Petersburg last winter, he was in Paris, and when I was in Paris, he was at Nice. One is very separated from his friends here. One might as well be a convict."

You answer all his questions, and begin to feel as if you were at a little family party. Presently, in the midst of the double conversation,--for the Russians seem to talk and listen at the same time,--the boy comes in with a big samovar, and the other accompaniments. The banker makes the brew in the china pot. From this each of us serves himself as the compound conversation moves on.

"You have not yet seen the sights of Irkutsk?" he observes at last. "I will get my sleigh and show you around when we have finished."

"It is the middle of the day. I cannot break into your work like that," you protest.

But he rings a bell for the red-jacketed boy. "Order my sleigh.--We have the finest city in Siberia," he continues; "eighty thousand people now, and growing always. And trade has come with the railroad as we had not dreamed before. In the days when they used to bring the tea overland from Kiahta, the sledges from Baikal would carry as many as five thousand bales daily. We thought when this began to be shipped through by the railroad that it would hurt the city. But there was so much other traffic that the loss was hardly felt."

"The sleigh is ready," the boy announces.

"May I have the honor?" he says, with his easy grace.

He leads the way to the coat-rack, and is received with the deepest bows by the uniformed worthy, who solicitously helps him on with his coat and overshoes. Then with a stereotyped motion the man holds out his hand for the tip. Though this servant is at the door of the banker's own office and presumably upon his pay-roll, the incessant tribute is his perquisite. It is usual throughout Siberia for wealthy Russians to scatter small silver everywhere along their path--to friends' servants, to house-porters, to beggars on the street. The most profuse miscellaneous generosity prevails. Riding to-day with the Russian banker is like watching the progress of a mediæval prince dispensing his largesse.

At the entrance to the bank is the sleigh, skeleton-framed and high-built, unlike most of the sleighs of Siberia. Three big black horses, with the snake-like Arab head that characterizes the best Orloff strains, are hitched to it, troika-fashion, the centre horse under a big bow yoke, the outside animals running free. The coachman has the square pillow-hat, and the enormous wadded corpulence of Jehu elegance.

It is an interesting ride in which we move slowly up the Bolshoiskaia, receiving, so far as the banker is concerned, neighborly greetings from most of the sleigh-riders, and respectful salutes from the foot-passers on the sidewalks. A nice social distinction our host draws in returning the formal salute for uniformed officials, the cordial wave of the hand for intimate friends, a nod for the humbler acquaintances: but none go unrecognized.

Something like the Roman's idea of showing his city by turns up and down the Corso, is this Siberian's. We do halt, however, and look at the big Opera House and the Geographical Society's Museum and the many-domed Cathedral,--buildings which in no city would be other than sources of satisfaction. After an hour of driving in the piercing cold, one's conscience begins to prick. The banker, even though absent from his affairs, does not appear to feel either business or atmosphere. At length we are brought at a gallop to the doorstep of the hotel.

"To-night we dine at eight. Adieu." With a bow he draws the bearskin robes about him, and the black horses bear him swiftly around the corner.

An acquaintance from the train is in the hallway as you climb stiffly up the steps.

"Has the drive been a bit cold?" he asks. "Come in and have a _stakan_ of vodka."

"Is that not rather heady for a between-meal tipple?" you suggest.

"This is Siberia. When you run with the wolves, you must cry like a wolf,--but tea, too, is good."

You mount the stairs together, to the scene of last night's orgy, and order a couple of glasses of tea.

It is a strange anticlimax to find the room so deserted. At three this morning it was a good imitation of the traditional "Maxim's." At four in the afternoon it is simply a crude wooden hall, with the stiff-backed, plush-seated chairs ranged in bourgeois regularity at the discreetly covered tables. Only the shuffle of somebody practicing a new step on the stage behind the curtains suggests the double life of this innocent-looking hotel dining-room.

A couple of glasses of tea attack the cold in strategic fashion, from the inside, and are better than the external reheating method. We sip in silence for a while.

“I am going to drive over to the Banno and have a Russian bath,” observes your companion. “I do not like the tin tub they bring around here at the hotel. Are you impelled to come along?”

“Is there attendance and room for two? I’m not minded to sit around and wait.”

“Room for five hundred,” he says, with a long sweep of the hand. “Everybody goes there. It is one of the institutions of the city.”

As you are now warm enough to consider a further drive, you go down to assist in bargaining for a sleigh to make the tour to and from the Banno.

A big brick building a verst or so away, with a number of private equipages and a stand for public sleighs and droshkys, is our destination. A beggar-woman opens the double doors and gets her service percentage from each passer.

“How much is given in this part of the world to beggars!” you remark.

The Russian smiles. “It is a part of religion to give. At every big family affair,--a wedding, a christening, a funeral,--we distribute money and gifts to the poor.”

In the entresol of the bath-house, a big tiled anteroom, there are marble-topped tables, around which men and women are smoking and reading papers. One can dine here, even; but this comes after the bath. A ticket at the _kontora_ gives, for a rouble, the privilege of a preliminary boiling and a flaying by one of the naked attendants. A start is made by washing you with infinite thoroughness, section by section, the attendant continuing on each spot until told to stop or advance to the next. An unfortunate foreigner, in Irkutsk, had his head shampooed seven times in succession before he could recall the cabalistic word necessary to direct the man’s attention elsewhere.

One is scrubbed and rinsed, and is then conducted up onto a wooden platform, running along under the ceiling. Here, while the first inquisitioner dashes water on a steamer-oven below, the second scrapes the victim with new pine branches. One remembers an Irkutsk Russian bath at least as long as the smarting and the cold he gets from it endure.

Back at the hotel one can dig out his rather crumpled dress-suit in preparation for the evening’s entertainment. Later, he gathers in another sleigh, and sets out for the home of the banker.

In Irkutsk nobody relies on house-numbers to find his way. Even Moscow has not yet advanced to this refinement of civilization. If the driver does not know the route, he stops to ask passers-by, “Where is So-and-So’s house?” Again and again you are taken to the abode of somebody else with a name more or less similar. Then the driver will say, quite nonchalantly, “_Nietchevo!_”--ask the next person he encounters for directions, and start anew. You leave abundant margin of time, and usually arrive sooner or later.

Our host of to-night is, happily, well known throughout the city. So the driver whips up to a gallop and rushes down the snowy streets. It is not a long ride to the big arched doorway of the white two-storied plaster-covered house, in front of which the driver pulls up with a flourish. You ring a bell at the side of the door and wait. The _isvoschik_ has taken a station beside the curb, has folded his arms, and is nodding on the box, apparently prepared to camp there indefinitely. “Eleven o’clock, return,” you say. “_Haracho!_” is his drowsy answer, given without moving. The horses have drooped their heads; they too are settled for repose. The tinkle of a piano comes from within, but minute after minute goes by, the bell unanswered, the _isvoschik_ immovable on his little seat. Other pulls of the bell are at last of avail: the door slowly opens. A final objurgation to the coachman that he is not wanted until eleven o’clock falls on sealed ears. You go in through the massive doorway.

In the antechamber a gray-bloused attendant helps you off with wraps and goloshes, then silently disappears through a rear door, leaving you standing there unannounced. The vestibule is cumbered with coats and hats on the wall-hooks, overshoes helter-skelter on the floor, and canes and umbrellas in the corner. It is like a clothing establishment. Beyond the curtained doorway on the right are lights, and the sound of the piano is louder. This seems the most promising direction for exploration, so--forward!

Beyond the portières is a splendidly lofty room, like that of an Italian palace, brilliantly lighted with electricity. Many-paned windows run high up, starting from the level of one’s breast, and long heavy hangings half-conceal them. To the right of the door is a mahogany grand piano, at which, oblivious of the world, the host is diligently thumping away at _Partant pour la Syrie!_ with inadvertent variations, singing carelessly as he plays. Beyond him, in an imposing armchair of German oak, like King Edward’s throne in the Abbey, is a lady, propped with many cushions. She is slender and darkly clad, and is conversing with a young man in uniform, who sits very straight on a dainty gilt chair of the Louis XVI epoch. A low lacquered table before them is gayly painted with

geisha girls and eaved pagodas. It holds a massive brass samovar encircled by a row of beautifully colored tea-tumblers of the sort that one sees on exhibition in the glass-factories which front the Grand Canal at Venice. The chorus comes from the banker at the piano:--

Amour à la plus belle; Honneur au plus vaillant.

[Illustration: THE ICE-BREAKER, YERMAK--LAKE BAIKAL]

There is no use of paltering and waiting to be announced, so we enter the room. The performer hears the steps on the polished floor and swings round on the stool. "Ah, voilà!" he says, and rises to introduce you to his wife.

"A moi le plaisir," she says, smiling. "Mon frère, Ivan Semyonevich," presenting you next to the young officer, who rises abruptly and clicks his heels as he takes your hand.

You are motioned to a replica of the little chair, and your host returns to his piano, this time to play with immense satisfaction in your honor a hazy memory of some bygone variety show: "There'll be a hot time in the old town to-night."

"A friend is very welcome," says Madame Karetnikov, when he finishes. "We do not see many from the world here in Siberia."

"The life, however, is interesting, is it not?"

"O monsieur, I, too, was interested at first, but there are so few people of the world here, and we see them all the time. C'est affreux! I give you a month to change that opinion."

"You give a month, Irina; I give a week," growls her brother.

"If it were not that we get away during the spring one would perish of ennui," the hostess adds. "But Japan is not far. We go there or to Europe every year. Perhaps soon we shall get a transfer to another branch."

"You bankers have hopes," observes the brother, "but what of us poor officials of the Justice Department! We are chained to the bench like old galley-slaves, and all we get is three hundred roubles a month and a red button when we are seventy."

As the macerated song floats anew from the piano, the hall-door opens and there is dimly visible in the anteroom a curious much-encumbered figure, with a gigantic sheepskin hat and short blue reefer coat. He divests himself of these, and of a long woolen inside muffler, and, brushing back his long hair, comes into the room. His blue tunic is resplendent with brass buttons and he wears jack-boots. A light down is growing upon his upper lip. He is nineteen or twenty.

"Good-day!" says our host, hailing him in English.

"Good-day, uncle!" he replies.

He presents himself before Madame Karetnikov, who holds out her hand, which he formally kisses.

"_Zdravstvouitie_, Valerian!" says the official, shaking the young man's hand.

Then you are introduced with explanations.

"Valerian here is in his last year at the Irkutsk Realistic School, studying preparatory to engineering."

The status of science in Siberia becomes the theme, and the newcomer infuses considerable local color into his pictures.

"Does the professor in drawing suit you now, Valerian?" the banker inquires presently. Then he adds to you: "They all went on strike because the old professor of drawing had a method they did not like. The authorities had to replace him before any of the students would go back."

"The new professor respects our rights," says Valerian soberly, not liking the levity of his elder.

Soon, from an adjoining room, come in the children of the host,--a very pretty girl of the age at which misses wear short dresses and braids; and a little boy of about eight. The boy very respectfully kisses his mother's hand and is introduced to the stranger, but finds a superior attraction in his father at the piano.

The girl, Marie Pavlovna, sits down beside her cousin Valerian. Lacking the stock football amenities of a happier land, and half-embarrassed, half-superior in the status of a budding young man, Valerian is not much of a conversation-maker. Marie Pavlovna, too, is seen but not heard. She is evidently the typical product of the French system of sex-segregation and cloistered study, which keeps girls abnormally uninteresting until marriage, perhaps to make amends subsequently.

"I think we had better go in and eat. It is half-past eight," says the host.

"Si tu veux," replies his wife; and we stroll out into a big dining-room, at one end of which is a heavily-freighted oak sideboard.

As we approach this, the host opens a far door, and shouts down into the darkness:--

"Obeid, Dimitri."

We turn to the _zakuska_ sideboard. The official reaches for the vodka-bottle, and the little silver egg-like glasses.

"Vodka will it be, or do you prefer cognac?"

The various guests choose their tipple. With the gulp of a mountaineer taking his moonshine, the banker swallows the twenty-year-old French brandy, of the sort that gourmets protractingly sip with their coffee. The little boy slips out to his particular region of the house. The hostess takes her seat at the foot of the table, and the gentlemen pass and repass, bringing her assorted _zakuska_ dishes as at a ball. Caviar from the Volga, Thon mariné from Calais, sprats from Hamburg, Columbia River salmon, are spread out and attacked by the rest of us, standing, free-lunch fashion. One by one the men finish and straggle to their places at the table.

Three menservants, with gray blouses and baggy silk trousers falling over their topboots, appear now, one with a huge tureen of bouillon, another with the little silver bowls, and a third with a plate of the _piroushkies_ that accompany the soup. Madame Karetnikov deals out the consommé for the whole table, and also for little Paul and his governess in some outside quarters. Every one begins to eat, without waiting for the hostess or for anybody else.

"It is hard work managing a big family like ours," she allows, in reply to your question about the domestic problem. "We always have seven or eight, and one can never tell how many friends will come in to dine with us."

She casts a solicitous eye over the table, to see that no one has been neglected, and then serves herself.

"One must keep the men well fed," she observes. "Remember that, Marie, when you get married."

Marie at the far end of the table nods assent.

"But you must not think of marrying until you are told," adds the banker.

She nods assent to this, too.

"Don't mind him, Marie," says the official. "He thinks he is living in the time of the Seven Boyars. Take my advice. Pick out the man you want and go for him. You can't fail."

"Such ideas to put in a girl's head!" says his sister, smiling.

The soup-course is nearly over, when suddenly the banker ejaculates, and jumps up to welcome some new arrivals.

"Ah, father!"

He runs to a sturdy benignant-looking old man, and kisses him on both his white-bearded cheeks, then does the same to the little old mother.

"Come in, come in; we are just beginning."

At once the table is in a state of unstable equilibrium. The old lady is steered to a chair at the head, and the rest are pushed along to make room. The father makes his way, under similar escort, in the direction of the vodka-bottle.

"No French brandy for me!" he says, and puts the fiery Russian liquid where it will do the most good. He, too, goes to the far end of the table.

The student tells in a low voice that the newcomer is a veteran of Sevastopol, was once the personal friend of Czar Alexander, the Liberator, and was decorated by him for gallantry at Plevna.

"What a splendid old Russian he is!" one thinks, noting all the kindliness and courtesy of his honored age, and the grip of a bear-trap in his hand. Yet there is an indescribable air of melancholy about him, as if a great sadness were being bravely and uncomplainingly faced. A remark from the hostess turns you to her.

"Father is one of the Colonization Commission. We are all very much interested in hearing about his discussions with the settlers!"

"Colonization for the settlers or for the exiles here?" you ask.

"It is the government assistance for the voluntary emigrants, not for the unfortunate ones."

"But the latter must be a problem in themselves?"

Madame seems embarrassed.

The student leans over and in a low tone whispers: "His youngest son, the brother of Vladimir, is in hiding, is under sentence of death. They don't speak of him here."

"He has just come from the Governor," adds Madame Karetnikov, "who is a great friend of his. The Governor has heard from Petersburg that they may bestow the cross of St. Stanislaus."

"That is the autocracy here, which you do not know in your country," adds the student, in a low voice. "He is an intimate friend of the Governor and two of his sons are officials, yet his last son is beyond pardon. The old man himself knows not where he is. Yet they decorate the father. He still believes in the Emperor."

"Do not let my nephew talk politics to you," says the hostess, rather anxiously.

Valerian is silent.

A supplementary tureen of soup makes its appearance, and the two newcomers are served with it. The rest of the party have advanced to boiled sturgeon, with a thin sauce, compensated by Russian Château Yquem from the Imperial domain in the Crimea. Roast beef follows the fish, with the old general and his wife at length even with the rest.

Then come duck and claret, and finally dessert and champagne. The toast of the evening is drunk to the old general, who brightens as the meal advances. In the big reception-room, Turkish coffee is brought, which is poured from the brazen ladle and served in exquisite little cups without handles.

"We got them in Damascus on one of our trips," says the host.

Conversation goes round the table. The official is in eager talk with Madame Karetnikov about a common friend in a smart Petersburg regiment, who has got badly in debt.

"He ought to apply for a transfer to the Siberian service. The officers get more pay, and it costs less to live," she is urging.

"But for Serge we must consider how much greater is the cost of champagne here," retorts the official.

"We can marry him to Katinka, and make her father get him a promotion," the sister suggests. "I think he ought to have left the army and gone into the contracting,--every contractor I know is as rich as sin and goes to Monte Carlo."

So the conversation rambles on. Cigarettes are passed. The hostess will not have one.

"I used to smoke, but it is so common now," she explains. "Every peasant's wife hangs over her oven with a cigarette in her mouth. Even a vice cannot survive after it has become unfashionable."

The host comes up to show you his curios.

"This Alpine scene is one of Segantini's. We got it in Dresden before he had earned his repute. I am very proud of my wife's discrimination. The statuettes are from a little sculptor in the Via Sistina in Rome. Rien d'extraordinaire. The vase came from the Imperial Palace in Peking. I bought it from a Cossack for fifty kopecks. I have been told it belongs to the Tsin Dynasty, and is better

than those they have in Petersburg Hermitage."

So you are shown the spoil of two continents in connoisseur purchases.

"Hardly to be suspected in Irkutsk," he allows, complacently.

Every year host and hostess visit the Riviera, taking a turn at Monte Carlo and Nice and Cannes. The banker speaks English, French, German, and Italian fluently, and half a dozen other languages passably. His wife acknowledges only French and Italian.

The conversation turns to the idealism of Pierre Loti's description of the road to Ispahan. The banker has followed this road himself, and he has a much less poetic memory of it. The veteran--his father--is not up in French or English, but he has a good knowledge of German left from academy times. In this language he tells of the old days of the serfs and of the Crimea. He talks with the kind frankness of age that does not need self-suppression to prompt respect. When the guests rise to leave, and the buoyancy of the entertainment is passed, his cloud comes back. His voice has just a touch of bitterness as he says good-bye.

"I am glad we can welcome to our country a man traveling for pleasure. So many who come are here under less pleasant auspices."

"_De svidania_," you say at last to everybody, and out you go into the midnight frost. The droshky-driver is still there waiting. He has slept since you entered, unmoving through the hours. "_Gastinitza_," you direct; and he drives to the hotel through the bleak starlit night.

Valerian comes a few days later to visit us, and volunteers to be our guide for Irkutsk.

"If I miss a few days at the Academy, what matter? I shall improve my English," he explains.

Valerian is typical of the student class, all ideal and aspiration. He has gathered the heat of the epoch, and has concentrated it upon his philosophy. He is saturated with the French Revolution. Does he mention Danton, for example, it is with intentness of loyalty for the great Mountain speaker, which makes one almost think that the year is 1792, and that the place is sans-culottic France; "debout contre les tyrans!" He sings fiercely with his comrades, to the tune of the _Marseillaise_, the Russian revolutionary anthem, ending it with a swirl. "For the palace is foe to our homes!" America he considers one of the free nations, but he has reserves. Though he is not at one with our political system, yet he thinks that all learned about it is a great gain.

"Your land is free politically," he specifies, "but it is not yet emancipated from capital,--it is not free socially. You have an industrial feudalism and a proletariat. So will it not be when we have won our revolution."

Many are his anecdotes of the uprising of 1905, whose tragic drama will never be fully pictured and whose history is to be gleaned only from the mouths of cautious witnesses.

[Illustration: THE ORGANIZERS OF THE CHITA REPUBLIC]

"We rose at Irkutsk, many of us, students and workmen, but General Müller had a strong garrison of troops here. We tried them, but they would not come over. They shot down our men and dispersed all the meetings, and now he is Governor in the Baltic Provinces. They say that when he was drunk, he would shoot accused men in his own railway carriage; "the butcher!" we of the Cause call him. At Tomsk and Krasnoyarsk the city was held for weeks by our party. The railway men would not run troop-trains and the Government was paralyzed. Chita was held by a Revolutionary Committee of Safety. We manned the entrances with artillery. We took turns watching, and ran the whole city, not touching the money in the Treasury. But we were few, and word came that the insurrection was everywhere broken. Müller was marching from Irkutsk, and Rennenkamp came back with the troops from Manchuria. He promised moderate terms to all but the leaders. The townspeople were afraid, and rose against our men. Many were taken. Many fled away and got to Japan and America. Some were shot and some were sent to the Yakutsk. So it was crushed, and our great chance was gone."

"Will it come again?"

"_Ni snaia!_ The workmen are ready. The intellectuals are ready. The peasants back in Russia cry for land. Perhaps they too will be ripe next time, and the soldiers will be with us. In any case Siberia has seen the red flag float over the Chita Republic."

Many-faceted is the life in a Siberian city. In numerous ways it seems feverish and abnormal, for it represents the young blood of a capable race struggling upward, and knowing that in much its battle is desperate. The towns have hardly yet got settled methods;

they are outgrown villages where men of all stamps, who have become enriched in the new land, come for the pleasures or the benefit of a less monotonous existence. The traditions of peasant origins survive in the conditions and general civic neglect.

Irkutsk, once its novelties have become familiar, has lost its charm. That it is provincial is no discredit, but its amusements are of the grosser order, unredeemed by wit. Every evening the tawdry dining-room at the hotel echoes the songs and noise of the revelers. The same circle attends the theatres. The students discuss hotly the rights of man and the Valhalla prepared for all martyrs, and calm simple wholesome life seems to be reserved for the workaday world which moves on its slow toilsome upward way in silence.

There is, however, to-night an unwonted stir at the Hôtel Métropole. The corridors are thronged. A Russian friend points out the notables. The blue-uniformed official yonder with the gray mustache and the row of glittering orders on his breast is the Governor-General. Half a dozen members of the local bar, in frock-coats, pass through. In the dining-room a young lieutenant, dashingly clad in long maroon coat with the row of silver-topped cartouches and the clattering sabre of the Emperor's Cossack Guard, is being deferentially entertained by officers of the garrison. Three officials are taking champagne with two beautifully gowned women, Parisiennes even to their long pendant earrings. The hotel-pages in fresh red blouses and high boots pass here and there with messages. The waiters, with intensified deference, glide among the crowd in its many-colored uniforms and glittering war-medals.

"Who has arrived?" we ask, surveying the scene.

"A member of the Imperial Cabinet."

The announcement of his name has a personal interest and memories of earlier stays in Russia.

The Minister's life has been a romance indeed. Disagreeing with his family through liberal ideas, he went in 1862 to Birkenhead as a locomotive engineer, to the United States, to Argentine, and returning to Russia worked up from a very small government position to be chief of all the Russian roads, railways, and telegraphs, and Minister of Ways and Communications in the Czar's Cabinet. His brain threw the line of rails over half a continent. On the outbreak of the Japanese War he was called from his retirement to the colossal task of bringing to the front across the width of Asia half a million men, their artillery and arms, their food, their transport, all on the one line of rails. He has served under three Emperors and is life-member of the Senate.

You send a card in through one of the attachés. In a few minutes there is delivered to you the Prince's card, across which is written: "At noon."

At the hour appointed you mount to the apartment overlooking the Bolshoiskaia. Guards at salute, staff in brilliant uniforms, secretaries and callers in full dress,--the antechambers are full. You pass through to the furthermost room.

In a nest of books and maps, with blue-prints outspread on floor and chairs and sofas, is an elderly man in a plain frock-coat, without a ribbon or a button to hint his honors. He is vigorous, hearty, simple, almost unchanged from your earlier acquaintance, his keen flashing eyes hinting ever a reverse side to the great repose of his manner.

Personal questions occupy the first minutes, but presently we are into larger themes, and you begin to feel subtly the man's power. He has come on a special tour, to inspect, with his own practiced eyes, the projected double-tracking of the Siberian Railroad. Every brakeman and locomotive engineer, every traffic superintendent and division manager along the route knows he could step down from his private car and handle the levers and give them directions. His mind is a very vortex of ideas, and his range of conversation reflects world-wide interests. The talk gets to the American political situation and the race-problem. Later it shifts to the Japanese War, and he tells of some of his experiences getting the troops into Manchuria. A mention of the overland road to China awakens reminiscences.

"It was long before the railroad that I went over that route first," he says. He tells of his months-long horseback ride beyond Baikal before the railroad went through, inspecting the trade-route and the prospects of the country. By and by the conversation has got to the special problems of the Slav. With the straightforward frankness of a great nature which wishes the best for his country, he tells of the Russian aspirations from the standpoint of those who are facing the problems of the nation in their fact and practice.

"I too," he says, "was once for changing much in a little time, and worked to free the serfs and to start the elective Semstvos throughout the Empire. Alas! so much that they want is possible to no government! One cannot by enactment abolish want or bring all men to a _niveau_. We are trying to give every man the chance to rise, unchecked by any administrative barrier. But one sees

as he lives longer that all which one wishes cannot come at a _coup_. Great changes, great improvements, I have witnessed, but they have not come by violence. We must keep order, and hand on to our sons an undivided Empire of the Russias."

You leave this patient builder of the new order alone amid his maps and studies in the idle Sunday city. As you descend the steps, a black-capped student passes the door. He is humming the forbidden _Marseillaise_.

IV

SLEDGING THROUGH TRANSBAIKALIA

The sledge-route that leads to the Chinese frontier goes southward from Verhneudinsk across the territory of Transbaikalia. In old days one reached its starting-point by traversing the frozen Lake Baikal in sleighs, muffled in furs against the sweep of the terrible winds, with plunging ponies at full gallop.

Now, after mighty effort and at monumental cost, the line of the great railroad has been driven through the last obstacles that blocked an open way, and trains carry the traveler through the deep cuts and tunnels that pierce the barrier crags around the Holy Sea.

It is not the express that one takes at the Irkutsk station to reach the ancient fort, but the daily post-train, the servant of local traffic. Luggage-cumbered passengers crowd into the cars wherever there is a place. A few, and these mostly officials, establish themselves in the blue-painted first class. Many press into the yellow second class--merchants, lesser chinovniks, tradesmen, popes, and children on their way to the city schools. Swarms pour into the green wooden-benched third, where the thronging tousle-headed emigrants patiently huddle closer to give room to newcomers. Next to the engine, with its big smokestack, is the mail-wagon, on whose sides are painted crossed post-horns and the picture of a sealed letter. Behind this, with a sentry on guard, is the baggage-car. The sinister compartment of drawn shutters and barred windows is for the prisoners. In this princes or artel-workers, their identity unsuspected, can be run across a continent to their unknown places of exile.

The post-train starts from Irkutsk occasionally on time. In general, along the local line the time-table is about as reliable a guide as the calendars sold to the mujiks, with weather prophecies for each day of the year. Fifteen miles an hour is mean speed. Stops may be for minutes or for hours. One settles down therefore in the attitude sacred to a yachting cruise,--foie gras and bridge, if it is calm; double reefs and pilot-bread if it blows up. The high heavens alone know when we are to get in, and nobody cares. It is not unpleasant withal to sprawl over a great broad couch, and as the train crawls forward watch the white highlands slowly unroll, the towering cliffs and peaks with spear-like pines driving up through the snow, and the icy lake below.

For meals, one dashes out during the station-stops, and before the third bell gives warning of the start, devours meat-filled _piroushkies_ and swallows lemon-tinctured tea at the long buffet-tables decked with hollow squares of wine-bottles, and beer from the seven breweries of Irkutsk. If one has a teapot he can get boiling water from the government-furnished samovar, and milk from the peasant-women who stand in booths hard-by. He can add salt fish and hot fowl, together with rye-bread and butter, and then consume his rations at leisure in the compartment. At night the seats are let down, and one sleeps in fitful naps among the hills of baggage. When morning comes, an hour-long procession forms to take turns at the wash-bowl with its trickle valve, in a towelless, soapless, and cindered lavatory.

We leave Irkutsk at ten in the morning, and reach Verhneudinsk at seven next day, covering in twenty-one hours the 446 versts. Here is the last of the railroad. With troika, sledge, and tarantass, by highway and byway, over frozen rivers and camel-tracked trails, we must now follow the old road into the heart of Asia.

The post-station that serves as point of departure for the sledge journey lies some distance away, at the edge of the town. An _isvoschik_, after due bargaining, proceeds to transfer thither us and our dunnage-bags.

As we ride through the town, just waking for the day, the streets, the lamps, the telegraph-wires, the comfortable houses,--each and every symbol of civilization takes on a new significance now that it is to be left behind. On the parade-grounds the recruits are at the morning drill, shouting lustily in unison, "_Ras, dva, tre!_" to keep the step. We pass the barracks, the shops with their brightly illustrated signs, and ride under the wooden yellow-painted Alexander Arch.

[Illustration: BAIKAL STATION]

[Illustration: THE HIGHLANDS OF TRANSBAIKALIA]

Soon we reach a street of low log houses, and a lofty boarded enclosure is ahead. At its gateway is swinging a black signboard, painted with post-horn and the Czar's double-headed eagle. "_Postava Stancie_," is inscribed over the lintel. Between the black and white-striped gate-posts we swing into the courtyard. To the left stretches a low log house. To the right, along the wall, are ranked sledges. In front are the stalls. Grooms, whip in hand, stand around in the courtyard, muffled against the cold.

"Is the _gaspadine_ going on?" one of them asks.

On the reply, "Yes, at once," he scurries off to start harnessing, and you shoulder open the low felted door of the post-house and enter the big waiting-room.

"Three horses?" asks the young black-mustached agent within.

"Yes, a troika sledge."

He turns to the book of registry attached to the rough table by a long cord fastened with a big red seal, and begins to write.

"The name?" he asks. It goes down.

"The destination?"

"The Chinese frontier at Kiahta."

"Your first relay-station is Nijniouboukounskaia, twenty-seven versts."

The fare is set out in a printed placard posted up on the wall; as is the price of a samovar, fifteen kopecks, and all the other items that the traveler may require.

The agent hands you the slip: "One rouble, eighty-two kopecks, for two persons, the _gaspadine_ and his courier"; something under three cents a passenger-mile.

As you wait for the harnessing of the post-sledge, the courier overlooks anew the bags and counts out again the parcels. As light as possible must be the impedimenta. Now is the last chance for change.

The big station-clock ticks on. The agent moves about in the warm dusky silence of the house. The courier straps tighter the dunnage-bag.

"Look that your furs are snugly fastened," he says.

There is trample of footsteps by the door. A fur-clad, ruddy-faced driver stumbles in, makes the sign of the cross before the ikon on the further wall, and beckons to you.

"Ready!" he says.

Three shaggy ponies stand hitched to a wooden sledge, not high like those of city _isvoschiks_, but low and shaped like a wide bath-tub. The bottom is cushioned with hay and you are to sit some six inches above the runners. The bells hanging from the big arched _duga_ over the centre horse jingle as he frets. The side horses, that will run loose between rope-traces, look around at the _yamshik_ who stands by. He holds in his mittened hands four reins of leather, twisted into ropes--two for the centre trotter, one each, on the outside, for the gallopers.

You climb into the nest of rugs and furs superimposed upon your baggage! The _yamshik_ leaps to the precarious perch that serves as his seat. The whip falls, and with a bound the horses are off. Always one starts at top speed, however bad the way. Always one finishes at a gallop, however jaded the horses. It is the rule of the Russian road.

With bells jingling, the driver shouting to clear the way, and a white cloud rising behind, the sledge skims out between the log houses which flank the straggling street. Dogs bark and the idle passers-by stare. Fur-covered pigs scramble up with a squeal, and scurry from their resting-places in the road. Girls, with shako-capped heads, peer through the windows. Little chubby boys, in big brown felt boots, cheer.

Soon the uttermost houses of the town are left, and emerging we plunge into the country road through open fields, dazzlingly, blindingly white. The trotter's legs seem to move too fast, as if seen in a cinematograph. The gallopers, free of all weight and held

only by the two traces which fasten them, outrigger fashion, swing on like wild ponies of the steppe. Crude and massive as the sleigh may look, its burden is almost nothing on the hard compacted snow. The horses in the rush through the bracing air seem to be the incarnation of the wind. A rut in the glistening road does not produce a disjointing shock, for, as a huntsman's bullet glances from the skull of a wild boar, so the sleigh glides into the air and swiftly down again at a long low angle. It is a fact of "flying."

The cold is intense. After an hour of riding you have learned a certain lesson which adds to your experience. Whether the traveler shall make this winter journey equipped with full camp-kit, portable stove, folding-forks, thermos bottles, and shell-reloading tools, or Tatar fashion, with a rifle and a haunch of mutton, is important but not vital. Let him make sure, however, that the huge all-enveloping sheepskin overcoat is at hand to supplement the coats beneath, and that a shaggy sleeping-rug is provided in addition to the blankets. One obstinate newcomer started with the insistence that a mink-lined Amerikanski overcoat, with two heavy rugs as lap-robes, would be ample. After an hour on the road, he turned into a peasant's hut to thaw out upon boiling tea, while the driver went back to the town to buy the hairiest robe and coat obtainable. These were thenceforth worn on top of the initial outfit. Siberia for a midwinter sledging journey exacts this tribute of respect.

For versts the winter road follows down along the river between towering pinnacled rocks, where in summer eagles nest. The cliffs are vividly spotted with orange and green lichens; below they are fretted with the scourings of ice brought down in the spring freshets. All along beside the road are the familiar pine-saplings planted in mounds by the villagers to guide the way. In the vast monotony and drifting snows travelers would be lost but for these landmarks. Along the fertile river valleys hamlets are thick. A cluster of houses is met every six to ten versts. Presently the road leaves the river and bends to the left, cutting across fields. When it quits the bank, it climbs sharply a five-foot ascent. The driver does not even slacken speed. At the turn he swings the sure-footed ponies suddenly, and takes the slope, letting the outrigger bring up against a stiff clump of bushes. There is a crash, the sleigh has caromed off at right angles, nothing has befallen, and we are on again.

Verst after verst of plateau goes by, with rounded rolling hills of dimpled snow, treeless, houseless, a barren waste. Then comes a crest so steep that the horses can only toil up it at a walk, and the passengers must climb beside them. The forest closes in as the height is mounted,--white leafless birches and dark green pines. The light snow is seamed with rabbit-runs, and here and there are the far-spaced tracks of deer or wild goats.

A mound of stones and a small pole with a Buddhist prayer-flag--for here is the ancient home of the Buriats--mark the top of the ascent. There is a moment's halt while you climb in and the driver tightens the saddle of the centre horse; then down the giddy descent we sweep, in full gallop once more. The pines flash past, and you hold your breath in fear of the smash that must come should a horse fall, should a trace break, should a side rut swing the sledge over. One is, however, so close to the ground that an overturn is usually harmless, save to the clothes and the nervous system, both of which are at a discount in Siberian sledging. Then too the outrigger arrangement is such that the craft turns a quarter of the way over and slides on the supplementary runner until it rights.

The cold is intense. One wipes away the snow from his fur collar, and the dampness on the handkerchief has caused it to become frozen stiff. It is a crackling parchment that goes back into the pocket. Eyeglasses are unwearable, for the rising vapor from one's breath is caught and frozen on them in an opaque film. Fingers exposed but a moment become numb and useless, and uncovering the hand is an agony. Gradually as you ride, through the great felt boots, the triple flannels, the camel's-hair stockings, the fur-lined gloves, the coats and rugs, the cold begins to bite. You have become fatigued and depressed of a sudden. The driver points to your cheek, where the marble whiteness is eating into the flesh, and bids you rub it with snow. An involuntary shudder grips and shakes you relentlessly from head to foot.

It is time to stop. If you try to go on beyond the next station you will, if the gods are lenient and you do not freeze, get out nerveless and trembling, not for hours to rally strength and energy. The chill will cling, however hot the post-house oven. Even now you are weak, beaten down, querulous, in a sudden feeble old age. The shudder means that the human animal is near his endurance limit.

On an urgent call, with special preparations, you may travel for a hundred hours, night and day, without halt save for change of relays. Physically, it is possible to fight cold for a time. You can run along in all your furs beside the horses, you can beat your arms together, and rub nose and cheeks to keep the blood in motion. You can drink copious glasses of scalding tea in the post-houses, and live by stimulants on the road. Through ceaseless vigilance and resolution you can keep from freezing, even while intense fatigue creeps on and vitality is going. But the persistent awful shudder is Nature's red lantern. Run past it if you must,--it is at your peril.

Dark against the snows, now a low-lying village comes into sight,--Nijniouboukounskaia,--and among its first log houses is one bearing the post-horn signboard. A cry rouses the jaded horses to a gallop, and covered with snow, the sledge sweeps into the yard. Steaming and frosted white, the animals stand with lowered heads. Stablemen run to unharness them. Stiff with cold and muffled like a mummy, you clamber out, and on unsteady legs mount the steps to the felted door of the posting-inn. In the big bare room, beside the warm oven, robes and overcoats can be thrown off. A red-capped girl loads the samovar with glowing brands from the fire, and sets it humming for tea. Brown bread is produced and eggs, and a great bowl of warm milk. With these, and the contents of your bag of provisions, can be eked out a welcome _obeid_.

For the night's rest one need not seek a bed. There is never a spring to ease the bones from Verhneudinsk to Kiahta. There was discovered just once on the journey--at Arbouzarskie--an iron skeleton, bearing to a spring bed about the relation that the three-toed Pleistocene prairie trotter holds to a modern horse. The post-keeper had carefully hewn with his axe five pine planks to cover the gaunt limbs of it. The voyageur slept on the soft side of these timbers. Bed and board are synonyms in Siberia.

For a couch there is to-night the narrow wooden law-provided bench, or--a less precarious perch, and equally resilient--the sanded floor. For bedding, one has one's own blankets and coats. What if the shoulder slept on numbs with one's weight, or the corner of the soap-box in the traveling-bag, serving as a pillow, dents the tired head! One draws off felt boots and some of the outer layers of clothes, rolls the sheepskin about one, covers the head with a blanket, and sleeps like the forest bears in their winter dens.

Just before daybreak is the best time to start, so that one can cover the most road possible while the sun is up. At ten or eleven, an hour's stop for lunch is advisable, and then on again until sundown. It is better not to travel after nightfall, as the cold is so much more intense. We dedicate the evening to hot tea, and then turn to the blankets and the bench.

The stretch between Verhneudinsk and Troitzkosavsk, officially rated at two hundred and eighteen versts, is really somewhat longer. A run of average record took from 4:20 P.M. Tuesday to 11:30 A.M. Thursday--forty-three hours and ten minutes. This included all relaying, seven hours a night for sleeping, dinner and breakfast halts, two accidents (an overturning and a broken runner), and one calamity--a Siberian who snored. The actual driving-time, over a road for the most part hilly, was twenty-two hours, five minutes, or just about ten versts per hour.

Horses stand always ready, with special men at hand to harness. Drivers swing on their shaggy greatcoats, and with almost no loss of time one is out of the shadowed courtyard and on the road again in the dazzling whiteness of the winter day.

In traveling "post," however, with relayed sleighs and big empty guest-rooms, one does not become acquainted with the life along the way. One has only hurried glimpses of slant-eyed Buriat tribesmen, of galloping Cossacks, trudging peasants, post-agents, girls who carry in samovars and silently steal out, rosy-cheeked boys on the streets, and women at the house-windows. To know the people and see their daily life one must get away from the beaten highroad, strike out from the government-regulated inns, and blaze one's own path into the interior.

First, you get a low passenger-sledge, long enough to admit of stretching out, and without too many projecting nails on the inside; then, three good ponies of the hardy Cossack breed, that are never curried or taken into a stable through the bitterest winter. The best animals procurable are none too good for climbing the passes away from the river-courses. The whole outfit can be bought for three hundred roubles in any of the interior towns.

For drivers, there is a class of _yamshik_ teamsters, who spend their lives guiding the sledge-caravans which carry the local traffic. One of these men, Ivan Kurbski, can guide you through a whole province, and lodge you every evening with some hospitable friend or recommended host. Whether he has himself been over all the changing by-paths in the wilderness of the Zabaikalskaia Oblast, or whether he mentally photographs the directions of his friends regarding each village, is an unsolved mystery.

[Illustration: SLEDGING SOUTHWARDS]

When the day's journey is done, Ivan will drive slowly down the crooked street of the village he has settled upon for the night's repose, looking keenly for landmarks visible only to him in this country, where every village and every house is mate to all the rest. Sometimes he will ask a question of one of the innumerable urchins. But generally he seems of himself to hit upon the desired domicile. Day after day he will take you the sixty versts, lead you to the village stores to replenish the supply of candles or sugar, bring you surely to food and shelter at night, and take off all the burden of care for the outcome of each day's journey.

If for the third member of your personal suite you can get an old-time servant to keep the guns clean, build the camp-fires when midday tea is to be taken out of doors, bring in the baggage and rally the best resources of each halting-place, you are doubly lucky. You will be sedulously tended, and be treated partly as a prince, partly as a helpless baby.

Of this order is Jacov Titoff. Not the smallest personal service that he can render will you be permitted to do for yourself. The telling of unpleasant truths will be carefully avoided, however certain the ultimate revelation. Though honest beyond question, he pays you the naïve compliment of relying upon your generosity in all the little matters that concern provisions and petty luxuries. He will open the package which he is carrying back from the _torgovlia_ to extract matches and cigarettes for his own delectation, and will rifle unstintingly the reserve of canned _sardinki_. He cheerfully freezes himself waiting for deer, and stumbles up miles of snowy mountain in the beats. He is always in good humor, and without complaint for whatever comes. He is ready anywhere, at any time, to sleep or drink vodka.

Thus outfitted and manned, take your place, muffled in furs, and seated on the felt sleeping-blankets. Guns are at your side, the bag of provisions is in front, your own little ponies paw the snow. They start off now, trotting and galloping beneath the _duga_. The air is frosty, clear, and thrilling as wine; the snow is feathery and uncrusted, as when it fell months back; bells are jingling, and the driver is crying his alternate endearments and curses upon the shaggy ponies. Down the long rock-flanked river valleys, amid birch and pine forests, you will skim, by unwonted paths, through out-of-the-world villages, to see in their own homes the red-bloused peasants, the women spinning at the wheel, the peddlers and priests, the traveling Mohammedan doctors, the rough Buriats, miners and merchants, along the white way.

The smooth main road is left now for newly broken sledge-trails across fields and over snow-covered marshland. Every available river is utilized as a highway, for along its winding length the path, smooth and level, is marked like a boulevard by the evergreen saplings planted by villagers to guide the winter traveler. One can pierce the districts flanking the Chickoya's gorges, reachable at other seasons only by breakneck climbs. And one can see the real Siberia.

On this first night of his incumbency, Ivan Kurbski lodges us with friends. He leaves us for a moment while he enters the yard by the wicket-gate to make due announcement, and the ponies hang their tired frost-covered heads. Your own bows under an equal fatigue. But the wait is very brief. Soon the big double gates of the log-stockaded courtyard open. The horses of their own accord turn in, and swing up to the steps of the house. You are handed out like an invalid grand duke, and are welcomed at the threshold, with a hard hand-shake, by a red-bloused peasant who ushers you up the steps, across the low-eaved portico, and through the square felt-padded door into the big living-room.

As we all enter, Ivan and Jacov, caps in hand, bow and make the sign of the cross toward the grouped ikons high up in the corner opposite the door. The saints have guarded you on the way--are not thanks the devoir? Then you, as head of the party, must salute, with a "_Zdravstvouitie_," your host, the old _Hazan_ father of the peasant who, wearing a gray blouse sprayed with vivid flowers at breast and wrists, sits on a bench beside the window. Now you may sit down beside the massive table on the other bench, which is built along the whole length of the log walls, and survey the curious world into which you have fallen.

A woman of middle age, clad in bright red, is busy with a long hoe-like instrument pushing pots into a great square oven six feet high, ten feet to a side, and spotlessly whitewashed. To her right, in the room beside the oven, is a girl of fifteen or sixteen, rolling brown rye-dough on a little table, in perilous proximity to a trap-door leading into some dark nether region. An old bent woman gravitates between the two. Glancing up, one meets the wondering eyes of three sleepy blinking urchins, who peer down in solemn interest from a big cushion-covered shelf, two feet beneath the ceiling. Looking about to locate the muffled sound of crows and clucks, one discovers, beneath the oven, a corral of chickens, pecking with perky bills at the whitewash for lime. On the floor is sitting a little girl crooning some endless refrain to a baby in a sapling-swung cradle.

"The _gaspadine_ will take _chai_?" asks the patriarch. From the woman's room beside the oven the girl brings a samovar. She sets it on the floor, beside an earthenware jar standing near the door, and dips out the water to fill it. Then with tongs she takes a long red ember from a niche cut in the side of the oven, and drops it down the samovar funnel. Round loaves of frozen rye-bread are brought out and set to thaw. A plate of eggs is produced from the cellar. One rolls off as the girl passes, and falls to the floor. Instinctively you start. Not so the others. The egg has dropped like a stone and rolled away. But it is quietly picked up and put to boil with the rest. It is frozen so solidly that there is not even a crack on the shell.

Jacov meanwhile is making earnest inquiry of the "old one."

“How are your cows, Dimitri Ivan’ich? Your horses, are they well? And your sheep? All well? And have you had good crops? Is there still plenty of pasture-land in this village? _Good!_ GOOD!--and how is your wife?”

Poor withered wife; she is bustling around looking after the children, and trying to help her daughter-in-law. Not so the “old one,” the ancient man of the family to whom these courteous questions are addressed. The patriarch stopped his labors at fifty, and sits slumbering away his second prospective half-century in honored idleness. “Everybody works but father!”

The samovar is humming now, and the table is decked with a homespun-linen cloth ready for the _obeid_. The first formality, as dinner is about to begin, must be observed. The various members of the family turn, one after another, toward the ikons, reverently crossing themselves. Then the host produces a bottle of a colorless liquid, shakes it up and down, and brings the bottom sharply against his palm. The cork shoots out, and he pours into a little glass a drink of the national beverage, vodka, which one is supposed to swallow at a gulp.

Every time a guest enters, a bottle of vodka is brought out, costing 49¼ kopecks, half the average day-laborer’s pay in this district. On feast-days the visitors go from house to house drinking,--and these _prasdniks_ number some fifty-two days in the Russian year. Every business deal is baptized with vodka. Every family festival, the return of a son from the army, the marriage of a daughter,--all are vodka-soaked. As one passes through villages on a saint’s day, he may meet a dozen reeling figures and hear the maudlin songs from the courtyards where the men have gathered. The part played by vodka in the people’s life is appalling.

In the house now, all, beginning with the “old one,” partake of this stimulant, solemnly gulping down their fiery potions. Then the family sits down in due rank and order, the “old one” in the cosiest corner, with the samovar convenient to his hand. You, as the guest, are beside him on the bench that lines the wall, then comes Jacov, next the son, then Ivan Kurbski the _yamshik_, and on stools along the inner side of the table, the grandmother and assorted infants. The mother alternates between the table and the oven.

The samovar is tapped for tea as the first course of the evening. For all who come, tea is the obligatory offering, in a cup if the visitor be familiar, but for special honor in a glass with a ragged lump of sugar hammered from a big cone-shaped loaf. This one nibbles as he drinks, for sugar is a luxury, not to be used extravagantly. The brown rye-bread, which has been thawed at the gaping oven-door, is next brought out, and raw blubber-like fat pork, in little squares, eaten as butter, and boiled potatoes, and the boiled eggs, curdled from the freezing.

At Little Christmas, the _prasdnik_ day which comes in early January, _pelmenis_, or dumplings, egg-patties (grease-cooked), and meat will be served, with cranberries and white bread. In Butter-Week everybody gorges on buttered _blinnies_, or pancakes, garnished with sour cream. Even a substance showing rudimentary traces of a common ancestry with cake may be produced.

As the shadows of the northern evening close down, a piece of candle is lighted to-night in our honor. Generally the burning brands for the samovar, propped in a niche cut at the height of a man’s shoulder in the outer edge of the oven, throw the only light. Presently the candle is used up and the brands give a fitful flame, leaving the corners black as Erebus.

From the baby’s cradle comes now a plaintive cry, and one of the little girls goes over to dandle it. Up and down, to and fro, for hours together she works, singing her monotonous lullaby. The children, who have been lifted down from their eyrie above the oven, play on the sanded floor. The men remain oblivious and smoke their pipes, letting fall an occasional word, which comes forth muffled from their great beards.

Ox-like, all sit for a while, sipping occasional cups of tea. Then the woman and the girl go out and get wood, remove the pots from inside the oven, and build up a roaring fire. The children are rolled up for sleep in their little blankets on the floor. The men reach for their furs and felts. They go to the left of the oven, the women to the right, and the children are between, making a long row in front of the fire. Soon all are sunk in heavy sleep. The little girl alone sits up to rock the baby. As you doze off in the genial warmth of the newly-stoked oven she is still crooning her lullaby in the dim fitful light of the firebrands.

Through the long night all lie like logs. Toward morning, as the oven’s heat dies down and the bitter cold creeps in, sleep becomes uneasy. One stirs and then another. Finally the woman rises and wakes the girl, and they go out into the cold for wood and water. Presently the men bestir themselves, get up, and wait for their tea. The rising sun of another day casts its rays through the windows.

As the sleepers one by one arise and stretch, their blankets are folded by the watchful woman of the house, and thrust up on the children's shelf. Some of the men go across the room and let the water from the little brass can in the corner trickle over their hands. Some do not do even this.

For the outlander of washing proclivities, peculiar problems are offered by a country of no wash-bowls, no soap, only occasional towels, and the tea samovar as the only source of hot water, a copious draft on which not only postpones breakfast but compels some of the women of the family to go out and chop ice for a new supply. Necessity evolves the tea-tumbler toilet method as our solution. You borrow one of the precious tea-glasses from the old woman, fill it to overflowing with warm water from the samovar, and prop it up on the window-sill. The top inch of water is absorbed into a sponge which is put aside for future use. Into the remaining two and a half inches a soaped handkerchief is dipped, with which one washes one's face, touching tenderly the spots recently frozen. The reserved sponge will do to rinse off the detritus of this first operation. Two and a quarter inches of water are left, of which half an inch may be poured over the tooth-brush. With an inch and three quarters left, one has ample to lather for a shave, as well as to wet the nail-brush which is to scrub one's hands that will be rinsed with the sponge. Half an inch remains finally to clean the brushes and razors. "There you are!" With two glasses one may have a bath.

When the breakfast of rye-bread and tea is ended, the men go out to their various winter tasks, of which the most serious is felling trees in the forests, cutting them up, and getting home the wood. The women keep stolidly at their cooking, cleaning, child-tending, and turn to the spinning-wheel and hand-loom when other work does not press.

In the weeks that follow, each night brings us to a different home, but never to a changed environment or atmosphere. This type of life is found, not only among the Trans-Baikal peasantry, but throughout all Siberia. The log houses down the long straggly village streets look out upon the same wooden-walled courtyards,--the women peering from their little windows as the sleighs jingle past. The same ikons with burning lamps look down as you enter; the same whitewashed oven and shelf and cradle are there as you push open the felted door. The women of each district wear the same traditional costume. The bearded host produces the same vodka. One of the most impressive sights, when one drives out before dawn into the frosty air, is to see at almost the same moment from every chimney the black smoke roll upwards, then dwindle to a thin gray streak. Each woman has risen and heaped green wood into the cooking-oven. It is as if one will actuated simultaneously all the people.

At places the master of the house has a trade, shoemaking or saddlery, and the big living-room is littered with pieces of leather and waxed cord as he stitches. Sometimes there are hunters in the family, and ancient flintlock muskets rest on the antlered trophies. The men gather together occasionally to drive deer. But in general, as the winter is the men's idle time, a little wood is cut, the cattle are seen to, and for the rest, talk, tea, and tobacco, until it is time to eat and sleep once more. The women on the other hand seem to be always occupied, but they are not discontented.

[Illustration: PEASANT VILLAGE STOREKEEPER SIBERIAN TYPES]

The customs and institutions which bind together the household group are unique. In all families the _Hazan_ is supreme. To him first of all, strangers pay their respects. To him every member of the household comes for advice as to whom he or she shall marry, and which calf shall be sold. Howsoever hard of hearing he may be, there is related to him all the events of the neighborhood with infinite minuteness. He is the repository of all moneys earned by logging for a neighboring mine-owner, or for bringing out to the railroad the sledge-loads of rye. As head of the family he can summon a forty-year-old son from the merchant's counter in Krasnoyarsk, or his nephew from the fur-traffic in Irkutsk, and bid him return to his peasant hut. If a grandson wishes to go to Nerchinsk to seek his fortune, the "old one's" consent must be obtained before the youth receives his passport. It is all at the patriarch's sovereign pleasure.

We come one day upon a vexatious example of this ancestral authority. A report reaches us, by chance, of a hibernating bear's hole some fifty versts away, which one of the peasants has located. The host, noting our interest, asks:--

"Would the _gaspadine_ like to hunt him?"

There is no question on this score, so the peasant is quickly brought to the hut. Numerous friends crowd in with him, for one person's business is everybody's business in these primitive communities. For a liberal equivalent in roubles the man agrees to act as guide, and the start is to be made early next morning. All is arranged and he goes out with his body-guard to make the necessary preparations. By and by there is a stir. Our sledge-driver comes in with a long face. Then half a dozen peasants add themselves to the family quota in the hut. Soon more come, until the stifling room is as populous as a Mir Assembly. They are all

talking at once, and there is a great hubbub. At length one voice louder than the rest seems to call a decision for them all. They turn backward again, and with many gesticulations bustle through the felted doors into the snowy streets, and through the village to a house which they enter in a body as if with intent of sacking it. Instead they bring out and over to our hut a slight bearded old man, bent with the weight of many winters--the father of the peasant guide.

Humble but resolute, he faces the assembly.

"No, I cannot consent that he lead the _gaspadine_ to the Medvetch Dom."

"But assure the 'old one' that his son will only point out the den and then go away."

The "old one" answers:--

"The bear does not come to steal my pigs. Why should I get him shot? Besides, a bear chewed up three Buriats last year. It would be sad to be devoured even for the _gaspadine's_ fifty roubles."

The reward is doubled, and forty kopecks' worth of vodka produced. Many advisers give aid, and one suggests that "the son may mount a tree one hundred _sagenes_ from the mansion of the bear!"

But still the father refuses. "No, I will not allow him to take out his horse and hunting-sledge."

The son, whose half-dozen full-grown children are looking on, shakes his head dolefully. A big eagle-nosed peasant, of hunting proclivities, comes in.

"I will give my hunting-sleigh if he will go," he calls.

But the shrill voice of the "old one" rings out again, "I do not consent. I do not consent. My son shall not go to the mansion of the bear."

The guide shrugs his shoulders. We have hit the ledge of Russian authority. No one will budge. The old man has his way.

As is the management of the household, so is that of the village. While the _Hazan_ rules over the common property of the family (_izba_), the village elder (_Selski Starosta_) is guardian over the grouped households which make up the Mir. As the household goods belong to no one individual, but are common property, so the land farmed by the villagers is a joint possession whose title rests with the commune. The family is held for the debts and behavior of all of its individuals; and similarly, with certain limitations, the village community is answerable for the taxes and discipline of each of its members.

On a humble scale it is the spirit of socialism incarnate. Within the commune no capitalistic employers, no wage-taking worker-class, no castes exist, and no individuals are born with special privileges. No distinctions of rank or fortune lift some above their fellows. The manner of living is the same for all. Each head of a family has a right of vote, and elects by the freest, simplest means his own judges and village rulers. The land, the source of livelihood, is divided among the producers by their own unfettered suffrage.

The chief man of the community--he who drums out the voters to the Mir, lists those who do not work sufficiently on the pope's field, and reports the toll of taxes to the Government--is simply an elderly peasant clothed with a little brief authority. There is no household in the average village which is looked up to as more genteel than the rest. No such distinctions as prevail in America will reveal that such a farmer's family is musical and well-read, such another has traveled to Niagara Falls, such a third has blue-ribbon sheep. In Russian peasant circles all is equality, almost identity.

Here is presented the best example in the world to-day of an applied system based upon the communistic as opposed to the individualistic theory. It is therefore of more than local interest. Most apparent of all results is the economic stagnation which has accompanied the elimination of special rewards for special efforts. The man, more daring or more far-sighted than his fellows, who would take for himself the risk of a new enterprise, who would mortgage his house to buy a reaper, or would seek a farther market, is fettered by his plodding neighbors. His financial obligations, if he fail, fall on the others of a common family, whose members have a veto on his freedom of action. His own and his neighbor's fields by the allotment are proportioned in extent to the old hand-labor standard. A machine has few to serve until the fields are readjusted to a new standard. While technically a man may buy or rent lands outside the commune and may introduce a new rotation of crops or agricultural tools, actually the inertia of the peasants bound to him by the brotherhood of the Mir weighs the adventurous one hopelessly to the earth. Who can persuade an

assembly of bearded conservatism-steeped "old ones" to buy for the Mir the costly new machines? Perhaps, with the visible demonstration of profits which private enterprise could make under an individual régime, the doubting elders might consent. But who is there to show them when every village checks back the swift to the lock-step of the clod?

Nor is it simply in material things that communism manifests its lotus-fruit in these country hamlets. Ignorance, unashamed, broods over them one and all. What a dead level is revealed by the fact that one peasant in a populous village on the Chickoya, our guide upon a shooting-trip, could not tell time by a watch, and had never seen such an invention.

Some instances are related where the more ambitious men of a Mir have clubbed together to bring in a teacher at their own expense. The Semieski, or "Old Believers," big, red-bearded, obstinate men, settled in Urluck in the Zabaikal, who dissent from the sixteenth-century revisions of Bishop Nikon, will not send children to Slavonic schools and may have schools of their own. But these cases are rare. There is among the peasantry almost no education and comparatively little desire for it, yet how far this sentiment is from being a racial or national failing the crowds that come to the city universities bear ample witness. In one of the villages a teacher from Chita is established in the side room of a peasant's house, wherein one night we sojourn. He has been appointed by the Commissioner of Schools of the Cossack Government. He is of a good Nerchinsk family and is brother to an elector of delegates to the second Duma. He is one of the "Intellectuals"--the student class which forms almost a caste by itself. A free-thinker, keenly interested in the rights of man, a Social Democrat by politics, he goes shooting on Sunday with some peasant cronies. He plays Russian airs on his _balilika_ and gets the peasant's daughter to dance for the guest. He produces specimens of antimony and chalcopyrite, and discusses the geological probability of finding silver or platinum ores in these districts. Photographs of the amateur-kodak variety are along the walls, and on a table in the corner are a mandolin and a pile of books. We pick up a volume,--"L'Évolution de la Moralité," by Charles Letourneau. The young owner, who consumes a prodigious number of Moscow cigarettes, tells of the indifference to education among the people.

"Here we have a school in a big village, with two other communities near by. There are easily five hundred households,--with how many children in each, you can see. Yet we have but thirty boys at school. What can we do?"

He is discouraged, this single "Intellectual" of Gotoi. Profoundly solicitous for the future, an idealist, boundless in hopes for the good of his race, he sees the younger generation submerged at the threshold of opportunity by the inertia of the old.

"'What good will it do for him to read?' ask the peasants, when I urge, 'Send your boy to the school.' What can I say? The boy comes from my class after two years, and goes out with the men. He has no money to buy books if he wants them. No newspapers come to the village, no printed matter whatever, save that on the pictures which they buy in the fairs. In a few years all I have taught is forgotten. The darkness is over these villages. One must lift them despite themselves."

Beyond the range of the village communes, no people show a more eager zeal for knowledge and study. In the cities almost all of the younger generation can read and write. The school-boys, with their big black ear-covering caps, smart blue coats, brightened with rows of brass buttons, and knapsacks of books, are one's regular morning sight. "Realistic" and "Materialistic" schools are established in many towns.

The apathy of the rural element is to be laid at the door of the system which hinders those within the confines of the communes from reaping the fruits of special sacrifice and effort. No one attempts to raise himself in the Mir, where the dead weight of those bound to him is so hopeless. If any boy, brighter than the rest, follow some lodestar, it must be to a city. The aspirant must bury ambition, or leave the drudging Mir with its toll of taxes and recruits. He will not study law before the wood-fire as did Lincoln in his log cabin.

The cloud of deadening communism over their lives utters itself in the words continuously on the peasants' tongues. It is the northern equivalent for that buttress of despotism--"_mañana_." The possibility of the Russian condition is "_nietchevo!_" If the red cock (_krasnai petuk_) has crowed and has left the forty householders with charred embers where stood their homes, "_nietchevo!_" They build it up of wood and straw, with the oven chimney passing through as before. Does a raging toothache torture, "It is the will of God,--_nietchevo_!" If the weary day's climb sees a gameless evening, "_nietchevo!_" If the son is frozen in the troop-train, "_nietchevo!_" If the Little Father send to Yakutsk the other one who has gone to the city, "_nietchevo!_" Is the unrevised tax for a family of ten men pressing down upon three, "It has got to be borne,--_nietchevo!_" It is this bowing to fate as a thing begotten of the gods, when it is a force to be fought here on earth; the long-taught submission to evil, when evil is to be conquered, to limitation when opportunity is to be won,--it is this spirit which is holding rural Russia still in her Dark Ages.

The origin of the present village-system goes back to the time of serfage, when the overlord held his dependents herded together for easy ruling. That it extended to unfettered Siberia, where the rewards of individual effort were so obvious, cannot be laid entirely to old custom or government compulsion. Nor is it to be explained by the early necessity for protection against wild beasts or hostile natives. The same dangers threatened the pioneers of our own country. Perhaps the Russian spirit of gregariousness lies at the root of the fact that in the Czar's domains the peasant lives away from his fields to be near his neighbors, while our people live away from their neighbors to be near their fields. Whatever the cause, the outcome is that practically the whole rural population, even in the most thinly settled districts, is gathered into villages, and owns the lands in common.

The system makes enormously for homogeneity, welding, solidarity. The people are a "mass." Units are lost in unity. Nothing save Nature's imprint and law of individuality, that decree under which every created thing is some way different from every other, keeps the Russian peasant from quite losing his birthright. The commune, vodka, and resignation are the incubi of Siberia. In the towns and cities gather the energetic natures that have climbed out and above them. What these have done, their allied people--the peasants--can do. Beyond the horizon of the latter's narrow lives lies still the borderland of possibilities. One cannot doubt the vigor of the stock, nor the certainty of its rise. This quality of rugged worth is the basis of all the great advance that the pioneers and the city populations have made. It is only in the Mirs, frozen fast in their lethargy of communism, that resurrection seems such a far-off dream. The way is long for the peasants of Siberia--long and toilsome. But their vast patience is allied to as vast a courage, and both will lift them into the larger day.

The measure passed by the last Duma, decreeing the division of the Mir lands in severalty, and private ownership of property, will be one of the most momentous and far-reaching enactments ever legislated for a people. It should end for rural Russia the stagnation, and open an era of mighty endeavor and achievement.

There are many races here among the serenely tolerant Siberians, undiscriminated against and uncoerced. While one of the Orthodox may not abjure the state religion without severe punishment, those born to an alien faith are unmolested by official or proselyting pope. "God has given them their faith as he has given us ours," is the Russian rule.

This medley of races beneath the Russian banners gives to one's earliest contact the conception of a heterogeneous disorganized jumble of nations and peoples. But closer acquaintance impresses upon one the dominating and surviving qualities innate in the Slav, whose unalterable solidarity is beneath and behind the kaleidoscopic types of aboriginal tribes and exiled sectarians. By race-absorption, like that which has evolved Celts, Danes, Saxon, and Norsemen into English; British, Dutch, Swedes, Germans and Italians into Americans, the Slav is dissolving, transmuting to his own type and moulding to his own institutions the varied peoples.

Though the heterogeneous blood adds to the total of Siberian country life, it is the Slavic race that determines the permanent order of this great land. Primarily too it is the peasantry who shape its destiny. Their possibilities are the limit of Russia's ascent. Their condition is therefore of far deeper than sightseeing interest to the student. Unlike the picturesque peasantry of Holland, here they are the foundations of the state, forming not an insignificant minority but ninety per cent of the population.

Somewhat of a new spirit flickers here and there in Siberian hamlets. The peasant is superior to his Russian brother. The traditions of serfdom were broken by his severance from the old environment, and wider lands give him an abundance unknown save in a few favored parts of Europe. The political exiles have through the centuries added an upsurge of independence and personal self-consciousness, which is markedly higher than the Oriental humility of Occidental Russia.

The influence of the criminal, as distinct from the political convict, is felt primarily in the cities, such as Irkutsk and Vladivostok, to which the time-expired men drift. The convict element is always met with. It has been customary to billet a condemned, who was not wanted at home, upon some out-of-the-way village, giving him a passport for its confines alone. The victim might have been a Moscow professor or a locomotive engineer, but in the Mir he must farm the land given him. Naturally such seed as this planted in Siberian hamlets does not produce the traditional peasant faith in God and the Czar so faithfully preached by the popes.

Another influence making for upheaval is the returning recruit. We are in a peasant house when a _soldat_ comes back to the family from his service. If he has not brought any great burden of salary, he has accumulated tales enough of the outer world to hold in breathless excitement the circle of friends and relatives which gathers at once when the tinkling sleigh-bells and the barking have announced to the village his return.

Far down the street is heard the jingle of his sledge. It brings every girl to her peep-hole window, and every boy from his sawing to the courtyard door. At the gateway where the newcomer turns in, he is heralded by the commotion of the household guardians, wolf-like in appearance and nature. Everybody within the important house runs to the door. The village knows now which family is making local history. The arrival is accompanied already by two or three men who have recognized him as he descends. He tramps in with military firmness of tread, head erect. Before he greets the grandfather even, he makes the sign of the cross to the holy ikons, and, bowing down, touches his lips to the floor. Then comes the respectful kiss to the old man, next to the mother, while the younger brother, soon to go to service himself, stands awkwardly by, and the little children look half-dubiously at a form scarcely known after his four years of absence.

Then there is a scurrying of the grown and half-grown daughters to prepare _chai_ and to produce the _pelmenis_ and brown bread. The villagers drift in one by one, cross themselves, and speak their greetings, until the little house is packed, and as hot as the steam-room of a _banno_. The vodka-bottle is out and everybody has settled down for an indefinite stay. The soldier's tales of war and garrison duty and government and revolution hold the family and the audience breathless through the long evening. As you drop asleep, the hero is still reciting and gesticulating. The guests in departing will be careful not to stumble over you, so _nietchevo_.

In one of the houses where we put up, a shop adjoins the big living-room. It has dingy recesses from which hatchets and the commoner farm utensils can be produced, shelves of homespun cloth, and gaudy cottons for the men's blouses, and beads for the women's bonnets. Here, as in the country-stores of our own land, during the long idle winter days there is always a crowd and endless discussion of the village events,--the health of each other's cows, births, marriages, deaths, drafts into the army, taxes. Even in this remoteness something of the echo of great Russia's struggle is heard over the shopkeeper's tea-cups. We hum, unthinking, a bar of _Die Beide Grenadier_, in which a refrain of the _Marseillaise_ occurs.

A peasant looks quickly up. "It is not allowed, that song," he says.

"Why not?"

"That is the song of the strikers."

"But the _gaspadine_ is a foreigner. He may sing it."

"Yes," says the peasant, "he may sing it, but I may not. Would that I might!"

One meets quaint characters in this inland journeying--veteran soldiers of the Turkestan advance; "_sabbato_ sectarians," who keep Saturday holy rather than Sunday; austere "Old Believers," traveling peddlers, teamsters who have tramped beside their ponies over three provinces. One comes upon peripatetic Mussulman doctors, in snug-fitting black coats and small black skull-caps, who show their Arabic-worded road-maps and much-thumbed medical works bound in worn leather. Beside their plates at table the kindly hostess puts piles of leathery bread, unleavened, and made without lard in deference to their caste rules.

[Illustration: PEASANT TYPES]

A shop in one village is kept by a Chinaman, who, lettered like most of his race, seems a far shrewder and more intellectual person than the uneducated Russian peasants. He invites the stranger to drink tea that his special caravan brings, and presents Chinese candy with the courtesy of a grandee. When, in reciprocity, the traveler buys sugar for his _chai_, he receives it wrapped in paper covered with hieroglyphics and exhaling the faint unmistakable Chinese odor.

Going always southward, one begins to meet more and more frequently the villages of the Mongol-descended Buriats. "_Bratskie_" (brotherly people), the Russians call them, for despite the forbidding aspect that flat Mongolian features, high thin noses, yellow-brown skins, and big squat bodies give them, no more peaceful, harmless, and hospitable people exist. They are great and fearless hunters, unexcelled riders, and though still only on the threshold of civilization, are rapidly moving to better things.

All phases of the advance from the nomad to the agricultural stage may be studied among them. The pastoral Buriats, decorated like the Chinese with queues, ride around after their flocks. Their villages lie far away from the lines of convoys, unmarked on the Ministry map, which one is supposed to be following. Each family occupies a little windowless wooden hut, some fifteen feet in diameter. In front of it is planted a pole, carrying at the top a weather-faded pennant, the colors of which in Buriat heraldry indicate the tribe and name of the occupant. Behind the hut are stacks of hay and a wooden corral with sheep and horses. Beside it stands the summer tent, of felt, looking like a great inverted bowl. It is empty in winter, save for a shrine with grotesque pictured gods,

fronted by offerings.

In the homes of these least advanced Buriats we loiter no longer than we must. The wooden house which shelters them is hermetically sealed, and is crowded with people and animals. Fenced off in a corner of the first that receives us is a corral of thirteen lambs, which at uncertain moments begin to bleat suddenly in unison, producing, with startling effect, a prodigious volume of sound. When one has been roused from sleep half a dozen times a night by this chorus, he is strongly inspired to move on. The men are out during the day looking to their flocks. The women spend a good part of their time sewing furs or making felt. They are very unclean, and it is a decided relief to get out of their homes, to which the cold compels one to have recourse on a long journey. In spring, with great and understandable relief, these semi-nomads take to their felt tents and move where fancy and pasturage dictate.

One grade higher are those Buriats who have learned some rudimentary farming from the Orthodox. You will see the men threshing on a level floor beside the corral. They are dressed in long blue or magenta fur-lined cloaks and colored cone-shaped hats. Other Buriats are permanently resident in the Slavonic settlements, and send their rosy-faced children to school. They mix with the Russians, subject to almost no disabilities, and their better classes contract inter-racial marriages, which seem, to an outsider, at least, completely happy and successful.

It is no small thing, this which Russian rule has done for the Buriats. A people whom any other nation would spurn in racial ostracism, perhaps would eliminate, live side by side with the good-natured Slav in perfect accord, progressing in civilization and material well-being as high as the individual can aspire to and attain.

They are ruled by their own chiefs, whose sway is tempered by the benevolent supervision of the general government. They are represented in the Duma by men of their own selection. They freely worship the Buddhist Burhan in their lamasery near Cellinginsk, without pope to preach or missionary to proselyte. Their easy citizenship is unharassed by money taxes, and their only obligation is Cossack service in the army. But Cossack service to a Buriat is what a picnic is to a boy. Riding around on horseback, rationed by the Government, visiting a city with real tobacco and vodka sometimes attainable, sleeping on a straw-stuffed mattress with no tethered lambs to murder sleep, when they are used to a sheepskin on the dirt floor,--all this is luxury of blissful memory, during the years of the reserve. The net result is that the Buriats are entirely content. They are progressing all along the line, and are being made useful to the nation, not by unpayable taxation, but by the service which they are so especially fitted to render.

As one nears Chinese territory, by the lower waters of the Chickoya River, the villages of Slavic colonists who hold their land on tax-paying peasant tenure, have given place to the Buriat tribesmen and to the _stanitzas_ of the Cossack guard that occupy the pale of land flanking the frontier. Within this border-belt, every village _stanitza_ holds its quota of Cossacks. These soldiers are for the most part descendants of the levies from the Don region, transplanted to the Trans-Baikal by the Government's despotic hand in the eighteenth century, and since then forming an hereditary military caste. Many of them are bearded Slavs, indistinguishable, save for their accoutrements, from their more peaceful neighbors. Others are of a peculiar cast of countenance, due to the mixture with the Asiatic tribes in ancient times, when the hunted people fled to their ancestors' asylum, the territories beyond the Volga and on the Don. There is great variation in type among the imported Cossacks. Most are Orthodox, but a very large number are "Old Believers," or Semieski. In all the houses now hang the yellow cap and the uniform coat, which must be ever ready against the call of duty. Arms are in the corners of the rooms, and everything has a military look, in marked contrast to the peasant homes. Crude, highly-colored prints of Japanese defeats, which circulated broadcast in Russia during the war, share the attention usually devoted exclusively to holy ikons. Portraits of Generals Linevitch and Kuropatkin, and Admiral Alexiev, are tacked to the walls. In one house we saw hanging a prized silver watch, one of those distributed by General Rennenkamp among the soldiers of his command.

One of our Cossack hosts is an old man, Orthodox, and of Russian origin, but with some ancient Asiatic blood, for only a stringy beard grows on his kindly, wrinkled face. With reluctant pride he tells of his three sons away on service, leaving but himself and two daughters at home. With frank happiness he shows you his medals. Every soldier at the front received a round brass service-medal; his, however, a silver cross with St. George and the Dragon on it, is given for valor. He will not drink the vodka he offers you,--rheumatism. But in order that you may smoke some alleged tobacco that greatly interests him because he gathered it himself by the roadside, in Manchuria, he starts up his pipe despite the dust-induced coughs that it begets. He is a kindly, loquacious old man.

Another Cossack, privileged to the broad yellow top on his cap and the yellow stripe on his trousers, is, for the time, our guide and gun-carrier. His flat strongly-mustached face is open and ingenuous. He tells of his _sotnia_ in Manchuria.

"I was with Mitschenko at the front during the war, in his great raid," he says. "Ten of our _sotnia_ of a hundred were killed, forty wounded. We got behind the Japanese and burned four hundred of their wagons. We had two hundred rounds of cartridges, and more when we wanted them. But food often not, and meat sometimes not for two months. We had thirty Buriats in our hundred, but the Verhneudinsk Polk were almost all Buriats."

In one house where ikons, oven, bench, and stockade reveal the Slav peasant's home, the mirrors are shrouded for their forty days' veiling. It is a place of death. The owner was a full-blooded Buriat married to a Russian woman. In silent grief she plods through her mechanically-executed duties. Their son, in red blouse, is in prayer beside his father's body. They have pressed us to remain. The advent of strangers seems to distract their thoughts a little. From outside comes a hail, and heavily there dismounts from his pony an old grizzled Buriat Cossack. He has ridden two hundred versts to pay this last respect to his friend.

His military training makes the Cossack a little less gentle than the average peasant. When off duty, hen-roosts near a garrison are in some danger. For the rest, he is naturally brave, generous, and will share the chicken he has just ridden forty versts to lift. He will give his pipe to be smoked, and will behave with a thoughtfulness and courtesy that is not found in finer circles. His children have the free unrepressed air which speaks of genial home kindliness and sympathy. His wife is far from being a mute drudge.

Assuredly this is not the Cossack of legendary fame, the "implacable knout" of the czars. It requires almost courage, in the face of the savage of literary tradition, to assert that the Cossack is other than a dehumanized monster of oppression. Why then did he cut down with utter ruthlessness the helplessly frozen grenadiers of the Grande Armée? Why will he massacre indiscriminately men, women, and children on his path from Tien-tsin to Peking? Why will he beat with his knotted whip the striking girl students of Kiev? Who shall tell? To a certain extent he is callous to suffering because of a defective imagination. He will ride his best horse to death if need be. Loving it, he will yet leave it out in weather forty below. He is cruel, often, because he has not the substituting gift needed to translate another's suffering into terms of his own. He is valorous because, even so far as regards himself, he cannot think beyond the immediate privation into the future of imaged dread, so he goes fearlessly into unpondered peril. He offends the traditional ideas of humanity and civilization in killing people, because of his failure to recognize a wider radius of sympathy than circles his own tribe. But if the tribe circumscribes his idea, the nation circumscribes the sympathies of others who make tariffs to crush an extra-national industry and raise armies to destroy a foreign liberty. But if outside the Cossack's recognized circle, you are to him beyond the pale, in his home, you are, _ipso facto_, a member of the tribe, a brother in whose defense he will gayly risk his life, and spend his substance.

The deeds that are recalled to the Cossack's discredit often fall for judgment really to those who plan and issue the orders which loyalty makes him obey. Where his allegiance has been once given, there it remains. His _hataman_ is more than a superior officer; he is the chief of the clan, the head of all the tribe, and the subordinate is united to him by the traditions of centuries of mutual dependence. Where other than blood-kin officers are put over the Cossack he mutinies, as when, in Manchuria, Petersburg-schooled lieutenants were drafted and raised to command. But give him his own rightful chief, then if the Cossack is told to do something it is done. He will cross himself and jump from the tower, as in Holland did Peter the Great's guardsman at the word of the chief to whom he had given his loyalty.

The savage valor of the warriors in Verestchagin's picture, _The Cossack's Answer_, is typical of the spirit of these soldiers. Surrounded by battalions of the foe, fated to annihilation when the summons to surrender is rejected, the leaders, laughing uproariously in approval, hear their _hataman_ dictate the insulting reply that dooms them all. If one would ride to China he can have no better guards and comrades than the Cossacks.

We are close to the border now, climbing the last crest which separates the Chickoya from the Cellinga Valley, our toiling tired ponies white with frost. All day the long sweep of the hills has been taken through heavy snow. The landscape is barren, desolate, and lifeless save for the occasional sight of a distant Buriat horseman. The sun is slowly sinking.

The crest at last! The driver points with his whip to the dark masses of houses below, wreathed in the curling smoke of the evening fires. Here and there is a brilliantly painted building or tower, and sleighs and horsemen are passing in the streets. "Troitzkosavsk!" he says. He points further ahead to another more distant town, whose most dominant features are the great square tea-caravansaries and a mighty church, green-domed, with a gilded far-glimmering cross. The huddled houses end sharply toward the south, as if a ruler had marked off their limit in a straight stretch of white. Along this pale are little square sentry-boxes, striped black and white. In the evening sun a distant glint of steel flashes from the bayonet of a pacing sentry. "Kiahta!" the driver says. Then, across the white strip where a wooden stockade girds a settlement of gray-walled compounds, fluttering with tiny flags, gay

with lofty towers and temples flaunting their red eaves, he points a third time: "Kitai!" (China).

He picks up the reins, and lifts the whip; "Scurry!" he cries to the horses. The ponies leap forward, throwing their weight against duga and collar, and we sweep down the hill toward the nearest Russian town, Troitzkosavsk, four versts from the border.

As we come down to the main road hard-by the town, officers of the garrison drive past with their spick-and-span fast trotters, city-wise, as one sees them in Irkutsk. Behind rolls a Mongol cart driven by a burly Chinaman. A Buriat, come to town to replenish his supply of powder and ball, follows on his shaggy pony.

Down a long street, flanked first by log cabins with courtyards and fences like those in the peasant villages, then by stucco-plastered houses, cement-walled government buildings, and great whitewashed churches, we pass and reach the centre of the town. Then we turn up a side street to the house of a mine-owner, to whom we are accredited.

Nicolai Vladimirovitch Tobagov meets us at the door of his log house, clad in gray flannel shirt and knee-boots. A not unnoteworthy product of Siberia is this man,--squarely built and yet wiry, with nervous strength expressed on his bearded face. He is self-made, risen from the masses. A peasant-boy, he started life as assistant to a surveyor, learning to read and write by his own efforts. During this apprenticeship he studied his chief's books on geology, by the light of the brands for the samovar in the peasants' houses where they were billeted nightly.

He located placer gold in a number of spots, at a time when the oblast was a lawless "no man's domain," without any legal means in existence for acquiring title to property. Guarding in silence his secret, he waited years, until at last a mining-law was enacted for the oblast where his prospects lay. When this law ultimately made private ownership possible, he started in to realize. A friend lent him the money for a mill, which he constructed, according to book-descriptions, on the model of those in California. At first it failed to work, and broke again and again. His riffles were set too steeply. They had let the gold scour away, and his neighbors reported that there was no gold to collect. But he fought it through to victory, returned every borrowed kopeck with interest, bought new machines, and prospered; till now, besides controlling several mines, he possesses a great domain in the river valley, some hundred versts away, with fields of wheat and rye and hay-meadows.

When the visitor has stamped the snow from his felt boots and emerged from his shaggy bearskin coat and hooded fur cap, he enters the main room, with its walls of great logs bare of ornament and showing the scorings of the axe, but clean as new-planed wood can be. Between the chinks straw and moss are packed to keep out the cold. Two great benches flank the sides of the room. Not a picture, not an ornament, not a curtain, not a drapery, not a shelf, breaks the plainness of the log wall, but here and there are hung guns and rifles. In essentials this large house does not greatly differ from the typical peasant's dwelling. But a copy of the "Sibir" newspaper lies on the table, and photographs of the female members of the family are added to the many reproductions of relations in military dress, which the photographer has touched up with brilliant dashes of red, to pay tribute to the coat-lining, and white to indicate the gloves. Lamps replace the lowly tapers, and they burn before more gorgeously gilt ikons. The windows are double, with cotton-wool and strips of colored paper between. This is a great improvement on the single ice-crusted window, with its perpetual drippings down along the sill. There are the little sheet-iron stoves, whitewashed after the tradition of the oven; chairs with backs, as well as the square stools; and small rooms curtained off from each other. A clock hangs on the wall, and there are carpets on the floor. A large table stands at one end, on which is the ever-boiling samovar, which is nickel instead of brass.

We are made acquainted with the wife of the host, a stout matron of fine domestic proclivities. Though of humble origin, she has discarded her peasant shako and bandana-handkerchief headdress for a bonnet, and dispenses, as to the manner born, many luxuries. On the other hand, she has lost the robustness which keeps her peasant sisters fresh and hearty. Sewing-machines, and beds, and servants, must exact toll even in Siberia. Her boys are clean-cut and intelligent. They go to school and are the future "Intellectuals" that are seeding Siberia. Sixteen children--eleven Nicolai Tobagov's own, five adopted in open-hearted generosity--sit down to four very solid meals a day in the big hall. Ivan Simeonski, _optovie_ and _argove_ merchant, and Nicita Baeschoef the lieutenant, traveling west on furlough, are stopping in this friendly house, and many other guests are here. The hospitality of the household is conducted on a scale of patriarchal magnificence.

Before our furs are fairly off, the host has called aloud for _obeid_. One's first formality is, as usual, to salute the ikons and the guests. One's second is to escape the scalding vodka, seventy proof, and then begin with the _zakuska_ of ten cold dishes on the side table. There is black caviar from the Volga, though the rapid diminution of the supply has raised the price to ten roubles a pound. There is red caviar from the Chickoya, cold mutton, cold sturgeon, sardines, ham, and sliced sausages made at home. The latter must be abundantly and appreciatively sampled, because they have been specially prepared under the direction of the

souprouga herself. One stands before the _zakuska_ and dips from dish to dish. Next, the guests take the square wooden stools and draw up to the great table, where the plates are set for the real dinner. Each one helps himself to the smoking soup, which is passed in the tureen. As this is being ladled, a plate of round balls comes by, the delicious _piroushki_, dough-shells filled with hashed meat, always served with soup. We have entered upon a typical Siberian meal, with the boiled soup-meat eaten as the second course, and madeira, champagne, claret, and rum, indiscriminately offered. A perfect babel of conversation goes on, and one is pressed to try this, try that, try each and everything of the long menu, under the watchful eyes of the kindly host and hostess.

At all times of the day the samovar is left simmering, ready for any one of the multitudinous household to brew tea, and constantly replenished _zakuska_ dishes deck the sideboard. Guests, attendants, children, and friends come and go in the utmost freedom. Such is the _Hazan's_ life.

In another part of the building there stuffs to repletion an army of dependents. Servants, artisans, drivers from the caravans which pass up from China by the road below the house, a whole other below-stairs world is here. Twenty caravan teamsters, _karetniki_ or _isvoschniki_ of the sledges and carts that fill the ample courtyard, huddle in the back rooms for tea. An old bespectacled maker of string-net doilies, who reads Alexander Pushkin's poems, is working out a week's board in the room where the chickens are kept. The housewife does not disdain, either, to find a place for the traveling _sapojnik_, who will put leather reinforcements on the felt boots which have been worn through at the heel. It is a large easy way of living, this of the man who holds a leading place in the border city.

[Illustration: A CHICKOYA GIRL]

[Illustration: TROITZKOSAVSK STUDENT]

A mixture of crudeness and culture, of luxury and hardship, of Orient and Occident, runs through the quaint fabric of frontier society, with its medley of races and types. Fine avenues flanked by stuccoed houses pierce the main city. Back of them lie the log houses of the plainer citizens, while the outskirts are occupied by the felt huts of the Buriats and Mongols. Students in uniform elbow Cossacks of the Guard, and maidens from the seminary brush the Mongol wood-choppers.

"Téatre?" suggests one evening the twenty-year-old son of your host. Of course the invitation is accepted. At eight o'clock you put on your felt boots, and tramp down past dark-shuttered log houses and the silent white church into the field, where stands a barn-like building placarded with the programme. The young guide secures seats at the ticket-counter of rough lumber. Seventy-five kopecks they are, each. With them are handed out eight numbered slips of red paper. Then together you break a way to the front rows, through the crowd of burly Cossacks of the garrison, bearskin-capped students, citizens with shiny black boots, and here and there a husky stolid-faced Buriat. Keeping hat and coat on, as does every one else, we find seats on the rough benches wheresoever we like or can; for nothing is reserved save the elevated perch of the musicians, where a four-piece orchestra drones out a monotonous Russian march. What a fire-trap! is the first thought. To each of the posts that sustain the rafters is fastened a lamp shedding an uncertain light on the hangings of bright-red cotton cloth, in dangerous proximity to which, utterly disregarding the "no smoking" signs, stand the crowd of forty-kopeck admissions, rolling and smoking perpetual _papirosi_.

As the impatient audience begins to pound and stamp, a bell rings, and the curtain rises on two comic characters busily engaged in packing for a hurried departure from their lodging. The stage has become a room, with red-cotton-covered walls and bright green curtains. A merchant comes with a bill for comestibles six months due. He is quieted with extravagant tales of forthcoming change for a hundred-thousand-rouble note. The landlady enters, and the shoemaker's apprentice with a pair of mended boots. Both are likewise cajoled and bullied away. The Jewish money-lender is more difficult, but at length, to the manifest delight of the audience, he, too, is staved off, and the pair draw the vivid green curtains and go out through a window for parts unknown, amid much glee and applause.

We now go out to the "buffet" and contribute to the dangers of conflagration by smoking an offered cigarette. We also add to the theatre's income by buying a glass of hot _chai_ for ten kopecks. Something special is in the air for the next act. The audience is buzzing and moving in eager expectancy. We return to our seats. The curtain rises upon a double row of two-_pud_ (sixty-four-pound) weights, such as are used at the bazaar to sell frozen beef. Amid a thunder of stampings on the plank floor one of the escaping debtors of the last act, dressed in tights, comes out from behind the green curtains, and lifts one of these above his head. Then he poises one with each hand. Finally a wooden harness is adjusted to his body, and sixteen weights (or about half a ton), are heaped upon him by the jack-booted Buriat stage-attendant on one side, and the defrauded merchant of the first play on the other. It is the most unspectacular performance possible, this athletic test, but it takes the place of a football match in Siberia.

The applause is ferociously appreciative.

More _chai_ and cigarettes, and we come back to hear a very pretty girl, dressed in the peasant's costume of Little Russia, head a chorus, and to see a boy in red blouse and boots dance the wild dervish whirl which the peasants of tradition are supposed to execute. The boy is in the midst of his performance when there is a tumult among the forty-kopeckers under the musicians' eyrie. The latter, being human, try to watch what is going on below and play jig-music at the same time, and sharps and flats fly wide of the mark till the sounds become frightful. Everybody jumps up on his bench to see a peasant having a turn with a Buriat, and further trouble brewing with a Cossack who has got upset in the mêlée. There is a chaos of tossing hats and brandished fists, and the two armed soldiers who are on guard as policemen press in, with gruff shouts to make them way. The tumult finally goes out the door and into the street, and we turn back to the poor dancer still trying to beat out his stunt.

The curtain rises next on the manager, who has been up to date weight-lifter, escaping boarder, and part of the peasants' chorus. He is seated at a table, looking very ordinary in his street clothes. Behind him is another table covered with an assortment of crockery, mirrors, spoons, vases, pieces of cotton cloth, and a big striking clock. He calls for a volunteer from the audience for some unknown purpose, and a little rosy-cheeked uniformed Buriat schoolboy, who has been peeking behind flapping curtain between the acts, responds. The boy reaches into a box and pulls out a slip of paper. The manager reads a number from it, "_Sto piatdeciet sem_." An eager voice from the rear answers "_Jes!_" The stage-attendant takes a glass tumbler from the table and carries it solemnly to the man who has answered. Your host nudges until you comprehend that you are to excavate the eight theatre-slips, which you do, to find that two only are seat-tickets. The rest are numbered billets, and you are liable at any moment to receive a perfumery-bottle or a candlestick from the lottery which is in progress. The scene now takes on an imminent personal interest shared with the banked forty-kopeckers behind. A breathless strain accompanies the drawing of the numbers. It mounts to a climax as the big musical clock is approached. The fateful billet is at last drawn in intense silence. Every eye is fixed on the reader. Not a Cossack speaks, not a Mongol moves.

"_Dvesti tri!_" and a sharp "_Moi!_" tells that the clock goes to ornament the table of a burly peasant, who grinningly receives it. The tense breaths are let out, the forms relax, and the crowd straggles to the door, lighting cigarettes and pulling down caps. The drama is over. Next morning at eight a soldier visits your host with a message from his chief.

"Bring to the police-station the passport of the stranger seen with you at the theatre last night."

A town droshky will take one the few versts to Kiahta, where in the Geographical Society's museum is the celebrated sketch of the Dalai Lama made at Urga by a Russian artist, when the young Tibetan monk had fled before the English expedition to Lhassa. Here, too, are ore samples and reconstructed Mongolian tents. But it is hard to look at fossil rhinoceros-heads and at stuffed sabre-toothed tigers and musk-deer when the camel-trains are passing and China is a verst away. A courier is necessary now, for resourceful Jacov and driver Ivan are strangers beyond the border. Perhaps our host knows of a man acquainted in Mongolia? He will inquire. Next day there presents himself a slight, bearded, intellectual man, Alexander Simeonovich Koratkov, usually called, for short, "Alexsimevich." Bachelor of forty, educated in the Troitzkosavsk "Realistic" school. He speaks, as well as Russian, Mongolian, English, French, German, and some Chinese. He has translated for the English engineers who were brought in to work the Nerchinsk mines. He is deeply read in Buddhist mythology and sociology. Will he go down into Mongolia with you? Yes; and so it is arranged.

Provisions are cheap and abundant in the Siberian towns. Sixty kopecks buy a pound of caravan tea, seventeen kopecks a pound of sugar, the sort that comes in a cone like a Kalmuck hat. It is a luxury by warrant of public opinion, so much that it has, of note, been served on baked potatoes. Before the Buddha pictures of the Buriats, a few lumps may be the choicest offering. Flour costs six kopecks a pound. Beef, if a great pud-weight forequarter is bought at the market, twenty kopecks. Frozen butter will cost twenty-five kopecks per pound. Eggs, of the Siberian cold-storage variety, forty-eight kopecks a dozen. For thirty kopecks one gets a piece of milk as big as one's head. But do not try to go beyond the native produce, for canned goods, coffee, or sardines. It is bankruptcy speedier than buying bear-holes. A big magazine will sell pâté de foie gras, imported from France, at two roubles the tin; while beneath the Chinese caravansaries' arcade, bales of tea will be sold at a few kopecks a pound. One gets cigars in a glass-covered box, with the government stamp, for a rouble and a half, and they will be worth about as much as the strings of twisted tobacco-rope which the Mongols carry off as their single cherished luxury.

And now for transportation. The sledge can serve no more, for the snow goes bare in places along the caravan trail. We must have a tarantass, and in time one is produced for inspection. A cask sawed in half, lengthwise, is the image of its body, a lumber-cart the

model of its clumsy wheels and framework. To the tarantass is hitched the trotter, with his big bow yoke to bring the weight of collar and shafts on his back rather than against his neck. At each side of him, with much such a rig as is used to tow canal-boats, are made fast the two galloping horses.

When one goes beyond the post-route with his own equipage he has, fastened under the driver's seat and behind his own, bags of oats and hay, which must serve as emergency-rations for the horses against the days in which none can be secured along the often deserted trail. Personal provender must be likewise stored away, bags of bread, frozen dumplings to make soup with, tea, sugar, milk-chocolate, milk, candles, cheese, matches, kettles, and whatever else one can think of, or that the ingenuity of Alexsimevich can devise. Hay is piled into the tarantass bottom to supply the want of springs.

A driver who knows the trails has been found, André Banchelski, a tall Siberian, of timbering and hunting antecedents, who has a small stock of Mongol idioms regarding the price of hay and the location of water. He has reached a very good understanding with Katrinka, one of the household dependents, and Nicolai is taking an interest in him.

To-night we go to sleep on Nicolai's plank couch, ready for the march of the next day. All is ready. To-morrow we cross the Chinese frontier.

V

IN TATAR TENTS

The shaggy ponies, white with the frost of the morning, stand harnessed to the tarantass; André in his belted sheepskin _shuba_, whip in hand, is perched on the bag of oats; Alexsimevich sits in a greatcoat of deerskin, with only a nose and a triangle of black beard visible. The host, in his gray surtout, and the red-bloused drivers of the sledges scattered in the courtyard, all have left their samovars to see the start. The children of the family peep from behind the mother with her gray shawl-covered head. They group at one side, under the eaves of the doorway, while Josef, one of the household servants, swings back the ponderous gates. The reins are drawn in, the whip is lifted, the horses are leaning forward into their collars, when the cry of "André!" comes through the opening doorway.

From behind the gathered onlookers, who turn at the sound, runs out Katrinka, dressed in her best red frock. "André!" she cries. He pulls back the starting horses, and Katrinka lifts up to him a little bag embroidered with his initials in blue and red. "For your tobacco."

He looks down into her eyes and smiles. "_Spasiba_ _loubesnaia_," he says, and pushes it into the breast of his shuba.

"_De svidania_, André!" she whispers, then runs back, confused.

The teamsters laugh, pleased and amused as big children at her blushes, and her brother shouts a commentary from the gateway. "_Vperiod! vperiod!_" says the interpreter. He has reached forty now without falling before the charms of any Siberian girl, and he does not sympathize. "On! on!"

The horses swing out of the great gateway into the snowy streets, with "Good-bye! Good road!" called in chorus after us.

At a slow trot the lumbering carriage rolls through the quiet town, misty in the cold of the morning. The row of shuttered shops, with their crude pictures of the wares within, are opening for the day. The little park with the benches, which are trysting-places of summer evenings, cushioned now with six inches of snow, and the low log houses beyond, loom up and retire rearward, as we pass. The white church and the fenced cemetery of Troitzkosavsk are left behind, and we are on the broad paved road by which a sharp trot of half an hour brings us to Kiahta.

Its scattered houses now in turn begin. The big tea-compound, of four square white walls, flanks us and is gone. The officials' residences and the barracks of the garrison appear and vanish behind. The street opens out into a big square, where, shimmering against the white ground, stands the great church of _Voskresenie_, the Resurrection. On its green dome, lifted high in appeal and in promise, gleams the gilded cross. In white and green and gold Russia raises inspiringly the symbols of Slavonic faith before the doors of the heathen empire. As we pass the white Russian church, the litany of the popes and the answering chant of the choir come faintly wafted from within. But even as the Christians sing, the clash of distant cymbals and the roll of a far-off prayer-drum meet and mingle with the echoes. On the hill across the border, in vivid scarlet against the snow, with painted walls, sacred dragon-eaves, and flapping bannerets, flames a Chinese temple.

Here now is the borderland of empires. The neutral strip is in front, a hundred _sagenes_ broad. The Cossack sentries stand at ease before their striped boxes, which face toward Mongolia. Far to the east and far to the west are seen stretching the long lines of posts marking the boundary. The outmost sentry, as the tarantass rolls across the strip, hails you with a last "_De svidania!_" (God speed!)

Past the Chinese boundary-post, covered with hieroglyphic placards and shaped like the lotus-bud, we drive, and in under the painted gateway of the gray-plastered wall. No Männlicher-armed Chinese regulars, like those that in Manchuria throng to hold what is lost, guard this half-forgotten road. No sentry watches; no custom-officer bids the strangers stop. Through the open gate we ride into the narrow street of the trading city of the frontier--Maimachen, the unguarded back door to China.

In life one is granted some few great impressions. None is more striking than that experienced in passing beneath the shadow of this gabled gateway. Behind are kindred men, the manners of one's own kind, police, churches, droshkys, museums, theatres, the whole fabric of European civilization. From all these one is cut away in the moment of time taken in passing the neutral strip. Two hundred yards have thrust one into the antithesis of all western experience, into an utterly strange environment, where the most remarkable of the world's Asian races lives and trades, works and rules.

Everything which is made sensually manifest by sight, by sound, by scent, by action, is weirdly alien. You three in the tarantass are as men from Mars, isolated, and moving among people foreign to your every interest and experience. The solitary strangeness of your little party in the tarantass, started into a forbidding land, the first confronting vision of the eternal Orient--these are the things for which men travel.

As you go slowly down the narrow lane-like street, you catch glimpses of banner-decked courtyards seen through great barred doors in the gray mud walls. Here and there a sallow blue-coated Chinaman, with skull-cap and queue, passes by, his folded hands tucked into his long sleeves, fur-lined against the cold. Chinese booths and shops are open. Waiting traders, seeing yet invisible, behind the many-paned paper windows, look outward through the peep-hole.

In the city square a halt is made before a Chinese store, for a last provisioning. At the entrance half a dozen Russian sledges are drawn up. Here can be had the supply of small silver coins indispensable for the road, canned goods of European origin, and a bottle whose contents may be less like medicine than is vodka. Though the goods come all the way from Peking on camel-back, they are much cheaper than the tax-burdened provisions over the border in Russia. Indeed many of the main Chinese stores, with their surprising stocks of wines and pâtés de foie gras, candies, and Philippine tobacco, are supported by Russian inhabitants of Kiahta and Troitzkosavsk. It is amusing to watch the enveloping of champagne-bottles in sleigh-robes, and the secreting of cigars beneath fur caps for the return journey.

We stroll a little way down the street, among the Chinese booths for native wares, where sturdy shuba-robed Mongol tribesmen are bartering sheepskins for blue cotton cloth, metal trinkets, quaint long-stemmed metal pipes, and wool-shears with big handles. They are probably getting deeper in debt, as usual, to the wily traders. We pass the haymarket in the shade of a ruined temple, where the Mongols have heaped their little bundles of provender.

All the while one has an eerie undefined sentiment that something is lacking. It is not that the houses which face the narrow main street are low and poor, that the gray mud-walled compounds are grimly unwelcoming with their closed iron-studded gates. It is not that the small stocks of goods in the shops tell of a vanished prosperity, now that the bulk of the tea-trade has left. It is not anything material, but an oppressive indefinable feeling that something is lacking. Only when Alexsimevich makes a chance remark, do you realize consciously what it was you instinctively felt, "It is queer to be in a city where there is not a woman or child."

Some have explained the exclusion law which controls the situation by the self-sufficiency of the Chinese, who wished no real settlement of their people here,--the fruit of a pride deep-rooted as that underlying the custom which brings every corpse back to China for burial. Others, by the desire to avoid transmitting to the Empire the diseases that are rife in Mongolia. Whatever the basis, the regulation is in full force to-day. At one time merchants in Maimachen kept their wives across the border in Russia, which under a subterfuge was not technically forbidden. But the ability to hide behind a technicality is a blessing enjoyed especially in democracies. It did not go with the chief of police, who came down for a squeeze which made it more profitable to pay the women's fare home than to continue to offend.

[Illustration: A WAYSIDE TEMPLE]

Associating with the native Mongol women is here precluded by the fact that there are no settlements near by from which the Chinese might get indigenous consolation. A deserted tract lies behind the town. Only camel-drivers, wood-cutters, and sellers of cattle come into Maimachen, and they leave at night. For though the Mongols, in their pointed hats, pass along the streets, none may lawfully live within the stockaded walls, and none keep shop beneath the carved eaves of the houses which flank its narrow streets. This is the prerogative of Chinese traders from beyond the far-off Wall.

The spectacled merchant Tu-Shiti, who has become prosperous from the sale of Mongol wool, retakes for a visit, every two years, the long camel-trail to Kalgan and China. The tea-trader, Chantu-fou, drinks his wares alone. The slant-eyed clerks and booth-keepers trotting down the streets in their skull-caps, hands tucked up the sleeves of their blue jackets, plan no theatre-parties or amity balls, or sleigh-rides in the biting air, as over the way in Kiahta. The seller of sweetmeats will never be told to be sure and inclose the red and black New Year's card. There is no red-cheeked Chinese boy to smile as he munches your sugar; to puzzle over your ticking watch as at Kotoi, or to tease the tame crane in the courtyard. Not a girl appears on the narrow streets. It is the sentence passed upon the generations of Chinese who have gone to Mongolia, that no woman of their race shall pass the Wall. And so it must remain, for never a home will be founded till China, the unchanging, shall change.

Back and forth through the thoroughfares go the little men with the queues flapping against their backs and their sallow uncommunicative faces. Are they thinking of the time when they will have made their little fortunes and can get back to China to enjoy them? As they wait for customers in the little booths, do they plan the homes which none of their blood may ever possess in Mongolia? When they sleep on their wooden platforms, do they dream of faces in the Kingdom of the Sun? Never will one know. Around the thoughts of the Chinaman arise the ramparts of his isolation. What he believes, what he hopes, what he dreams are not for you. The soul of China is behind the Wall.

The tarantass rolls out of the quaint weather-worn gateway of the woman-less city of Maimachen. "How much they miss!" says André, filling his pipe from the new pouch. "How much they escape!" retorts Alexsimevich.

When in hot haste Pharaoh ordered out his great war-chariot to pursue the rebellious Children of Israel, and thundered through his pyloned gateway with plunging horses urged by the shouts of his Nubian charioteers, he must have experienced, despite contrasts, much the same physical sensations as those which we feel when the tarantass starts in full gallop across the level plain to the distant range of mountains; but where Pharaoh's robe was white with dust, ours is white with snow, and the sun, which baked his road, makes ours endurable.

The horses leap free under the knotted lash of the Siberian driver. With the rumble of low thunder the ponderous wooden wheels bound over the rutty road, hurling the springless tarantass into the air and from side to side. You brace yourself with baggage and hold to the sides, but toss despite all, like corn in a popper. The hay on which you sit shifts away to one side, leaving the bare boards to rub through clothes and packs. A sudden splinter makes you jump like a startled deer beside the way. In this noisy tarantass, down the narrow road grooved with the ruts of the Mongol carts and sledges that have gone northward, you tumble and groan and bump and roll out across the open country.

There is a wide plain from Maimachen. It climbs into the first barrier-range and the forest belt of Mongolia, whose plateau is the third terrace in the rise of land from the low frozen flats of the Northern Lena to the Roof of the World,--the Himalayas of the south. The northern city of Yakutsk is at a very low elevation, only a few feet above the sea. Irkutsk on the fifty-second parallel is 1521 feet in altitude, Troitzkosavsk on the fifty-first is 2600, Urga on the forty-eighth 3770, Lhassa 11,000 feet.

Far to the northwest, Mongolia is a forested fur region; far to the south is Shama--the desert. Here at the north and east the forested belt of the Siberian highlands south of Baikal breaks off almost at the boundary.

Snow is over everything, but thinly. It has been worn away on the road, leaving brown patches over which the tarantass, mounting the long slope with horses at a slow trot, lugubriously thuds. A long stretch of straggly trees and stumps tells of Kiahta peasants going over the border to cut wood where no timber-laws limit. Up and up we go, the way steeper every _sagene_,--afoot now and the horses leaning and pulling at the traces. Finally silhouetted against the sky appears a rough pile of stones. At its top bannerets are waving from drooping poles. It is the Borisan on the summit of the pass to which every pious Mongol adds an offering, until the pile is many feet high, with stones, sticks, pieces of bread and bones. Some throw money which no one save a Chinaman will commit the sacrilege of touching; some give a Moscow paper-wrapped sweetmeat, some a child's worn hat or yellow-printed prayer-cloths waving on their sticks and fading in the wind;--everything is holy that is given to the gods.

A piercing wind, searching and paralyzing, meets the tarantass beyond the crest at the southern border of the forest: it is Gobi's compliments to Baikal, the salute of the great desert to the great lake. The horses stumble through the drifted snow, scarcely able to walk. The driver, blinded, half-frozen, keeps to the general direction of the obliterated trail. Barely one verst an hour is made, until, under the shelter of the bald white range of hills, the road reappears and the wind is warded off.

A rolling plain between the heights is the next stretch of the way. The afternoon sun, dimly bright, creeps haloed through the lightly falling snow. Deep in the mist appears a dark moving mass. It grows, focuses, and takes shape into a shaggy beast of burden, and camel after camel emerges from the haze, loaded with square bales of tea.

"Ask if there is shelter near," you shout to the muffled head of the interpreter.

"I will ask," he replies. Then to the caravan leader: "_Sein oh!_" he cries in greeting.

The foremost camel stares stonily as its Mongol driver twitches the piece of wood which pierces its upper lip, and the whole train stops.

"_Gir orhum beine?_"

"_Ti, ti, orhum beine!_" comes the answer. "It is close at hand."

Forward the caravan slowly paces, each camel turning his head to stare as he passes out into the mist again. One of them has left a fleck of blood in each print of his broad spongy foot which the driver will cobble with leather at the next halt. Along their trail you drive southward. The mist is clearing as you rise, and the sun shines down on the snow which has crystalized in little shafts an inch high. These spear-shaped slivers have a brightness and a sheen of extraordinary brilliance, and like prisms show all the colors of the rainbow. They cast a gleam, as might a mirror, a hundred yards away. It is as if upon the great white mantle had been thrown haphazard treasuries in rubies and emeralds and diamonds and opals,--myriad evergrowing rivals of Dresden regalias. The sun goes down with its necromancy. Beyond, the soft blanket enfolds the rolling hills. It drapes the rocks and weaves its drooping festoons about the barren mountain-sides.

"Mongol _yurta_!" calls André, turning to point out with his whip the low dome-shaped hut, black against the darkening sky. On its unknown occupants we are to billet ourselves, sheltered by the rule of nomad hospitality. As the tarantass nears the wattled corral, the watchful ravens stir from their perches. The picketed camels turn to stare. A gaunt black hound stalks out, with mane erect and ominous growls.

"_Nohoi_," cries out Alexsimevich, to the inhabitants of the hut; then adds to you, "Very bad dogs! It is a Mongol proverb: 'If you are near a dog, you are near a bite.'"

Beneath an osier-built lean-to a woman is milking a sheep, with a lamb to encourage the flow. She calls a guttural order to the dog, which slinks back. Then she comes to the wattled fence, while the sheep which has been getting milked escapes to a far corner of the yard. The woman's head is curiously framed by a triangular red hat, and silver hair-plates, which hold out like wings her black tresses. The shoulders of her magenta dress are padded up into epaulettes two inches high. She is girded with a sash.

"_Sein oh!_" says Alexsimevich.

"_Sein!_" she answers, and opens the gateway to the enclosure around the hut.

André drives in among the sheep and cows, and you climb lumberingly down with cold stiffened limbs. André puts his whip upon the felt roof, for it is a deadly breach of etiquette to bring it into the house.

"You go in," said Alexsimevich.

It is like entering a kennel, this struggle through the narrow aperture, muffled to the eyes in double furs and awkward felt boots. As you straighten up after the crawl through the entrance, a red glare from the fire just in front meets the gaze. Stinging smoke grips the throat; you choke in pain. It blinds the smarting eyes. You gasp and stagger. Then some one takes your hand and pulls you violently down on a low couch to the left, where in course of time breath and sight return. There is no chimney, nor stack for the fire of the brazier, which stands in the centre of the hut. One can see the open sky through the three-foot hole above. The smoke, finding its way toward this aperture, works along the sloping wooden poles which form the framework of the felt-covered tent, filling the whole upper section with its blinding fumes. To stand is to smother. Sitting, the head comes below the smoke-line.

With recovered vision, one can look around within the hut. The couch of refuge, raised some six inches above the floor, is the bed by night, the sitting-place by day. Against the wall at the left hand, and directly opposite the door, is a box-like cupboard, along whose top are ranged pictures of grotesque Buddhist gods, before whom are little brass cups full of offerings, millet or oil, in which is standing a burning wick. Beside the door is a shelf loaded with fire-blackened pots and kettles. Branches of birch for fuel are thrown beneath. On the far side of the room, three black lambs, fenced off by a wicker barricade, are huddled together, quietly sleeping.

[Illustration: A MONGOL BELLE AND HER YURTA]

[Illustration: A ZABAIKALSKAIA BURIAT]

Seated beside the fire close by is the girl of nineteen who has just saved you from asphyxiation. The long fur-lined working-dress, common to all ages and sexes of Mongols, is buttoned on her left side with bright brass buttons, and is belted in with a sash. She has not the padded shoulder-humps, nor the spreading hair arrangement, which gave to her mother, who welcomed us, so weird an appearance. Her complexion is swarthy like an Indian's, not the Chinese chalky yellow, and she has red cheeks and full red lips. Her eyes are large and black. The rest of the party have stayed a moment outside to ask about hay and water. You have made this solitary and awkward entrance. The girl has no more notion than a bird who the strange man of another nation may be, who has stumbled into her home. But it does not trouble her in the least. For a moment she looks you over calmly, with a smile of amused curiosity, rolling and wringing with her fingers a lambskin which she is softening. Then composedly she bids you the Mongol welcome, "_Sein oh!_" and holds out her hand. Her grip is as firm and frank as a Siberian's.

Now Alexsimevich comes tumbling through the door, and next André. Both are used to these huts, and artistically stoop below the smoke-line. All our impedimenta--blankets, furs, pots, kettles, bread-bag, rifles--are heaped in a mound within the space between the couch and the tethered lambs. The girl has not stirred from her work.

"They are friends of yours then, Alexsimevich?" you ask.

"No, no, I never saw them," he answers. "Any one may take shelter in any _yurta_ in Mongolia."

A small head suddenly makes its appearance from the pile of rugs on the sofa opposite on the women's side of the tent. There emerges, naked save for a bronze square-holed Chinese _cash_ fastened around her neck, a little slant-eyed three-year-old. The water in the small cups offered to the _dokchits_ has long been ice, and one has full need of one's inner fur coat and cap in the hut, where the entrance, opening with every visitor, sends a draft of air, forty degrees below zero, through from the door to the open hole which serves as chimney. And still this tot can step out naked and not even seem to feel it.

"The child's name?" asks Alexsimevich.

"Turunga," replies the girl.

"And your own?"

"Sibilina," she says, and smiles.

Turunga carefully inspects you, and solemnly accepts a lump of sugar which she knows what to do with, even if it is a rare luxury offered to gods. She sits down, in an evidently accustomed spot on the warm felt before the brazier, to play with the scissors-like fire-tongs, carefully putting back the red coals that have fallen out on the earthen platform.

The tarantass-driver, having piled up your impedimenta, excavates from its midst the bag of rye-bread, which he sets to thaw. He gets next the little bag of _pelmenes_, the meat-balls covered with dough-paste which you carry frozen hard. The mother comes in from under the _yurta's_ flap, and, placing a blackened basin over the brazier, puts into it a little water and scours diligently with a bundle of birch-twigs. She brushes out this water on the earthen floor near the entrance. This is the picketed lamb's especial territory, to which the felt rugs before the couches and the altar do not extend. A big bag of snow which she has brought from outside is opened and the chunks are piled into the basin, where, while one watches, it melts down into water.

"_Boutzela! boutzela!_" she cries soon, holding a lighted sliver over the basin to see by: "it boils." Into the Mongol's pot go our _pelmenes_, to brew for a few moments. An accidentally trenchant description of Siberian _pelmenes_ was given on the quaintly-worded French bill of fare in the hotel at Irkutsk: "Meat hashed in bullets of dough." They come out, however, a combination of hot soup and dumplings, very welcome after the long cold day's drive across the plains, the frozen marsh, and the

rolling hills. The wooden Chinese bowls from the bazaar at Troitzkosavsk are filled now with our hostess's big ladle, and the application of warmth inwardly gradually thaws the outlying regions of the body.

But there is trouble in camp. Turunga is moved by the peculiar passions of her sex and her age, curiosity and hunger. It does not matter in the least that she has home-made _pelmenes_ every two or three days--she wants these particular meat-balls. The little mouth begins to pucker and the eyes to screw up. No amount of knee-riding by the mother takes the place of the _pelmenes_. We fill a heaping ladleful and André furnishes his own bowl. The mother receives it, holding out both her hands cup-fashion as is the etiquette, and Turunga is satisfied.

The mother looks kindly to the stranger and smiles at André, then throws more sticks of the precious firewood on the embers. André has caught, likewise, the not unadmiring glance of the young maid. The girl who waits in Troitzkosavsk is not the only one who appreciates our six-foot Siberian hunter.

The dog barks in the yard, but without the menace which hailed us, and the crunch of a horse's hoofs sounds on the frozen ground outside. The flap opens, with its inrush of freezing air. Stooping, there enters a typical Mongol, squat of figure, round of head, with broad sunbrowned face and a short queue of black hair. He wears a funnel-shaped hat, magenta-colored, and is enveloped in a long _shuba_, with brass buttons down one side like a fencer's jacket. About his waist is a sash with jingling knives and pouches. He is the head of the family, come in from herding his horses. He turns back the long fur-lined cuffs which have protected his gloveless hands, and stretches out both his arms for you to place your hands over his. It is the man's ceremony of welcome. Then he produces a little porcelain snuff-bottle. This must be received in the palm of the right hand with a bow. It is to be utilized, and passed back. If the herder is out of snuff, the bottle is offered just the same and you must appreciatively pretend to take a pinch. Such is etiquette.

The soup is gone now; the pot, cleaned out for the tea, is again on the boil and the leaves are thrown in. André has borrowed a hatchet from his host, and has chopped off a piece of milk, which goes in as well.

It is in order to ask the new arrival, Subadar Jay, to pass his wooden cup for some of the beverage. He takes it and the lumps of sugar without a word of thanks. The Mongol language has no expression to signify gratitude. Silence does not, however, mean that he does not appreciate. The dozen pieces of Mongol sandal-sole bread which he gives you later are worth two bricks of tea in open market, and this current medium of exchange--caravan-brought tea--is worth sixty kopecks the brick. No small gift, this bread, to an interloping stranger who is brewing tea by his fire, and camping unasked on his bed. A Tibet-schooled lama knows the Buddhist maxim, "Only accomplish good deed, ask no reward." But the unlettered Mongol layman knows its practice.

Little Turunga has played naked before the fire long enough now; she is caught up; her reluctant feet are put into the boots with pointed upturned toes, and her body into a miniature sheepskin "daily," such as her mother and father wear. The little girl is as smiling and shy and coquettish as any child of white skin and complex clothes.

"Will you sell Turunga for a brick of tea?"

"No, no," says the mother, gathering the little one quickly up into her arms, while the rest of the family smile at the offer and her solicitude. "No, no, not even for ten bricks!"

Everybody laughs, Turunga with the rest, in a child's instinctive knowledge that she is the centre of admiring attraction.

Far more petting than the Russian babies get is lavished on the little Mongols. Perhaps the much smaller families (only two or three children to a hut) allow more attention per capita. The mother hands Turunga over to her father,--unheard-of in Siberia,--and he plays with the child, giving her pieces of sheep's tail to eat from his mouth, answering her prattle or baby-talk and endless questions. At night, about eight o'clock, the mother takes the child to the couch and they both go to sleep, Turunga cuddled warmly under her mother's _shuba_.

Meanwhile we men sit cross-legged by the fire and talk of many things,--of the pasturage for the sheep, of the snow on the road, of the beauty of the housewife's silver headplates, of water and roads, of whether or not the Mongol _dokchits_ on the altar are like the Gobi wolves that hate Chinese.

It is interesting to note how some of the words used (few, however) have a familiar sound--although there is said to be no common ancestry with the Indo-Germanic tongues; perhaps it is only the instinctive sound-imitation which makes the Mongol baby cry "Mama" to its mother, as does the child in Chita and in Chicago. "Mine," for instance, is _mina_; "thine" is _tenei_. A horse or mare

is _mari_. The word for "it is," "they are," is _beine_, a fairly respectable form of the verb "to be" in Chaucer's English.

The grammar is delightfully simple. In the vernacular there is no bothering about singular or plural. "One hut" is _niger gir_; "two huts," _hayur gir_. "Milk" is _su_, and apparently the word for "water" was formed from it--_ou su_. If one wants to know whether it is time to throw in the meat-balls he says, "_Ou su boutzela?_" with a rising inflection ("Water boils?") and the answer is, "_Boutzela_." The "moon" and a "month" are _sara_, and the years go in cycles of twelve. If one wants to compliment the host on the excellence of the sandal-shaped bread which he hands out, loaded with gray chalky cheese (_hourut_), one says, "Bread good be" (_Boba sein beine_); this gives him great pleasure.

Some of the written numbers are somewhat like ours: 2 and 3 are nearly the same, but they have fallen forward on their faces; 6 has an extra tail. When the teapot overturns, they say "_Harlab!_" to relieve their feelings. There is no word for "so good," "farewell," or "much obliged." These are just squeezed into the heartiness of the final "good" (_sein_). So when one leaves, he holds out both arms, palms up, for the host to put his own upon, and says loudly, "_Sein oh!_"

A not unbarren amusement is to study out one's own derivations for some much-explained words. _Tamerlane_ is often given as meaning "the lame." Why does it not rather come from _temur_ (iron) and mean "man of iron," as the ruler of the Khalka tribe was called Altan Khan, the golden king? The Amur River has _khara-muren_ (black water) usually given as its derivative root. Why not the Mongol word _amur_, which means simply "quiet"?

In the hut to-night, while we are comparing mother tongues, the brazier-fire has burned to red brands. The girl reaches into a basket beside the door for pieces of dried camel-dung, and puts them on, that the embers may be fed and live through the night. These _argols_ do not smoke; she may close the chimney-hole with the flap of felt, and the hut will be kept somewhat warm through the night. The Mongols prepare for sleep: they take off their boots, and slip their arms from the sleeves of their fur _shubas_, in which they roll themselves up as we in our blankets. But how hardened they are to the cold! A naked arm will project and the robes become loose, but they do not wake.

We keep on all our inner clothing and roll ourselves about with skins until we are great cocoons. André gives a good-night look to his horses; then he, too, lies down. With our heads beside the altar of the gods, we sleep, in the Mongol's _gir_.

How cold it is in the morning when we wake! The embers have burned to a gray ash; the iciness of the waste outside has gripped like an octopus the little hut, and sucked its precarious warmth through the night-long radiation. The chimney-hole is open again, and the mother is starting a blaze with her few pieces of birch firewood. André has gone out to harness the horses. He has left the door flap a little wrinkled, and the wind whirls through it and up the chimney, keen as a scimitar.

Alexsimevich is getting out the tea-bowls and the bread. You put a reluctant hand from under the blankets and seize your fur cap. Then you disengage the inner fur coat from its function of coverlet, and struggle, sleepy-eyed, into it. If you have the moral courage to take off these friends in need, and the inner coat and sweater, to get a bowlful of snow-water, and hunt among the baggage for soap and a towel, all at five o'clock in the morning of this freezing weather, then you have full license to call the Mongols dirty degraded heathen. If, however, you sit and shiver, and promise yourself that you will bathe at Urga, it is elementary fair play to be discreetly silent about the little failing of your hosts. You will rejoice, too, in open admiration of courage, when you find, as you sometimes will, a clean-shaven well-groomed lama, or a washed and combed village belle, on the road to the sacred city.

"Ready," says André. You finish a goodly portion of rye-bread and several bowls of Alexsimevich's tea, while he is carrying out the luggage and making a pyramid of it in the tarantass. You put both hands out to shake those of Subadar Jay, of his wife, and Sibilina. You give a last chunk of sugar to little Turunga, and crawl out under the tent-flap. The family calls "good-bye" from the gateway as you climb in. Then up the hill you start, for the next day's ride.

It is slow to travel by this schedule. One can advance by day and rest by night, but daylight travel and night sleep, while most comfortable for a man, are the least efficient for a horse. If progress be the aim, one must adopt the teamster's system. This involves a start at midnight, and eight hours of travel at a slow trot,--six to seven versts per hour. Then, at eight in the morning, a halt for the ponies. One hour they stand in harness, before getting their quarter _pud_ of hay; after which comes water, and finally, seven and one half _pfunde_ of oats. Four hours of halt are involved, in which one can roll up in his blanket and sleep. Then off again for eight hours of trot, and another four hours of halt at eight in the evening. So the watches go, with some hundred versts made daily.

Noon to-day finds us climbing the hills on foot, to stretch our cramped limbs and ease the horses, as in old times the English tourists climbed the St. Gothard on the way to Italy. We are chilled, and racked by the jar of the road, and glad of even strenuous freedom. Presently we get on again, and ride down the far slope. It is the camel-boat of the steppe, this tarantass.

A solitary gnarled tree shows in the waste of snow--the one seed that lived, on the barren waste, of all that the Siberian winds had brought. An eagle is watching from its upper branches. Further on are higher hills, with trees growing on their northern declivities alone. No foliage can stand the sun, which steals the moisture and bakes the rocks on the southern slopes. As we pass one of these isolated groves, the bald trees are seen to be packed with old nests; for the birds from miles around come hither, as the only refuge for their eggs. Deer watch us, standing ten yards off; for these Mongols are poor hunters and their religion sanctifies life. A lama may not kill even a fly: it might be his own father, transmigrated into this form for insufficient piety. A big white hare starts through the trees, stops, and runs again. Thousands of little marmots scurry to their holes in the plain at the alarm of the tinkling bells. A kite soars with a marmot writhing in his claws. Big gray jack-rabbits bound along the road ahead. A troop of partridges let us pass their wallowed holes six feet away. They peer up, their heads protruding from the snow, their yellow aprons glistening like shields, tame as guinea-fowl. At length we drive into Zoulzacha village.

One becomes after a time somewhat of an adept regarding quarters. To-night the village gives a chance. The most promising exterior is selected, and driving up, we prepare to enter. Cold and cumbersomely muffled, you worm under the felt hut-flap, and see through the pungent smoke of the brazier a dim figure seated to the left of a veiled altar. Bowed over a red-beaded rosary, he is chanting in a low voice, a weird oft-repeated phrase. He ceases as you struggle in, becomes silent, and looks up. "_Amur sein!_" he salutes in quiet greeting, and motions you to a place on the low sheepskin-covered couch, to the right of the altar, opposite him.

The open smile of his welcome shows white teeth hardened by the tough biscuit of his daily diet. You note next, with the pleasure born of seeing anything good of its kind, the light color and unwrinkled features of this young man of twenty-five. The gaze of his brown eyes is direct and frank. He is clean-shaven, his hair is close-cropped, and he has the appearance of a well-groomed horse. In contrast with the smoke-blackened, hardship-wrinkled faces of the older Mongols, his is as a drink from a clear mountain spring after stale drafts from a long-carried canteen. His color is that of an athlete trained under the suns of the running-track. His features are defined, the nose not so flat, the eyes larger than the usual Mongol type. His expression is earnest and sincere as he now stands up in his robe of rich orange, trimmed and girdled with red.

He welcomes the guests without question,--it is the rule of Mongol hospitality, but you feel for the first time what an intrusion it is for your great Russian tarantass-driver to shoulder his ponderous way into the home of a stranger, loaded with your bearskin rugs and rifles and bags of bread, and to pile them loutishly on the native's couch. At the other huts wherein you have lodged, this sentiment has not come so strongly. Poor places they were: the hardship-lined faces; the soiled and ragged robes of the women, the threadbareness of the heaped-up sheepskins on the couch, all these revealed that your two-headed eagle of silver was needed, and your coming a windfall. But here are no sheep fenced in, making one feel that standards are superfluous. The fuel is put away in a basket, the bright fire-irons are ranged in a row. The couch of polished wood is orderly, and the skin-rugs on it are folded in their places. The little chests of drawers are brightly polished, and the yellow cap, with its lining of fox-fur, on one of them is new and clean.

But most of all, in the proprietor himself is there an air of freshness and cleanliness, of youth and vigor, and of self-confidence. When you burst into a place like this, covered with snow and muffled up in furs, disturbing the master of the house at his prayers; when your driver lays the uninvited mattress down in the warmest place, a man cannot but feel like a thrice-dyed barbarian bounder, even if the home be a fifteen-foot felt hut open at the top, and situated on the borders of the Gobi Desert. So feeling, the first impulse is to let the host know that you are not quite, of intent, what you are by accident,--a big hulking foreign savage. So you hastily think over what you can give to put yourself less at a disadvantage. The prized reserve of milk-chocolate comes to mind. "Will the host have some?" you ask.

"_Da blagodariou!_" he answers in Russian, to your surprise.

With mixed gladness at having made good thus far in any event, and regret at the diminished store of this commodity, you take a little spoonful of the snuff which the host is now offering in a beautiful porcelain bottle, patterned in flowers. Then you come back with a cigarette. Most of these people know what cigarettes are, though some smoke them with their noses.

"No, thanks!" and he points to his closely-cropped head.

Alexsimevich, who has followed into the hut, explains: "You speak to a priest, he does not smoke."

A screen hangs before the altar opposite the door. You look hesitatingly at it. Without demur, the lama, at the visible interest, draws back the veil. There, in painted grotesqueness, is Janesron, the red god of Thunder, and bearer of the lightning sword. He glares down with his three eyes upon the sunken orbits of a sheep's head, laid out as an offering. Black Gumbo, the six-armed good spirit, is also there, and both are surrounded by attendant demons. All are pictured artistically, the minute detail of Tibetan workmanship showing in their squat bodies. The polished wood of the frames is as finely wrought as a Japanese sword-hilt.

On the box-top, beneath the gods, are set out in neat array the best of Mongol dainties. These are disposed in little polished brazen cups shaped like wine-glasses. There are raisins and dried plums, caravan-carried from the far-off Middle Kingdom, and lumps of sugar brought down from Russia in some trader's pack. Millet fills one cup, water another; each symbolizing some ancient seizin. A wick, sunk in oil, flares in the centre, and casts a flickering, uncanny light upon the deities. Spread on a low seat, six inches above the felt rug on the floor, are rows after rows of _boba_, the gray Mongol biscuits, in shape like the thick soles of a sandal. As a centre-piece between the stacked loaves rests the brown roasted sheep's head. It is the feast of the New Year that this unusual volume of offerings betokens. The old year of the Horse passes with the rise of to-night's new moon. The leap-year--that of the Ram--will then begin. All the families in the _eimucks_ of Mongolia will feast on the grosser part of the offering which now lies in its ranked regularity undisturbed. For the present the priest takes light refreshments while waiting for his midnight rite.

"Will you have some of the tea that has been brewed for you by the old mother while you were looking at the altar?" asks Alexsimevich.

It has been made, not from the loosely-packed leaves, but from the hard tea-bricks. A chunk of this has been cast into the great iron bowl over the brazier when the fagot-fed fire has melted the ice and has brought the water to a boil.

Solemnly you are presented a wooden bowl of tea, which you receive in both hands, and as solemnly sip. The evening meal is cooked and eaten, your sugar reciprocating the lama's tea.

As the evening wears on, amid the smoke of cigarettes and brass-bowled pipes, the lama brings out quaint paper slips of Buddhist prayers.

"You are interested?" He will write for you a charm. "_O mani padmihom_," he tells you. "The Buddhist prayer."

"Oh, thou jewel in the lotus-flower, hail!" says the interpreter.

It is mighty, this ancient Buddhist prayer, which is murmured by so many millions from Japan to Persia, from Malay to Siberia. It is symbolic, esoterically, of much. The jewel is the soul, the lotus is Buddha, the prayer, a wish that the spirit be in them which was in _Saka-muni_, their Lord. On endless rosaries this prayer is told. It is on the lips of priests and women, it is carved around the stones which travelers throw upon the _obos_, the "high-places" of Old-Testament record. It is murmured by the pilgrims as they prostrate themselves. The disciplined body, the praying tongue, and the mind intent on sacred things, all incline the soul to the acquirement of merit.

The lama draws now with his quick hand, trained to the Tibetan script of the Urga monastery-school, sketches of his temple, _Zoulzacha Soumé_, of his people's summer tent of cloth, and winter hut of felt. He writes out the Mongol numerals, and explains the cycles of years, in answer to questions regarding the New-Year festival. He describes the puzzling element-and-animal system, by which the _chére mari_, or earth horse, is 1907, the _chére khoni_, or earth ram, is 1908, and so on through a sixty-year epoch.

He quotes Mongol proverbs come down from old priests and rulers: "One may buy slaves, but not brothers," and, in the spirit of Macchiavelli, "You can govern a State by truth as well as you can catch a hare with an ox-cart."

Now it is nearing moonrise. From his rolled purse the priest draws a small slip of paper ruled into a half-inch checker pattern, in every square of which there is a symbolic group of letters. The lama consults this. Then he brings from the chest beneath the altar a long narrow box in which are strips of faded paper thick as parchment. On these in red and black are traced quaint characters, written, as is our script, from left to right. The priest selects a dozen of his long sheets and puts them carefully on his couch. He touches the box to his forehead and restores it to its place. Then he turns and speaks to the interpreter.

"The lama must make ready for the night of the New Year," you are told; and as you look, off comes the red sash and yellow robe. The young priest stands up in his vivid blue jacket and walks to the entrance of the _gir_. From a cupboard he takes a towel, and

from the fireplace, ashes. Pouring warm tea into a wooden bowl, he scrubs hands and face with the vigor of an athlete after a run. Then back to the cupboard he goes, and off comes the blue jacket for a clean new silken one. A rich yellow robe is donned. A bright silver knife is slung upon a new red sash which girdles his waist; and smart and erect as an officer of the Guards, the lama steps over, prostrates himself before his deities, then goes out into the night to his temple service.

"Creeds are many, but God is one," murmurs Alexsimevich.

It is regrettable that the rule of lama celibacy prevents the arrangement of the usual kidnapping marriage-ceremony between this young priest of Zoulzacha, and Amagallan (blissfulness), the belle of the Odjick encampment. It is early in the first moon, Sara, of the year of the Ram, and holiday still reigns in Mongolia. Doubtless she, too, is a sooty Cinderella at other times; but to-day she is a reigning princess, dressed in the best that a father, owner of a hundred sheep, can furnish. A bright new blue coat, lined with fine white lamb's-wool, is belted around her rather ample waist with a red sash. Her boots are of evident newness. But the triumph, the chef d'œuvre, is her pointed red hat made of the brightest Chinese silk. It is topped with a gold and black knot and is garnished with gold braid. The flaps, turned up at the sides and the back, are of a long silky dark-gray fur. A broad red ribbon fastened behind is brought forward and rests on her breast. She has a feminine eye to its brilliant contrast against the blue dress. Two long tassels of pearls, set in coral-studded silver earrings, frame a rosy, laughing face; for Amagallan is exhilarated with the consciousness of being very well-dressed.

The presence of two young herdsmen in dark red and blue, and one lama of the first degree,--and consequently not estopped from the race, like a full-fledged priest,--bears testimony to the effectiveness of the costume and the girl. The wiles with which she distributes a smile to one, a dried Chinese plum to another, and a mild frown to a third, reveal even more the universal woman. Amagallan is not at all averse to adding to her string three masculine Russians. There are only two foreign nations in Mongolia, Chinese and Russians. Into the latter class come all stray visitants--Americans, Buriats, and Troitzkosavsk teamsters. The girl stands up now and greets this American with a frank hand-shake. She invites him to sit down with the rest. Since there is scriptural permission to eat meat offered to idols, the fact that the evening's feast has stood at the feet of Buddha need not deter one from partaking of the little dumplings, gray cheese, and dried fruits. Amagallan hands them out on one of those sole-shaped biscuits, which serve as plates until one has eaten what is on them, after which they go down themselves. A fat sheep's-tail is sliced for your benefit, while a coarse lump of dusky-looking sugar is an ultimate delicacy, eaten as candy. Muddy brick tea follows, of course. The Mongol bread is good, but it takes resolution to do one's duty by the gray cheese, the resin-like desiccated milk, and the sheep-fat just seethed.

A chatter of conversation goes on, the neighbors drift in and out, and those of our _gir_, as the evening wears on, make excursions to the other huts and exhibit and drink more muddy tea for politeness' sake. The hostess in each tent shakes your hand before feeding you. The formality makes you temporarily one of the tribe and family, to be treated with courtesy and hospitality. Thus you are taken into the social life of a simple affectionate people.

We meet in one hut a traveling friar who has tramped sturdily from Tibet, pack on back and prayer-beads on arm, begging, praying, selling relics claiming to cure rheumatism, and the eye-diseases which the smoky huts induce. He carries on a pole an image of Gumbo and others of the _dokchits_, together with a hodge-podge collection of rosaries, strips of silk, bells, beads, pipe-picks, etc. These are jingled during parts of his prayer, where it is necessary to keep the god attentive.

[Illustration: A MONGOL "BLACK MAN"]

In one hut they are playing the age-old game of _tawarya_. A bag is produced containing hundreds of sheep's-knuckles, colored blue. Everybody gets a handful. Then a girl holds out her fistful of them, and each man guesses the number. There is a rapid fire of shouted numerals,--"_niger, hayur, urbu, durbu!_" The one who guesses correctly gets the handful of knuckles. This person next holds out his fistful, and so it goes. It is an uproarious sport, interspersed with quite unnecessary grabbings of disputed handfuls,--part of the game that Amagallan is playing, even if not germane to _tawarya_.

Finally through the darkness you make your way back to the _gir_ in which you are billeted. The wreathing smoke from its dome is illuminated to-night by the beams from the fire below. It rises in dimly bright convolutions, beautiful in its small way as the great Northern Lights. You spread your felt on the floor of the tent and roll up in your rugs. The teamster needs a timepiece to regulate his hour of harnessing, for you must start at daybreak. Leave your watch for him on the altar of the _dokchits_. It will be safe in this hut by the desert of Gobi, among the remnant of the Golden Horde.

* * * * *

The days' marches have taken us well up among the ridges of the Kentei Mountains. To the eastward is the peak which, despite the claims of Urga's Holy Mountain and of a site near Tibet, has the best authority for being the burying-place of Genghis Khan.

In 1227 the great conqueror died. The confused records tell of his body's being taken northward to a mountain which was the heart of his empire, from whose slopes sprang the sources of the three great Mongol rivers,--the Tola, the Onon, and the Kerulon. Beside its sacred lake the Manchu Amban of Urga sacrifices annually to the Nature-spirits. It is both a survival and a memorial to the bloody sacrifice of every living being on the road to the grave,--a tribute which tradition says the guards of Genghis Khan's funeral cortège offered to their departed chief.

Huts are far apart in these highlands now, and the whistling winds pierce the very marrow. The tired horses can hardly crawl forward on the doubtful trail. Far up in the heights, beside an old caravan-route, superseded by a newly-cut artery of travel, we come very late upon an ancient wooden shrine.

The worshipers have gone. They lived their time in a village near by, but with the exhaustion of pasturage for the flocks, under nomad necessity they moved. A new camel-road was tramped out by drivers, who must find shelter amid habitations. So in the shrine, long unpainted, the smiling Buddha presides now over his famished altar.

Very, very old, very, very poor, is Archir the warden, who welcomes you. For forty years he has watched in his _gir_ by the dragon-gargoyled gate. The spear with which he stood to his post of old is blackened, and its red tassel is dulled and faded. A tattered fringe is along the edge of the felt door to his _yurta_, and holes are under its walls close to the ground. His pile of wood is pitifully small, and few are his sandal-sole biscuits. His _shuba_, sheepskin-lined, is blackened with the soot of years.

Archir refuses courteously what he knows is a rare foreign delicacy, a Russian cigarette. "A lama," he says, "may not smoke." But his own hospitality is of the thoughtful kind which comes from the heart. He hands you a sheepskin softened by long massaging between his trembling old hands, that his own covering, not your coat, be burned by the sparks from the brazier. He notices that your tea-bowl is awkwardly held, and he brings a little table to put before you. He sees your driver fumbling for a match to light his pipe, and reaches him a coal with the fire-tongs. He clears his couch that you may sit in comfort. He offers you the first use of his fire for cooking.

In the old days many came to pray to the smiling Buddha. The drivers of the tea-caravans from far-off China left their offerings of fruit and silk scarves. The herdsmen whose lambs had lived well through a bitter winter gave sheep fat of tail to the two yellow-robed priests who chanted and clashed the cymbals through the long days and into the nights. The little boys dedicated to the gods, shaven-headed, rosy-faced, crooned their lessons in the Tibetan tongue, sitting on the floor of the big blue school-gir beside the shrine. Every day pilgrims on their way to Urga stopped to pray in the _soumé_, and filled the tent of the young guardian with eatings of noodle-soup and drinkings of tea, with gossip and with song.

But all is changed now in his little hut. The rule of non-marriage he keeps in the spirit, where so many lamas observe it only in the morganatic letter. This has left him alone in his old age, and pitifully solitary now that even the dwindling camel-trains, of whose tea-traffic the Manchurian Railway has robbed them, pass by no more. The priest is unfed even by pilgrims. These have gone with the rest to the routes of a better prosperity.

Archir has seethed his evening meal of sheep-meat and flat pieces of dough. He has let the fire die down to embers, and has pulled the covering over the round hole. The freezing winds very soon make his hut so cold that one feels like a thin shaking uncovered creature even beneath the heaped furs. One's ungloved hands grow numb as he lies by the brazier.

In the morning we too depart, and like the Roman legionary beside the Vesuvian gate of Pompeii, the old priest waits, alone, unquestioning, uncomplaining, till a greater God than he of the _soumé_ shall send the summons of relief.

* * * * *

The mountain-ranges, one after another, stretch their towering barriers across the path. They trend northeast and southwest, as in Siberia. First comes the Sharan Daba, the white range, whose pass leads down to the Iro River, rich in alluvial gold. The streams flow westward into the Cellinga, whose waters empty into Lake Baikal, and thence by the Angara River, into the far-off Arctic Ocean.

Ridge follows ridge now, and valley follows valley,--narrow cuts, with shallow streams, and huts clustered upon their sides. Out from the almost deserted borderland, the Mongol encampments are not unfrequently pitched where there is water for the flocks. If any wood be near by, it is well, since then the dried dung can be reserved for the smokeless evening fire when the top hole is closed.

When the steep mountain climb has been passed, it is as if a gateway had been opened through the constricting ridges. The broad valley of the Haragol stretches out. Down, down, we go, onto a plain, in the centre of which we come to an enclosure with a high mud wall and a peaked gateway, gaudily decked with red banners and vivid placards. Outside the mud walls of the compound, far and wide, are checker-board squares with irrigation ditches between. Huge stacks of hay and straw are piled up near the gate, the wonder and envy of the nomads, who never have more than the scantiest store. Within are booths facing the courtyard. A little temple occupies one corner. Two-wheeled carts are drawn up along the wall. Troughs and picket-poles are ranged in line, ready for the caravans.

Now, around the tarantass, there gather from their threshing the dwellers of the compound,--coolies from the far-off Pink Kingdom, with puffy blue trousers and tight-buttoned jackets, flail in hand and metal pipe in mouth. They stare stolidly without comment at the frost-covered horses, the robes, and the bearded strangers. Expressionless they stand watching every movement. Alexsimevich asks a question; no one answers. We sit for a moment mutually expectant. Not one of the Chinese stirs or speaks.

Then André swings down and leads the team through the gateway into the compound. Alexsimevich leads the search for shelter. We cross the courtyard to the building which serves for the lodging of travelers. Its walls are of mud, and a big adobe chimney projects up one side. Beneath low eaves a small window with white paper panes blinks like the sightless eyes of a blind man. We stoop, pushing open the crudely pivoted door, enter the smoky chamber, and the door swings back behind.

We are standing in what seems an unreal world--a stage-scene or a cavern from the Arabian Nights. In front and on each side close in dark windowless walls. Behind comes a feeble light from the little paper-paned window. In the dimness, a flickering fire throws fitful gleams on dusky figures, idols, and wearing-gear hung on pegs driven into the wall.

As your eyes become accustomed to the gloom, the details take shape. A clay stove is to the left. Fagots are heaped beside it, copper kettles rest upon its top, pigtailed figures are crouching around. In front, a platform, raised four feet above the clay floor, occupies the whole width of the room and extends back into the darkness. A group of men are seated, cross-legged, around a little brazier, smoking. Others are lying rolled in blankets.

With our luggage André staggers in. No one stirs. Some of the group around the stove turn their heads to look, but that is all. André heaps the food-bag and blankets in a vacant spot on the _kang_. We make room on the stove for our pots to boil the water for tea. On this self-elbowed place amid the rest we sit cross-legged, propped against the clay wall. The smoke from the oven, led under the _kang_, warms it so that the outer coat can come off. A little tabouret some six inches high stands in a corner, and serves as a table for the repast.

The shelter is far better, as comforts go, than any of the Mongol tents. The icy wind that sweeps the latter is barred off. There is a stove to replace the nomad's brazier; a warm _kang_ instead of the floor to rest upon. But how different is the spirit of the hosts! There are no frank hand-clasps here, no interested gossip and inquiries of the adventures by the way. No generous bringing out of fat sheep's-tails and snuff-bottles for the guests' delectation. You cannot but have the feeling that these people are as indifferent to your existence as they are to the pariah dog that howls outside the walls. They are exclusive, non-welcoming,--these Chinese. They are strangers to the land, self-sufficing in their toilsomely cultivated rye- and wheat-fields, an isolated, womanless, working settlement.

Despite the better quarters and comfort which these inns afford, one prefers to go to a Mongol tent and be among men more human, if less civilized. When the bread is thawed and the tea is boiled, we eat, pay the Chinaman who gave the wood, and with a sense of relief go out again to the tarantass and the road.

For versts now the way is along the alluvial plain, seamed with irrigation-ditches and dominated by several of these walled Chinese factories. As the sun goes down, however, there appears a solitary building, and André gives a glad shout, seeing that it is built of wood and has windows and big centre chimney. "_Russky dom!_" he cries.

A low mud wall surrounds the enclosure. Inside some quilts are hung in the air, that the cold may kill the vermin. A big black dog comes up, but unlike the scavenger beasts of the Mongol encampments, it signals welcome with friendly tail-waggings and

good-natured barks, approaching at once as if accustomed to kindly treatment.

The quilted door of the house opens. A booted figure appears with the familiar red blouse, and the Russian greeting hails you, "_Zdravstvouitie!_"

"An Orthodox Buriat," says Alexsimevich.

We mount his wooden steps, shake his hand, and enter the big warm room.

It is as if one were back in Siberia. The Buriat's Siberian wife, in shawl and kerchief, is busy at the whitewashed oven. Brilliantly-colored comic prints detail the misadventures of the young recruit, with doggerel ballad rhymes beneath. Chickens peck beneath the stove, the samovar hums on the table, and figures sipping tea are grouped around it on the benches, or are lying on the floor enjoying the genial warmth.

"Hail, Alexsimevich!" comes a voice; and a tall bearded Siberian, dressed in a Mongol robe, rises.

"Aha, Vladimir Vassilivich!" answers our interpreter. "Good-day!"

A volley of questions at once overwhelms him. The party has been long away from Kiahta, and we have the latest news.

"A Kiahta merchant, my friend, and his son," Alexsimevich explains.

Overcoats are being doffed, mufflers unwound, and boots kicked off. The babble of talk continues. A place is made for us at the table, and glasses of tea, with immense slices of cheese and ham, are placed before us. When more tea and cigarettes have completed the repast, Alexsimevich paces up and down, relating with dramatic gestures the latest gossip from Troitzkosavsk.

In the midst of his narrative, which all are following with great interest, there comes an incident of heightened vividness.

"Sh--sh!" a warning signal sounds. One of the auditors points to a shape rolled in blankets, and lying on the bench.

"_Gaspaja_" (a lady), they say.

Alexsimevich completes his tale in a lower tone and with more artistic circumlocution.

But it is the other side's turn to tell a tale, for why, in the ferocious cold of midwinter, with--save for this one Buriat's house--the Mongol huts only for nightly shelter, why does a lady come down here?

The merchant explains: "She has twisted her knee-joint, and in Irkutsk, in Tomsk even, the Christian doctors cannot heal her. A lama tells us that warm sulphur-water will soften the sinews, and the bone can be brought back into place. We go to the warm springs of the Holy River. I have been there in old times, and I know the way."

With pathetic eagerness the party has gone to do the lama's bidding, and bathe in the Mongol Jordan. Evening comes. The lady's bench is pulled over close to the oven. The merchant and his son lie down beside it on the floor. Servants and drivers roll up at their feet, and all sleep, in amity.

It takes resolution to awake at daybreak and leave the luxury of this shelter. But when horses are harnessed, riders must ride. The rising sun comes up over the white plain. The Buriat waves "good-bye" from his doorstep; the dog barks in farewell, and we lumber on southward.

A sugar-loaf hill marks the end of the valley. We turn up now into the mountains, the driver somewhat in doubt as to the way. A boy of about fifteen years, a yellow-robed lama novice, rides by. Alexsimevich hails him to ask the road to Urga. A complicated explanation follows, hardly understood.

"I show you," says the boy.

For a dozen versts he rides along on his pony beside us, chattering and laughing. When, after a devious trail, the pass is in sight, he starts off, and will not, at first, accept any present for his trouble.

Valley follows valley now, the trail fairly well defined. Mongol huts give a chance for rest and for cooking. A welcome is bidden us in each, the nearest water is shown, and invitations to come back are freely extended.

There is now one last range to cross, the Tologoytou, highest and steepest of all. Even the mounted Mongols, who have caught up with our toiling tarantass, swing off and climb afoot. Trees are on either hand, and the white wall-like face of the barrier passed in the morning seems a bare verst away. There comes a whole slope of boulders and rocks, jagged and broken, like the moraine of a glacier. And then, at long last, we reach the high-heaped Borisan at the summit, with its fluttering prayer-flags. The foremost Mongol throws on a rock, leaps upon his pony, and rides twice around the mound.

"_Argila! argila!_" (bridles free! bridles free!) he cries, and trots down behind the crest.

We, too, throw on a stone, and take the steep descent.

Beyond the low rolling ridges below is the white of the Holy Mountain, topped with green foliage. Here one may not kill the thronging hare and deer and pheasants. As we gallop down, the _obos_, the white memorial monuments, take shape from the snow. In the dark-gray dimness of the city beyond, green and gold roofs become distinct, lighted by the last glow of the sinking sun. Huts cluster close now along the road, and the shadows of innumerable dogs pass and mingle and pass again, where the gray mud walls and houses begin to be continuous. In the dim twilight the tarantass thunders into the great wide way which ends in the main street of Urga.

Two hundred feet broad is this street. Mud walls twenty feet high flank it. The gates to the enclosures are closed. The fast-fading light discloses hardly any passers-by. Save for a distant tom-tom there is deep silence brooding over the city. A great empty square is entered, where a few figures are passing in the distance. We approach one of these, who upon our question lurches up to the tarantass. He is a Russian clad in Mongol _shuba_, rather the worse for liquor.

"I will show you," he says amiably.

Affectionately leading the horses, he reels down one dark alley, then down the next, until we come to a second broad street and to an enclosure with a lantern-lighted gate. A cry brings at length a stir within. The gate swings open.

"The _Varlakoff_ house!" says the guide thickly.

The tarantass is led in, and we stumble through the darkness into a Russian home of some pretensions. In the main room is a lamp and a table covered with a red cloth. A glass of tea is available and is quickly swallowed. Then, tired out, we roll up in our blankets, on the floor, and drop off to our first night's sleep in Urga, the Holy City of Mongolia.

VI

THE CITY OF THE REBORN GOD

The murmur of many voices pierces the blanket over your head. Sleepy-eyed in the warmth, you peer out from the chrysalis of coverings to watch the people moving about. Alexsimevich has extricated himself from the mound which he constructs nightly on the floor, out of luggage-bags, felt mats, rugs, and overcoats. Under all the heaped wrappings that he uses in the icy Mongol tents, he has camped and slept close up against the white wall of the oven. Truly the Siberian is brother to the salamander. He pulls on now his big felt boots and runs a pocket-comb through his beard.

The wife of our host, come to the door for a survey, notes progress and returns to the female region. The Hazan Varlakoff, gray-bloused and wearing deerskin boots, enters next. He lights his first cigarette; his wife with the bowl of sugar and the plate of bread follows. She has gotten up earlier than her husband, so she is several cigarettes ahead, but he is cutting down the lead.

Perhaps one had better get up one's self. It is an easy operation here. "Getting up" consists in emerging from the rolled blankets and stretching. "Dressing" means pulling on boots. One can wash over in the corner, where the brass can lets out a trickling stream of cold water when the needle-valve underneath is pushed up.

The samovar hums on the red cotton cloth of the table. Varlakoff moves along to make room. From the little pot of infused tea your glass is partly filled; then you place it under the spigot for hot water, and the beverage is ready for sipping. No lemons are here, as in Russia. In a few Chinese shops one can buy spherical citrons, but they are like unripe oranges, and are a luxury as great as pineapples in old New York.

A wool-buyer from Kiahta reaches for the bowl of broken loaf-sugar, and holds it for you to choose the piece whose size pleases best. The housewife comes from the kitchen over by her oven-door, bringing some crestfallen cake which she has made in your honor.

"_Kuchete! kuchete!_" she commands, arms akimbo, puffing contentedly on her cigarette.

We revel in the luxuries of Varlakoff's room; warmth such that we may take off the cumbersome outer coats; chairs to sit upon, instead of crouching cross-legged; hot samovar-made drinks, and a chance to wash in water. The latter is a privilege which can be appreciated only after a period of ablutions in lukewarm tea. We stretch out and bask and sip, and whiff _papirosi_ in epicurean idleness.

As we luxuriate, one by one the neighbors of the Russian colony come in, to hear the news of Kiahta from Alexsimevich. The expedition has become part of the gossip-transportation system. Half the population of Kiahta must have sent messages here,--half the Russian traders in Urga have come to receive them. First, there is the general news dispensed into the expectant ears of the group at Varlakoff's. Alexsimevich is for an hour the cynosure. Questions and answers flash back and forth, going off sometimes explosively like fireworks. Then follow the special events and the individual messages. At last these are all detailed. Now come invitations from various men to visit their houses "Will the _gaspadine_ come?"--"The _gaspadine_ must see the city."--"_Da! da!_" echoes the group.

Varlakoff goes out for his stick and overcoat. The wool-merchant gets into his fleece-lined _shuba_. He achieves the feat by the usual Siberian method. Putting the garment over his head, he pushes his arms through the sleeves, and gradually struggles and writhes up into it as one gets into a wet bathing-suit. Alexsimevich finishes his fourth glass of tea, lights one of the _Hazan's_ cigarettes, and worms his way also into his deerskin greatcoat. Then out we go into the bright sunlight and the snow-covered streets.

[Illustration: TEMPLE OF GIGIN, URGA]

The houses of the Russian quarter of Urga were only glimpsed in the dusk of last night. We have daylight upon them now. Squat whitewashed buildings they are, with neatly paned windows and big square chimneys. Across the mounds and hillocks of a broad street is the one-storied Russian Club, where one may drink vodka, play billiards or cards, and while away the winter evenings. Further on is a row of shops. The bearded owners stand behind their counters, dressed in belted Mongol _shubas_ and Russian fur caps. The doors to all the shops are open, that the Mongols, perplexed with knobs, may not take their trade elsewhere. Enameled kettles are hanging in festoons down the walls. The shelves are crowded with bolts of vivid-colored cotton cloths to be sewed into _shubas_ by the Mongols who ride in to buy. There are big cases of sweetmeats, Moscowski caramels, acceptable offerings to the grotesque _dokchits_ on the family shrines. Russian monopoly tobacco is there, in stamped paper packets for the delectation of Muscovites and Buriats who have the taste and the means, and villainous South-China tobacco and snuff for native purchasers. One can get vodka almost as bad as that of Siberia, and far cheaper, for it is compounded by a local distiller who rejoices in an excise-less market. Foreign brandies and wines fill big walls of shelves.

"_Zdravstvouitie!_" one of the merchants calls, hailing our party.

"It is Vassili Michaeloff, old friend of mine," says Alexsimevich. "Let us go in."

We enter and are led back into the private part of the house.

"_Chai!_" shouts the host to somebody behind the oven.

"_Haracho_," comes the answer.

We all sit down. If any purchasers drift into the shop, they can wait until we get through our visit, or they can go down the line. For wherever the Eagles are planted, the Russian joyfully drops his business to entertain a friend. At the call of "tea" the shovel goes into the ditch, the ledger onto the shelf, the pen into the potato. If "_chai_" interferes with business, cut out business. Nor does it matter in the least that we have just had breakfast; by the rule of etiquette we must be entertained. "Tea" consists first in a ceremoniously clinked toast drowned in vodka. Then appears the samovar in charge of the woman of the house, the glasses, and the sugar. Next follow the cigarettes. The talk is animated, for its local history absorbs each little world. The fact comes out that the cousin of Michaeloff has bought a new pair of horses for a hundred roubles. The price, the quality of the animals and of the man, all go into the crucible. Kiahta beer arrives as the conversation turns to the death of one Ivan Vladimiraef, which it is agreed was not

unnatural, since he had reached the age of ninety-odd years. Still the provisions come. The good wife brings in a heaping plate of lard-impregnated Hamburger steaks, called "cotlet," which Alexsimevich attacks as if his last meal were half a day instead of half an hour distant. Other bottles accumulate to help out the dwindling flagon of vodka. We enter upon Château Yquem, Pomeranian, and Caucasian claret. Then cakes are set out, and more tea, and finally a quart bottle of champagne.

Alexsimevich stands to his guns like the 38th Siberians at Tien-tsin. But it is hard for any one of less rigorous training in this sort of thing to hold even the straggler's pace at nine o'clock in the morning. Mentally we hoist the flag upside down, and wink at Alexsimevich as the outward and visible sign of the inward and spirituous distress. He takes the rest of the champagne in a last gulp, and with a series of thanks we gain the entrance to the shop, where two Mongols and a Buriat are waiting patiently, looking vacantly around at the crockery.

We are shown ceremoniously to the door, shake hands, remark about the weather, give our compliments to the wife, and depart. When at the corner, we glance back. Vassili Michaeloff is still standing on the threshold; his three customers too are looking out leisurely at the people passing.

"We have thrown his business out of gear," we remark to Alexsimevich.

He seems surprised.

"There is plenty of time. Why should they mind waiting? _Nietchevo._"

Another host is overjoyed to see us, for an engineering problem of great perplexity is, he tells us in due course, harassing his mind. No one in Urga can help him out, but perhaps we will.

"The Chinese governor, the _Zinzin_, wants to make an automobile line from Kalgan," the host announces. "I saw an iron bridge once, so I agreed to build him one over the Lara River. Have you ever seen an iron bridge? How shall I do it?"

You allow that you have seen an iron bridge,--that you have even gone across one. You suggest that much depends on the river. "How wide is it, for instance?"

"I have not picked out the place for the bridge yet," answers the host; "but the river is somewhere between sixty and three hundred feet wide. Have some vodka?"

"And how deep is the water?" you ask.

"Well,"--after much thought,--"it is deep in the middle and shallow at the edges. Have a cigarette! Have some tea! If we build this bridge, the _Zinzin_ will give us a decoration. How much will the bridge cost?"

"That depends upon what sort of bridge you build, and how long it is, and how much material you use!"

Alexsimevich comes in.

"You see, the more iron you use, the more the bridge costs," he observes.

"_Navierno! navierno!_ you speak sagely, Alexsimevich. That is what I told the _Zinzin_."

"It must have piers and abutments," you venture.

"But the _Zinzin_ does not like piers, because the water was not made to put such things into. Yet I said with you, one must always have piers. Here is brandy. Take a few sardines!"

The problem certainly needs something special for its elucidation. You ponder, and Alexsimevich and the host breathlessly watch the hatching of your official pronunciamento.

At last you deliver yourself.

"Find out how wide and deep the river is. Then write to a steel-manufacturing company, to quote prices. They will send a blue-print of an automobile bridge of the specified length, together with the weight of the steel. You can buy pieces to build it at so many kopecks a pound, just like butter."

“Ah, my friend, you do not know how great a service you have rendered! What a providence is your coming! Pray, have some cognac! Will they send me a picture with piers,--a picture that I can show the _Zinzin_?”

“Yes,--yes, indeed.”

“I go to-morrow to tell him of this.”

We are once more in the street and the banded escort is turning into still another Russian’s house. Their idea of sightseeing is apparently to take tea with every Russian in the place. A mild desire is registered to come in contact with some of the other people. The idea strikes them in the light of a strange new doctrine.

“You wish to see Mongols?” one asks. Though surprised, they acquiesce amiably. “To-day they have holiday; you are favored. Go see the doings and make me visit later,” says the disappointed third host.

Then the wool-merchant speaks.

“Near by is the great temple of Urga, which few have seen, for it is one of the most holy places of the Lama faith. It is the temple of Maidari, the Future God. If the _gaspadine_ wishes to see it, I, who have bought wool from the uncle of the keeper of the gate, can gain admittance.”

[Illustration: TEMPLE IN THE URGA LAMASERY]

For this we start. The Russian section, made up of shops with posters and signs in Slavonic letters, and homes with centre chimneys and little square panes of glass, is left behind. Through a long dark lane we come out into the main thoroughfare of Mongol Urga. The town is in festival for the New Moon. The streets are ablaze with color. Red posters are on every door and wall. The brilliant picture is framed by the snowy girding hills and the green trees of the Holy Mountain to the south. The tomb-like altars on the plain are dazzlingly white against the gray-plastered fronts of the houses behind. The gilded gargoyles of the temples flash in the sun. Down the main street, a hundred feet broad, go bevies of girls, their hair bedecked with the gaudiest ornaments of silver and pearl, their silken robes striped and banded in green alternating with yellow and blue and gold. Lamas stride here and there dressed in bright orange robes and hats, their silver knives hanging at their sides. Great shaggy-haired dromedaries swing past. Horsemen, robed in vivid scarlet and blue and magenta, dash at full gallop across the wide open _piazza_ in the centre of the town. A donkey-cart is driven slowly along, crowded with brightly-dressed girls. A squad of Chinese cavalry trot by in white jackets, red-lettered. Two of the Cossack garrison swagger past. A bearded Siberian trader strolls across, clothed in the dark Mongolian cloak which most have adopted, going toward the Russian quarter we have just left. A string of oxen plods by, drawing cartloads of wood.

Walking on, we come to a long line of kiosks which a continuous procession of pilgrims in holiday attire is entering. In each booth is a cask-shaped prayer-wheel, a magnified model of those which women carry, twirling them in their hands as they walk.

Along this main square of Urga, and girding her city stockade, are hundreds of these cylinders. All the day long, men and women are going in and out from one kiosk to another, turning. Some say that formerly one could enter a great Tibetan temple only after saying a prayer so long that even a Grand Lama’s memory could not carry it. So, for convenience, a cylinder with the written text was set up at the temple gate. By degrees it became the custom, without reading it, to rotate the petition for a blessing. Others say that the wheels are whirled in literal obedience to Buddha’s precept to “turn over and over his words.”

Alternating with the wheels are stone shrines graven with Tibetan characters, before which, on wooden couches, silken-dressed women are abasing themselves in abject worship. A long line of pilgrims is doing the circle of the city. They stand, then drop prostrate in the snow. Rising, they move conscientiously forward to where their heads touched, and again lie prone, making thus a penitential circuit of the stockade. Most are in deadly earnest. Some, hired for a proxy service, steal forward a few inches on each prostration.

Suddenly three distant guns boom out.

“_Scurry, scurry toda!_” says the wool-merchant. “Quick, this way. He is coming.”

You hurry forward to where a trail leads across the square. Afar off, in the direction of the Holy Mountain, is seen a band of galloping cavalry. The Mongols on horseback around you are drawing rein. The pilgrims are looking toward the approaching cavalcade. Brilliant red and yellow are the robes that flutter as the body-guard ride. Now a rumble of wheels is heard among the

clattering hoofs. Preceded by twenty horsemen, followed by twenty more, rolls down a Russian droshky, with a yellow-robed lama driving. Propped among the multicolored cushions sits a clean-shaven, silk-robed man, with puffy cheeks and tired eyes. The European watch which he carries hangs in anomalous awkwardness at the breast of his robe; his leg is propped on the front seat, as if he were lame. Most turn their backs to him in Oriental honoring; many prostrate themselves in the snow; every horseman in the square has dismounted.

"He drives from his palace beside the Holy Mountain to the temple on the hill beyond the city," says the wool-merchant.

"But who is it?" we ask, as the last galloper rides by.

The Russian looks at us as an old Roman might, if in the Forum we had not recognized Cæsar.

"That! That's Gigin, the Living God! That's Buddha come back to earth,--Gigin!"

You stand a moment to take it all in. Then, despite your purpose of respect, a smile works to the front.

At once the wool-merchant laughs gleefully. "Ask Varlakoff about the Buddha," he chuckles. "Varlakoff sold him his ponies for ten thousand roubles. My friend showed him a picture of the ponies, little horses, you know, and Gigin told him to get them. They had to send to an island of Europe, Scotland. But Gigin was very pleased. He said Varlakoff was the only man who had never lied to him."

The expression of the wool-merchant was that worn according to tradition by the Roman augurs.

"When there is not a holiday, the people have the market here in this square," the merchant continues. "I was here in the bazaar with a friend last week, and we heard a commotion over by that prayer-wheel. We went up, to find that two of the Buddha's lamas were borrowing a fine horse, worth three hundred roubles, which belonged to a Mongol woman. It was all she had, she told us, and it was being taken to the Living God's stables. The woman was in great distress.

"'It is mine. I will appeal to the Consul,' said my friend.

"The Gigin's men could not take a Russian's horse, so they had to give it up. The Mongol woman came and wept on him, she was so glad. She brought a gift to my friend. Generally the Gigin returns such borrowed booty when he has used it a while, but often not. Anything that is new, the God will buy. These pilgrims, you see, bring him offerings. Kalmuks come all the way from the Volga, Manchus make pilgrimages, Buriats come down from north of Baikal, and tribesmen from Tibet. He has half a million roubles a year from his priests, and he does not care for anybody."

Becoming more and more steeped in celestial gossip, we go past the gray-plastered compounds piled high with wood and timber, a main export of Urga. Tall masts with logs suspended from them are the signs. We reach at last a big stockaded courtyard, the beginning of the monastery quarters.

"Come, look in here!" says the guide.

You peer through the gateway at six of the biggest bronze _burgoo_-kettles that ever existed outside an ogre's kitchen. Each kettle can hold a couple of cows.

"It is to feed the monks," says your companion.

The Mongols are going up to the vessels, with buckets suspended to the end of a milkmaid's yoke. They dip up a load. The soup looks like gray tapioca pudding. What it is made of remains one of the secrets of the monastery, whose chef is stirring the mixture with an oar.

A big stockade, enclosing tents and peaked _soumé_, from which the sound of chattering is heard, appears ahead. As we approach, a whole hive of boys swarm out and scatter in all directions. Some are in red, some in yellow, some wear ordinary Mongol caps, some wear high, yellow sugar-loaf fools'-caps, which fall over on one side. These are the novices in training for the lama hierarchy.

The first-born of each family must by immemorial custom become a lama. In babyhood and boyhood one of these dedicated children is clad in yellow robes and is especially tended. "_Ubashi_," he is called. When about ten years old the boy goes to school, at Urga. He becomes a _bandi_, or student of the prayers and of the Tibetan language. He runs about as those we have just seen, and at about twenty he becomes a _gitzul_, or first-degree lama. Now he shaves head and beard, and wears a brilliant yellow and

red robe. Next he takes the more advanced examination and catechism, and becomes a full priest, or _gilun_, forbidden to marry, to kill, or to work. He may continue his curriculum in one of the departments of the lamasery, studying divinity, medicine, or astrology.

In the divinity course a lama will memorize Tibetan prayers, and pore for years over the big holy books which lie within the chests of the lamasery chapels. He will repeat the creed over his beads, in rapt self-hypnotism, meditating in celestial holiness. He will pray down rain for the grass, and will exorcise glanders from the ponies.

A priest taking the medical course will gain a knowledge of the innumerable herbs that grow on the Tibetan mountains, many of which are of great value as drugs, and are known only to these monastic seekers. Massage, warm sulphur baths, and waters, are part of his pharmacopœia. Mixed with genuine instruction in anatomy and medicine, he will be taught the incantations that cast out _tchutgours_, or evil spirits, the words of power to be written on rice-paper and rolled into a pill for the patient to swallow. He will learn what devil is responsible for the disease which has brought low the lusty herdsman, and the right order of image to make for allaying the infernal anger. He will be taught when the fever crisis is at hand, so that the cymbal-clashers, the drum-beaters, and the prayer-wailers may assemble, and by these holy noises and a transcendental counter-excitement, lift the patient over the fever-point.

[Illustration: A PROSTRATING PILGRIMAGE]

If he elects astrology, he will be instructed in casting horoscopes of unfailing value, in reading the stars, predicting their future stations and the coming of eclipses. He will be prepared to declare the reasons for visitations of murrain and to track the trail of straying camels.

Divers are the paths of knowledge, but all may lead to the honor of Grand Lama, head of a monastery, or member of the college of _shabniars_, who form the Council of the Living God. And when the great reaper has called the high priest from his earthly glory, a whitened tomb will be raised to his memory just outside some town along the camel-trail, while his ashes will be moulded into briquettes and godly images, to rest before the gods in the shrine of some _soumé_.

We have arrived at the gateway to the great temple. The wool-merchant disappears inside to work his pull. A young lama comes out to the door, smiles at the foreigner, and then goes in again, and you tremble lest your advent is being announced to some other than the one man who can supposedly be "fixed." This is the most important temple of Urga, forbidden to foreigners, and seen through good fortune by a few only of the old residents. But every gate they bar to hate will open wide to love--and a ten-rouble note. The merchant comes back.

"We can go in while the lamas pray," he whispers.

The uncle appears, with an expectant look on his face, and motions us in through the darkness to the anteroom of the temple sanctuary.

From the chamber curtained off at one side comes a low swelling chant.

"Service begins, you may see it from here," the lama says, just above his breath.

Your station is in darkness, but just the other side of the curtain are the lamas, and their apartment is lighted by windows. Two rows of benches extend the length of their chamber, leaving an aisle between them, reaching from the door to the altar. A score of priests in yellow robes, with red sashes slung tartan-fashion over a shoulder, are sitting on these seats facing each other. They are ranged evidently in the order of their ages. Two old _giluns_, fluent in the Tibetan litany, sit next the altar. Then come younger lamas, the _gitzul_, not yet full priests. Finally next to the door are _bandi_, ten or twelve years old, intense in youthful delight that their part in the ceremony is to pound as lustily as they can the big prayer-drums. The service begins with the chanting of a ritual in form not unlike the Slavonic litanies of Siberia. At appointed times it is necessary to call the god's attention to the fact that something is going on in his honor. At once a most deafening clamor begins. The small boy with a drum is drowned out by his big brother, further up the line, who officiates upon a huge wooden cornet, and by his uncle with the conch-shell or the cymbals. The droning of prayers is like the buzz of hiving bees. There seem to be no responses, but all of them read together. Presently comes a sudden clamor, almost like a fire-alarm; then the crash and the droning suddenly cease.

"It is over!" says the guide.

The lamas file out by a further door, and we tiptoe in to inspect the holy of holies at the heart of the great lama sanctuary. In the dimness one sees first before him the table for offerings, on which are the two main sacerdotal instruments,--a silver bell and a silver handle like a carving-knife-rest,--and row after row of targets made of dough-paste, of brass cups filled with oil to serve the tapers, of millet, rice, currants. Behind this altar, towering far up into the hollow of the dome, is the bronze colossus of the smiling Buddha, Maidari, the Future God.

Fifty feet in height, the figure is, cross-legged, with open, painted eyes. From Buddha's hands hang long silken streamers. One of very fine quality is embroidered with the ten thousand gods.

"This," the priest whispers, "is a present from the Dalai Lama."

A great festival takes place in summer in honor of this god, who will rule a myriad years hence, when the race of giants descends to kill mankind and to people the earth with their own kindred. The Gigin's elephant is brought out, and he himself takes the lesser dignity of a carriage in deference to Maidari. Even the gods of the present must honor the gods of the future.

The Gigin's throne is to the left of the statue. It has triple silk cushions. Around are twelve colossi of Buddha, some ten feet in height, and entirely gilt save for the red lips and the eyes. The hands are held in differing positions, folded, outstretched, pointing. Here and there a silk scroll is hung.

The walls of the sanctuary are lined with shelves like a book-store, and these are loaded with statuettes of the ten thousand gods.

We tiptoe back the way we came, and are soon in the street of the monastery. The uncle has seen us safely away. We betake our route from the Mongol toward the Russian section.

"You saw the throne cushion of Dalai Lama?" the wool-merchant asks. "They have put it back now. Gigin kicked it out of the temple when Dalai Lama left. The Angleski drove Dalai Lama from Lhasa, and he came to Urga to visit Gigin, because here is the second great Buddhist holy place. Now Dalai Lama is very monkish, very austere, and always prays and fasts. But our Gigin"--here follows another expansive smile--"Gigin rode out with his Council, the _shabniars_, and took some of Pokrin's best champagne in the cart, for they would not have it in Lhasa. Dalai Lama was very stiff. Gigin asked him, 'Have a drink!' Dalai did not understand, for drink is forbidden. Then he asked him again, and Dalai Lama refused rebukingly. They came to Gigin's palace at the foot of the Holy Mountain, which is built like the Russian consulate. After the prostrations, Gigin said to Dalai that he had come far and few women were on the road and those mostly old and ugly. Dalai Lama refused that too. Cigarettes and snuff, and canned tomatoes he offered, but Dalai Lama refused them all. Then, in the Assembly of the Lamas, Dalai rebuked Gigin, and made him sit below his servants in penalty, for Dalai Lama is more of a god than Gigin. All the pilgrims came to offer gifts to Dalai Lama, and Gigin did not get his. For months Dalai Lama stayed here. Afterwards he went away to China. Gigin came to this temple then and kicked Dalai Lama's throne, throwing it down. He celebrated in the summer palace when Dalai Lama left, for he was very happy."

* * * * *

Mongol Urga is left behind, and we reënter the Russian town. A hail from one of the passers-by is not long delayed. "Will you have _chai_?" he questions. He is an alert-looking Russian, smartly clad in a _shuba_ of green leather trimmed with sable.

"Must we eat any more dinners to-day?" we inquire.

"Only tea," is the reply. It is not quite reassuring.

"That is Pokrin, the one that sells to the Gigin," the wool-merchant whispers. "Go with him: he can tell you some tales."

Obviously one must not miss the acquaintanceship of this modern Ganymede, cup-bearer of the many-bubbled French nectar and jugged ambrosia; so on we march to his compound.

Pokrin was on his way to a business appointment; but no rendezvous will interfere with prospective _chai_. He hangs his coat back on its peg, bids his wife start up the samovar, and produces the vodka-bottle. Yes, his family is very well, and he is very busy buying hides. We talk up and down and roundabout numberless themes, and at last venture: "The Gigin!"

"Ah, the Gigin was here to see me only a week ago."

We bow our recognition of the host's great importance, and he is started; soon he buckles down into the story.

"The Buddha came up in his carriage with his lamas riding beside him, and they tied their horses all around here in front. Then Gigin came in, walking softly because of his gout, and he said, 'Let us drink together like friends, without quarreling.'

"I brought out the drinks, and we sat down,--Gigin and I with the lamas around us. Gigin likes best the strong drinks,--not vodka, but cognac and sweet champagne. Very many bottles we drank, Gigin and I. And at last I fell asleep. But Gigin drank still. Then he too fell asleep. In the morning the lamas carried him to his carriage, and back he drove to the palace, with the people lying down in the street as he passed. All the next day I had a very bad pain in my forehead, and it felt large."

By non-Siberian standards Alexsimevich should be on the way to similar symptoms in the near future. For the purveyor to the Divinity has produced an assorted collection of his wares which are being sampled with due diligence. Cold meats and wheat-bread appear on the table with the samovar.

"We must eat, or he feels badly," whispers Alexsimevich, as he makes a sandwich, an inch and a half through, which is about the depth of brandy in the Siberian highball.

Other neighbors drift in as the afternoon wears on. The talk turns to that greatest of local events, the Metropolitan Handicap of Mongolia, under the high patronage of the Living God. Things become decidedly stimulating, and the recitals lively. Everybody is living over the excitement, ejaculating and gesticulating. The child-quality in their minds keeps so vivid their impressions, that the scenes are projected almost as by a cinematograph.

From hundreds of miles around, the herdsmen have assembled. The plain before the city is a riot of color, as the horsemen ride here and there. In the centre of the field is the gay pavilion for the yellow-robed bishops and cardinals from distant lamaseries, guests of the great Gigin.

All through the morning, hundreds of riders and horses have been making for the starting-point, twenty _li_ (about seven miles) distant. The jockeys are the smallest boys available: young red-cheeked lamas, perched bareback on the shaggy racing-ponies. The monks, who are stewards of the course, have with much shouting finally, at the hour, lined them up in a long row, facing Urga. One thousand ponies have been reported as entering. It is a regiment of boys. A signal starts the whole cavalcade together. The thousand small jockeys shout at once. A thousand whips come down on flanks. Two thousand heels dig into the ponies' withers. Over the irregular plain tear the racers, dodging around gullies, stumbling in marmot-holes, galloping helter-skelter amid furious yells. At length they come within sight of Urga. Crowds, mounted, have gone out to follow them in. The shouts redouble, the people become frantic; the riders yell at one another, and the horses are as wild as their masters.

Shabniars and cardinals get to their feet as the cavalcade appears. The Living God's heavy eyes brighten up with interest. His chief soul-mate waves a jewelled hand and chatters excitedly with a lama of the guard. The foremost rider is close at hand now, the jockey, wriggling like an eel and almost on the neck of his pony, yelling and slashing. The field thunders behind. The leader nears the pavilion, his pony is on the fierce final spurt,--a last cut of the whip, and in triumph, amid the deafening roar of the populace, the winner passes the line. Many other riders come in at his heels, but most straggle off to either side of the course when they see that the finish is lost. The victor is caught up by the priests and is brought before Gigin, where he lies on his stomach in adoration. He receives a gift, and is pensioned for life. The horse's owner receives a good price for the animal, which is added to the Gigin's stable. The mule-cart of the Buddha is then brought up and he is loaded in. The yellow bishops mount their steeds, and back to his palace goes the Living God. Thus ends the great Urga race.

There are other athletic tournaments during the season; most important of these is the championship wrestling-bout, which every year decides whether laymen or clergy are the better sportsmen. The Gigin's pavilion fronts a ring, with dressing-tents on either side. From one emerges a layman. He advances by huge jumps and prostrates himself before the deity. Next, palms on the ground, like a great frog, he leaps into the ring. The chosen lama executes the same pass from the other side. They meet, jumping like game-cocks, with quick breaks. At length the clergyman gets a leg. In an instant he heaves up on it, and over goes the black man,--out! The whole assembled populace raises a stupendous howl. Bout succeeds bout, with differing champions and varying issues. Partisanship is intense. The clergy usually win in these matches, and have long held the championship.

One guest tells to-night of the photographer who bribed a lama, and got the first photograph of Gigin. The tale runs that this man, a Russian, secured admission among a crowd of pilgrims, and snapped the god, unawares, among his entourage of priests. This photograph, enlarged and colored, is the one now hawked to the Mongols, and which they set up for worship among their other gods. The lama was beheaded, they say. That was several years ago, however: since then Gigin has been photographed at the

races and elsewhere.

At last we break away from the group and return to our lodgings at Varlakoff's.

[Illustration: A GRAND LAMA]

We are informed next day that among the invitations so lightly and uncomprehendingly accepted was one to take dinner with the mayor of the Russian settlement. We are expected therefore toward evening. So, late in the day, we gird on our greatcoat and move out heavily. Down the street we fare forth to the house of the host. A fine well-fed man is this mayor, with the cordial grip and the slow smile of good-fellowship. He wears a very long beard. He has taken a fancy to the embroidered green and pink Chinese ear-tabs as a substitute for the big fur cap of his own people. The ear-tabs are about as appropriate to his burgomaster build as baby-blue ribbon on the tail of a fighting bull-pup. Otherwise, deerskin boots and hunting-coat, he is the real Siberian. In the mayor's large sitting-room, along the wall against which the table stands, is a rank of bottles of divers heights and fatness, like recruits out for their drill. The samovar of shining brass leads the array. Four different-sized glasses stand at each plate, and the intervening area is covered with platters of sausages, cheese, bread, sprats of every conceivable variety, and a medley of cold _zakuska_ dishes.

The mayor reaches for the vodka.

"Please, none!" we blurt out.

The mayor looks hurt. Then an idea takes form in his head, and he shouts something to his Chinese boy, who promptly shuffles through the door into the street.

Out of the window we catch a glimpse of him turning into the establishment across the way, where Pokrin's clerk sells the wherewithal to make a Russian holiday. The Chinese boy emerges with a bottle, and trots back across the street with the curious gait made requisite by the unattached thick-soled slippers. He shuffles into the dining-room and makes space for one more bottle. Whiskey! The mayor has bethought himself of the English label, and has sent for it, on the theory that not to drink, like not to sleep, is unbelievable.

Evidently one must again sidestep, so _chai_ is besought and got down. Our virtue is rewarded, for the host smiles and is content.

"Poor Pokrin!" he says presently, reminded of the man by the beverage. "He made over a hundred thousand roubles from selling things to the Gigin. But now he can't think of any more things to sell. You saw the Gigin's new droshky? But that isn't like selling an elephant or an electric-light plant. Pokrin is down to pelicans and fountain-pens."

He shakes his head sympathetically, and reaches anew for the vodka-bottle. He goes on reminiscing, half-cynically, half-regretfully, of the past, while dinner to serve the appetite of a Cyclops keeps coming on.

In the midst of the repast cries arise outside. A Mongol with a flow of language is heard calling aloud for "_Bulun Darga!_" (fat policeman.)

"They are after me," says the mayor resignedly.

The Mongol comes hurtling in, pushing past the Chinese boy.

"Fat policeman," he cries; "Red Mustache and Long Nose and Blue Coat are drunk, and are disturbing my _gir_. Come quickly, O Lord, fat policeman."

The mayor sighs. "I go"; then he turns to us. "Will you accompany me?"

"Gladly, if we don't have to eat any more."

The mayor considers this a back-handed compliment to the amplitude of his hospitality and smiles.

"_V period_, it is not far."

He puts on his huge greatcoat, draws on his ponderous boots, takes a heavy stick, and in vividly embroidered Chinese ear-tabs stands ready to follow the Mongol. We shoulder open the felted door. From the low-ceilinged recess between this and the outer door he produces two other big sticks, like pilgrim's staves. These he hands to his visitors.

"For the dogs!" he explains.

The Mongol's hut is soon reached. It is in frightful disorder, and vodka-bottles are strewn around. The mayor looks up in a little book to see if Krasni, young Agueff, and Pugachev are not, as he suspects, the men who in native nomenclature are called Red Mustache, Blue Coat, and Long Nose. He finds that he has rightly surmised.

"I know them," says the mayor. "They will come around to me in the morning. I will tell them to make the Mongol satisfaction. When they come back and say he is satisfied, I tell them to be good and to do this no more. _Nietchevo!_"

The irate man is jollied along, and is told that it will be fixed up soon. Consoled and soothed by the protection of authority, he admits it was not so bad after all, and he bids us, as we leave, a grinning "_Sein oh!_"

"Now," says the mayor, "will you not come and see Urga at night?"

He leads along an icy back street, black as a canyon, with the bulging mud-plastered walls, twenty feet in height, so close that a cart can barely pass between them. Not a light is seen save as a ray pierces the shuttered planking of some compound door. Distant clanging of cymbals and far-off echoes alone break the stillness. Out from the gloom of the street we come into the open _piazza_, half a verst wide. It is unshadowed, and less dark. Threading the heaped-up refuse we stumble on. The black crows, with lancet-like blood-red beaks, which search the heaps by day, are gone. The black cannibal dogs wake and growl as we approach.

"They are afraid of a stick and don't generally attack people. But, if several do come at you, crouch down and stay perfectly quiet," the mayor counsels.

He then tells of the Cossack who last year, passing by a dog that did not move aside, drew his sabre and struck the beast. As soon as the other dogs smelled the fresh blood, they became mad, and half a dozen came at him. He put his back against the wall and slashed among them. Many he cut and wounded, but more came and more, in an instant. Soon he was pulled down, for hundreds were upon him.

A big black-furred brute looks insolently at us as we pass.

"They do not bury the dead here, you know," the mayor says. "The corpses are taken to the mountain northward outside the town, and are left. It is cold to-night. There will be death in the market-place where the poor lie shelterless. And the dogs wait beside them."

A little way off, where the prayer-wheel stands, is the twinkling light of a shrine. The new moon and the few brilliant stars are frigidly distant. They cast a pale white glow now on the dimly outlined walls and huts. A beggar, lying unseen, calls suddenly as we pass his heap of sodden hides. The six-foot Siberian hunter by our side cries out as he stumbles over and beholds a something, partly eaten, guarded by a great cannibal dog.

If the thought of the rights of man has drowned sympathy with all that concerns the government of Russia, visit Urga at night, and the Cossack of the Russian Guard, swaggering along among the Chinamen,--this Cossack whom you have heard execrated as the "knout of the Czar,"--will look to you like a Highlander at Lucknow. The chance to absorb an unwholesome amount of tannin by way of a samovar, and to sleep on the floor beside the oven in the whitewashed house of Michael Varlakoff, will become a privilege more prized than any possessed by His Holiness, the Living God.

The section of the Russian colony in which we have been lodging consists of five hundred-odd traders. They have drifted down from Siberia, and on the free ground of taxless Urga have established their shops of gaudy European cloths, enameled cooking-utensils, candles, and cutlery. These Russians, whose whitewashed many-paned houses fill a quarter of the town, have not the large interests watched by the English merchants, who dot the globe with their agencies. They are small Trans-Baikal shopkeepers, transplanted bodily. They build their houses in the Siberian way, and their wives toil personally at the oven. They wear blouses and felt boots as the house-dress, and keep the ikons in the corner. Prosperity is evidenced in the striking-clocks, the lamps, nickeled samovars, and curtained double windows. But they are still not many removes from the peasant.

There is, however, another section of Urga's Russian colony, grouped around the consulate, a large compound situated a verst east of the Mongol town, which was built in 1863, and was fortified in 1900, against the Boxers. Within this compound are the Orthodox Church, the Russian doctor, the rooms of the twenty Cossacks of the Guard, and the great empty barracks of the two _sotnias_ that were sent here in Boxer times, and were, to the regret of their compatriots, later removed. The barracks are still

ready for any future visits, and the breastwork, with its stake and fosse lined with barbed-wire, is equal to any force which from a five-hundred-verst radius can assemble against it.

In this quarter, the Russian consul is autocrat. He is the official notary, without whose stamp no contract is legal, the chief of police, the guardian of orphans. Around him revolves the society of the few dozen mondaines of Urga, whose personnel consists of the officials, the garrison officers, and some half-dozen commercial agents, single generally, or with distant families. They conduct their bachelor quarters through Chinese servants, and their cuisines are helped out by all the canned and bottled delicacies that can be ordered from the frontier. The gold-mines, and the extensive wool-trade which produces a commerce of twenty to thirty millions, demand that first-grade men watch the interests of the great companies which handle the business. So men of the best cosmopolitan Russian type come, at salaries proportioned to their sacrifice. They gather in the consulate evenings, or sit in the fenced-off boxes at the theatrical performances, which periodically come down from Kiahta.

A few families who have made their sixteen-day camel-trip from Kalgan and Peking have foregathered here with their household goods and gods.

Buttressed by the companionship of books, this other class lives in splendidly-furnished rooms, with pictures purchased in Paris, statuettes from Rome, and grand pianos drawn for days over the passes by laboring oxen. One converses at the consulate in French, the mother tongue of none, but the common tongue of all. The few favored guests, who are invited of necessity over and over, play chess endlessly in the evenings. The ladies read the latest French novels, or sing the songs that distant friends have sent from the Riviera or St. Petersburg.

They drive in imported carriages and sleighs for the afternoon airing, and bemoan Nice and Monte Carlo in winter over the pages of Zola's "Rome." The men subscribe extensively to English, French, German, and Russian periodicals. They invite such relatives as can be persuaded for lengthy stays, and shower a guest with the hospitality of old claret, caviar, and the varied courtesies which the rarity of visitors from the world inspires. They take long adventurous horseback trips in the dull season,--explore forgotten monasteries, study the Tibetan inscriptions, print monographs on the folk-tales, and dream of promotion and Petersburg.

The consulate has one uniquely circumstanced personality, whose career is a romance of Eastern adventure. Born in the Baltic provinces, he studied in the Oriental training-schools, and entered the Russian diplomatic service at Peking. Here he applied himself indefatigably, until he knew the Chinese language as did hardly another European. He could write the ten thousand ideographs, and could speak flawlessly the Mandarin and the popular dialects. He went to Mongolia and mastered its languages also,--its spoken idioms and its written grapevine letters. Then, with his diplomatic entrée, his knowledge of men and tongues, and the initiative of an adventurer, he launched his grand coup in the palace of Peking.

He carried away the sole right to the gold of two _eimucks_, a territory as large as France. Not a Chinaman may pan the metal, not a Slav may open a mine, save through this concessionnaire. A third of all gold washed,--these are his terms to those who would lease from him; just double what he pays the Peking Yamen for his privilege. Fortune upon fortune he is reported to have made, and the Chinese gold-washers and the Russian miners who lease from him have gathered their own stakes, too, despite the Cæsar's tribute which he exacpts of all that they produce.

He has spent large sums in bringing down machinery, to do on a great scale what the shallow veins of ore demanded should be done on a limited scale. An abandoned gold-dredge lies far up the Iro River, transported piecemeal at exorbitant expense over the hills. Traction-engines are here, which could not cope with the Mongol roads. They consumed forty days going one hundred and twenty miles to the largest mine. Now they lie rusting in their sheds. Thousands of ox-carts were engaged for hauling in the various purchases. River steamers and great oil-drills scattered over northern Mongolia are relics of his ambition.

His brick house, finely furnished, and his brick smelter stand hard-by the consulate. The Russians tell of masons imported from Sweden to build them. The life-history is a bizarre record of great things attempted by a man whose overleaping ambition stopped nowhere, and whose expenditures more than once brought him down. But his interesting meteoric career continues, and twenty _pud_ of gold are said still to come down yearly from the mines to the most picturesque character in Russian Urga.

We drive down with one of the officials, to be present at another of the events in Urga's meagre happenings--the arrival of the mail.

The Russian post, one delivery a week, crosses Mongolia. The horses bring in three mails from the Russian frontier. From Urga to Kalgan, the camel-post guarded by Cossacks, traverses the great desert of Gobi. Save the Imperial Chinese telegraph, it is the only regular method of intercourse with the outside world. The two thousand-odd roubles a year paid by Russia as a subsidy are a small

expenditure for the opportunity of accustoming the people to her service, and for controlling the avenues of news and communication.

The post-office is at the consulate, and a new postmaster has just been installed. Thereby hangs a tale which is poured into your ear before your stay in Urga has been much protracted.

A telegram came from Irkutsk to seize and bring to Verhneudinsk as propagandists the postmaster's son and daughter--twenty-one and eighteen. Twenty Cossacks surrounded the house at three in the morning. The two were arrested, taken to the mayor's house, and lodged there. The next day they were started on the trail to Kiahta. Once over the border, there would be no more hope. Quickly the leading men of the colony assembled and telegraphed the Russian ambassador at Peking, knowing that if the ambassador had official cognizance, he could not safely authorize an arrest on Chinese soil by the Cossacks of the Guard. The response was delayed, but there was pressure enough upon the consul to get the prisoners held at the mining-camp beyond Iro until the answer was received. At length the ambassador replied that Chinese suzerainty must be respected. The two were free. But the father had been advised to resign his post and accept a station which was offered him at Kalgan, where there were only three Russians, all warranted proof against propaganda.

Beyond the Russian consulate, six versts, is the Chinese town called, as are many of these trading-posts, Maimachen, or place of trade. One can get there by the solitary Cossack-driven droshky that the Russian colony supports. But more appropriately we go on pony-back, borrowing an army-saddle and a purple fleece-lined _shuba_, whose skirts reach around the knees, and whose long sleeves fold over the hands, keeping a rider reasonably warm in cold weather.

The houses of Mongol Urga are soon left behind, the stockaded lamasery is passed on the left, and we are on a big open plain. A few minutes' gallop takes us past the consulate. Beyond it stands a compound girded by a stockade of saplings, within which are the low mud walls of straggling houses, amid which the gilded eaves of a more pretentious residence lift themselves above the rest.

A troop of pig-tailed horsemen trots past: the white tunics of the riders are covered, back and breast, with red ideograph letters, which stigmatize the bearers as of the lowest caste--soldiers of the Celestial service. The man in front holds aloft a gilded pear-shaped standard, and between the ranks lumbers a covered cart with closed shutters. The cavalcade wheels to the right and turns in, dipping the standard as they pass under the gargoyle-tipped beams of the gateway. Servants come running out of the great house. From the cart is helped down a Manchu of pallid face and short gray mustache. That wooden house, girded by mud huts, is the seat of government for this greatest _eimuck_ in Mongolia. The figure robed in cheap blue cotton is lord of life and death, the _Zinzin_, Viceroy for the Emperor of China.

This Manchu Viceroy, and his _Tu-T'ung_, or lieutenant-governor, who represents Chinese authority in the city of Kalgan, are responsible for the collection of tribute, the administration of justice in the cities, and the maintenance of order. Over the Chinese inhabitants in the Maimachen the rule through the agency of the prefect of police appointed by the Viceroy is direct and absolute.

Over the Mongols, Chinese rule is exercised in an irregular nebulous fashion, with some force in the centres and almost none in the outlying districts, where the old nomad organization of society, with princes, barons, or _tai-tsi_, clergy, and ordinary black men, still persists. A code of Chinese laws exists, but in general justice is dealt out by the local princes, or _guns_, who receive also the cattle-tax in some districts, and who go by turns for a year to Peking in symbol of homage.

[Illustration: CHINESE MANDARIN]

[Illustration: GIGIN, THE LIVING BUDDHA]

These Mongol _guns_, ruling over each of the _hushouns_, or counties, which compose the _eimucks_, are under feudal obligations to the Chinese Emperor. Their visible subjection to China consists of ceremonial visits with tribute, for which the Emperor's return gifts are of far greater value. A total of one hundred and twenty thousand _lens_ of silver ($90,000) goes yearly from the Emperor to the nomad nobility. A khan of the first rank receives two thousand _lens_ ($1500) and twenty-five pieces of silk; lesser gentry in proportion.

This primitive aristocracy lives in barbaric state, with splendid carpets, silver-inlaid furniture, and jeweled accoutrements. The women are sometimes very good-looking. They are laden with ornaments, furs and silks, and have a spot of carmine on each cheek, which is the prerogative of a princess. But the normal imagination does not go beyond the gir as a dwelling. Finely fitted it may be, yet it remains a one-room hut, with the open brazier in its centre. Their wealth is in ancestral ornaments, and in the flocks

and herds of their private domains. Their one relic and memorial of a past sway lies in the custom under which the Chinese rulers call by the old Mongol names the _eimucks_, which were the ancestors' kingdoms. That of which Urga is capital still bears the name of Tu-she-tu.

The Mongol lords are responsible for the feudal army, and a caste of bannermen exists, who are paid nominally two ounces of silver per month and a supply of grain, with the corresponding duty of keeping their bows and arrows in order. In the Tu-she-tu khanate of the eastern Khalka tribes, there are twenty banners, each under an hereditary _yassak_, or tributary prince. In 1900 some banners of the Barukhs turned out to fight Russians, but they made no showing whatever, and hurriedly returned after a skirmish with the Cossacks. Spears and arrows are the only weapons the Mongol army can show.

While this feudal system applies in general to the whole _eimuck_, in Urga the Gigin has a unique position. The city is a great monastery, practically all of the permanent native population of fifteen thousand being priests. The laymen who are there are mostly pilgrims, or dependents upon the Church. Over these the Gigin is master, so that Urga is known as "The Holy Living God's Encampment."

Over the Russians and the Buriat tribesmen, the Chinese have no actual sway, and from them they collect no taxes. The Russian consul is dictator to this little flock; and behind his stockade, where the tricolor waves, rally the Orthodox in times of danger.

Across from the _Zinzin's_ doorway is a spiked stockade. Inside, where they have been thrust through a hole just big enough for a man's body, are the miserable criminals. In the big pit dug with their naked hands, the wretches cower, shelterless, under the terrible cold of winter. They live or die there, sometimes fed by the charity of Mongols, sometimes forgotten, sometimes purchasing miserable fragments of offal with the unstolen remnants of the prison allowance. Few waste sympathy on the inmates. The low level of existence of those outside makes the place perhaps less terrible than it would be to people who had known other conditions. It is a grim Chinese jest, this loathsome prison for those who have stolen bread in the market-place, set opposite the palace of the grafting governor who has filched the tribute of Tu-she-tu.

From the Chinese city now, there begins to come the distant throb of drums and clash of cymbals. Three gorgeous Mongols gallop past in their splendid free-reined horsemanship. A sentry stalks to the door of the stockaded prison, and looks toward the gray walls and temples of Maimachen. The procession of the New Moon is to pass to-day.

You leap onto your little Mongol riding-pony, and spurring him into a gallop, hasten along the way to the Chinese city. He tears down the broad road. The resplendent trotting horsemen take the pace as a challenge, and yell joyfully for a race as their whips come down on their own horses' flanks. Mongol girls walking hand in hand along the highway scatter and call out as the riders clatter by. It is contagious. Soon a score of riders are shouting, shaking bridles, and lashing ponies, and it is a cavalcade of racers that gallops up to the gate of Maimachen.

How different is this Chinese settlement from Mongol Urga! It is a magnified replica of the city at the frontiers. Instead of the straggly avenues a hundred yards broad, with cañon-like alleys flanked by high mud walls, all the streets are so narrow that two strides cross them. They are lined with miniature booths. Through the bars of their paper-paned windows one sees the little delicately-tinted pictures of pagodas and of Chinese girls, in quaint sweeping outlines. Red and black and gold, the New Year placards flame on every post and wall. Lanterns are hung before the gateways; green saplings stand sentinel by the doors; and in the unshuttered compounds innumerable lines of gaudy banners are seen, strung from side to side across the courtyards. From the houses come from time to time a thrumming and a picking of strings in minor music, broken by an occasional clang of cymbals or a drone of beaten drums. You pass a temple of marvelously carved wood, wrought into curves and flowers and arabesques, with eaves turning out into open-mouthed dragons. Everything is brilliant in paint and gilt--a blazing kaleidoscope of color.

In a friendly courtyard the horses are tied, and you walk into the teeming streets. All the Chinese of Maimachen and half the Mongols of Urga have come out to-day. Here is a little shifty-eyed Chinese clerk, in his low shoes, with white soles several inches thick, his white stockings, tied at the ankle, showing below the baggy trousers.

Here is a young Mongol lama, who hails you gleefully with a Russian word which he has learned from a Buriat, and points out where the procession will emerge. A Mongol woman passes, gorgeously dressed in flowered yellow silk, with red, sable-cuffed sleeves so long as nearly to touch the ground, and her head cuirassed with the burden of silver ornaments. She smiles at the burly Mongol camel-driver who so openly admires her.

A Chinese merchant, with red-buttoned cap, attended by a servant, is pushing through the crowd. His looks are surly; perhaps he is thinking of the whereabouts of his own establishment in this carnival.

Though the rich and wifeless Chinese may acquire Mongol companions, they cannot buy or give affection. For a poor Mongol, who has the sincerity and humanness which the Chinaman withholds, one of these Mongol concubines will either deceive her master, or, if he object too vigorously, will strip herself of his presents and go to her lover's _gir_.

A big Celestial with a fuse comes hastily through the gateway from which the procession is to emerge. The crash of his firecrackers startles the Mongol ponies pushed close along the houses. Beneath the multi-colored gateway, next pour out a score of horsemen with pennanted spears. They ride two by two, in white coats with red letters on their breasts. Then comes a crowd of footmen, who fill the street in a torrent. The curious Mongols press to each side, and watch the procession of their alien overlords. Two ranks are robed in vivid red, and carry poles with big gold knobs. Blue-coated Chinamen, with cymbals and shrilling fifes, follow; then come more horsemen; then the great silken umbrella, and a gray-mustached dignitary on horseback,--the chief of police; next, more fifers and wand-carriers, six abreast. With fireworks and clashing music, the vivid ranks in red and blue, and yellow and gold, and green and purple, and every other conceivable combination of hues, make their way around the stockade and back again through the gated city.

The crowd seems to be trending now toward a brilliantly colored archway spanning the main street. With the Mongol holiday-makers we follow along into a cloistered courtyard flanked by peaked temple-like houses. A crowd of Chinese is pressing around some one clad in blue, who has just stepped out between the beater of a tom-tom and an artist with a big pair of cymbals. A preliminary flourish introduces the performer--a pasty-faced young Chinaman. He starts a rhythmic chant whose cadence is within a note or two of one of the old crooning Negro melodies of our South. Over and over again he chants it. A poet this is. He has conned his verses, and now comes out to sing them. He ends with a special swirl in what is evidently a very comic climax. The drum and cymbals crash out once more, and another chanter comes--this one old and feeble, with a curiously penetrating voice. He drones a long hexameter-footed epic, in which the harsh Chinese _gh_ and _wh_ sounds are not so coarsely enunciated as in the poem of the first reciter. "That is one of the old legend-singers," you are told. It is such a ballad as Homer sang, or the Welsh bards chanted. It is the poetry and the history of the long past, the immemorial past, far before the infancy of other nations; for China keeps alive her antiquity, and in her old age never forgets.

[Illustration: CHINESE ARCHWAY, URGA MAIMACHEN]

This week there can be no buying or selling. The Moon must be honored, but visits are in order. Your friend brings you to meet a leading Chinese merchant. At the house, a grille of thick wooden bars runs down to the street level from the eaves just above one's head. Looking through them, one can see over the little square window the most delicately-traced pictures on a white background. The panes are of paper, all save one, which is of glass, so that the owner may see if, coming down the street, any one turns and climbs the three steps into the ordinarily wide-open door of his house.

The home of our host, which is likewise his office, is finely fitted up and faultlessly clean. His light-blue silk robes are immaculate. Two servants wait at table, bringing in the best of China tea and French "petit-beurre" biscuits for our delectation. Everything is appetizing and orderly.

As we are sitting over the cups with the Chinese merchant, the boy comes to announce visitors, and two blue-robed fellow countrymen enter. One has a strip of light-blue silk laid over his two arms, which he stretches out. The host extends his own arms and receives it, then gives it back to the newcomer, who goes down on one knee and again presents it. The merchant takes it a second time and bows, this time retaining it. The two guests bend and leave the room. "New Year's presents," the merchant explains. Again the boy comes in and announces a guest. A Mongol messenger enters, goes down on one knee, and presents a red slip, black-lettered. "Visiting-card," the host explains. Then, with a smile, "White, like yours, not polite." He accepts this too. "_Ch'ou Ta-tzu!_" (the dirty Tatar!) he says as the latter leaves.

The calls continue, and our visit. The host is charming, cultured, educated; he speaks English well, and lacks in no attention. But you wonder if, when you leave, he is not going to murmur about you, "Yong-kwei-tsz!" (foreign devil!)

Throughout all intercourse with these Chinese, one has always the uneasy consciousness that one is doubtless, as with the card, unwittingly offending. There are three hundred rules of ceremony, three thousand formulæ of behavior, regulated by a classic tradition. The ritual is so drilled into the Chinese as to become instinctive. Celestial breeding would dictate that the little formalism

which precedes a rubber, "May I play to hearts, if you please?" be stretched to cover every action of life. The left, not the right, is the place of honor, and to enter a room facing wrongly is a slight. An irregular method of folding a red New-Year's card, and the failure in writing to raise one character above the level of the rest, are breaches of etiquette.

For our race there is always felt, behind the soul-mask of Chinese eyes, a contempt. The kindness of our host to-day is unfailing. Yet we are not at ease or sure of the ground. Errors, condoned to keep face, are often inwardly resented. If you put your hat on the Mongol's altar, everybody in the hut will yell out for you to take it off. When you remove it, they will nod understandingly as the interpreter explains that the ignorant foreigner transgressed inadvertently. Forthwith all is forgotten in an enthusiastic discussion of the last case of botts among the horses. But with these Chinese one can never tell if, by taking a chop-stick between the wrong fingers, one has not intimated that the host's grandfather was a cross-eyed coolie soldier. No one will challenge or set a man right, but the breach will be silently resented, though the tea continues to be smilingly offered.

The old-time Chinese dealers at Urga grew enormously wealthy in the tea-trade to Kiahta. These have mostly gone back to China. But there are still a number of the better-class merchants whose wares are sold to the traders and by them to the Mongols. The house of Liu-Shang-Yuan claims two hundred years of establishment. The Urga people are still prosperous, for great sums in religious tribute come from all Mongolia to this Lourdes of Lamaism. There are also many Chinamen who make large profits from wool.

Of a total trade in Urga estimated at twenty-five million roubles per year, nine tenths is in the hands of Celestials. The remainder is Russian, for the Mongols are entirely without a merchant class. Of the exports, wool is the main item. Some two hundred thousand _puds_ are sent from Urga annually, four fifths of which go to the United States. While cotton cloth, cutlery, kitchen-utensils, and other European goods come down from Russia, the bulk of the imports are brought from China by caravan, through Kalgan. Silks come from Shanghai, and tea from Hankow, passing via Peking. There is trade, too, with Ulasati in western Mongolia. It is the centre of a fur and hide country which is isolated from outlets toward Russia by the high mountains, and must send caravans to Kiahta. Its communication with China is either by Urga and Kalgan, or by the caravan-route further south.

When the holiday-time is over we see more of the Chinese traders. Sitting in the shops, with one of these, and glancing out over the little counter of the sales-room, we converse as the customers come and go.

The Russian in his shop shows all he has of wares, the red and magenta cloths, the enameled kettles, the cutlery and sweetmeats. But the Chinaman wraps his goods in hieroglyphic-covered papers, and all that can be seen are rows of long-stemmed brass-bowled pipes, and an array of silver and bronze teapots on shelves at one side. Very rare things, too, our Chinese host can produce. Shanghai silks of finest texture, ten roubles the _arsheen_; jade mouthpieces for the pipes at a hundred _taels_; Hankow tea culled from the tenderest shoots. Everything is labeled and systematized in the Chinaman's place, and he goes at once to the packet which he wishes to show.

A dozen Chinese, with bright blue silk jackets over their black surtouts, invade now the home of the merchant. The red knot on their black skull-caps and the length of their queues and finger-nails show them to be men of some importance. They take off the bright-colored ear-tabs as they enter. They are down to buy wool. To-day they visit, next week they will trade. Then all but one will sit in the outer shop, while the spokesman alone will go into the inner room and confer with the merchant. From time to time the spokesman will go back to the party and consult, till in the end the bargain is made. They will all hold to the agreement, too, whichever way the market goes. For in this the Chinese are inflexibly honest. A local Chinaman dispatched a mounted messenger the six versts to Urga, to return to us twenty kopecks which he had overcharged by a slip of his abacus-adder.

Yet the Scotch engineers saw shells in the arsenals loaded with clay when the native troops went against the Japanese. The English miners in the Province of Shan-tung have had their profits cut to nothing by the official "squeezes," and Chinese have bought in the depreciated stocks.

The ethic code of the squeeze seems to be very nice. It is a point of honor, almost always scrupulously observed, that the first-fruits of official graft go to repaying the one who advanced the money to buy the office. A Chinaman, who could not be trusted to administer honestly a trust fund of a hundred _taels_, will repay this obligation to his backer. Thus must he keep face.

From the tax-appraiser who numbers the sheep to the civil governor who receives the lumps of silver tribute for transmission to Peking, every official gets his squeeze. They say in the _eimuck_ of Ulasati, where sables are part of the tribute, that the officials take out the best furs and put back poor skins to keep the number the same; and in Urga, that the enormously rich administration

takes a Tammany third of the tribute. There has never been a viceroy yet, it is reported, who has left Mongolia poor. Yet each official plays straight with his backer, his "belly-band." Very curious is this race, and there live few Westerners who can at all understand it.

We ride back in the evening from the Chinese city (for none may stay for the night), buried in recurring reveries. How brightly glitters the face, and how barren is the heart in Maimachen! Never the thousand ties of kinship and affection, never the thrill of citizenship, never the love of a home. How little generosity, too, or sympathy for the people of the land! The Mongols are but "tame barbarians," as of old were stigmatized the tributary Formosans. Now and then one finds a Chinaman out among the nomad Mongols. Perhaps he may be a watcher at a distant temple, perhaps a telegraph-operator on the two lines that go, one to Kalgan and Peking, one to Kiahta and Russia. Always he is something solitary--different. There is an almost sinister splendor in this aloofness--this self-sufficiency of walled cities and compounds where none but Chinese may dwell. What a rebuff of nationhood in the gates that shut out at night all save the alien outlanders! What contempt in the law that no woman of China may come among these Mongol people, as if the very air were contamination! How the natives are silently despised, whose bodies in death go to the dogs, while the Chinaman's, in a casket, is sent back over the long leagues to his home!

The homeless, wifeless, Chinese city, with the quarter of Mongol women without the walls,--it is in many ways typical of all Chinese rule in Mongolia. For, as the Celestial trader defaults in the duty of marrying the Mongol mother of his children, so China defaults in many of the duties that are inherent in suzerainty. One resents the heavy Chinese yoke on the necks of these simple frank-hearted Mongolians. They are a race of great good-humored children, and they are exploited while disdained.

We are thinking of this unfairness as we ride back along the road to Urga. Behind is the distant Chinese city, the Manchu Viceroy's straggling palace, the picketed prison-stockade. Before is the drooping tricolor banner of the Czar, and the white and green of the Greek Church, with its far-seen golden crucifix. A crowd of brilliantly-clad Mongols, lamas and laymen and girls and youths, are strolling back from Maimachen. They are laughing and chattering, and in uncouth playfulness are pushing one another about across the road.

Half a dozen of the _Zinzin's_ Chinese foot-guard are likewise coming from Urga, stolid-faced, superior. As they reach the tumultuous band it sinks into silence, and the men crowd to the side of the road that the Chinese may pass.

[Illustration: THE GREAT WALL]

They tramp by without a glance. Then out from the Russian barrack-gate swings a little Cossack in his great black sheepskin hat, gray tunic, clattering curved sabre, boots and spurs. He is one of the Zabaikalskaia Buriats, whom Russians call Bratskie, the brotherly people. He speaks a tongue so similar to the Mongol that all these people can understand him. They look up to him as a rich relative, fortunate in overflowing measure. For on the pilgrimages of Buddhist Buriats to Urga, their wives have told the wondering Mongol women of the sewing-machines which they have at home to stitch linings, and have allowed the visitors to peep into their mirrors. The Mongol men have admired the Buriats' breech-loading rifle, worth six horses at current quotations. They have enviously heard tell that in Russia one pays no cow-_alba_, but the young men get a uniform and free food when they ride out to give their Cossack service to the Czar. They have listened to Buriat boasts of the warm houses of Siberia, and stacks of hay, and stored-up harvests. So Mongols smile when the Buriats come to their _girs_. They say, "Rich smooth Buriats! Great lords! Give candle, give sugar, give tobacco, give vodka."

Has not a little Zabaikalskaia Buriat reason to swagger when he starts from the Russian barrack-gate to see his lady in Urga? And should a Cossack of the Czar step aside for a Chinaman in the shadow of the Eagles? Head erect, with a look to right and then to left, hand on sabre, he swings straight down the centre of the road, and right through the Chinese soldiers. Without dispute they open a way. He chucks a not unwilling girl under the chin as he passes the Mongols, and he is good-naturedly hailed by the rest: "Hello, Cossack! Why so fast? She has gone away with a lama." And he goes a bit faster toward Urga.

These Cossacks, terrible in war, friends and equals with the conquered in peace, are those who have held the Russian vanguard in this march to China,--the march which began when the two _hatamans_ of Moscow, commanded by Ivan the Terrible, started in 1507 on their long tramp eastward. The Cossacks it was whom Yermak led to the conquest of Sibir. Through them, in storm and stress, despite oppression and convict-gangs, with faults and failings, omissions and commissions, the advance of Russia has been the way of civilization where none could otherwise have come.

"It will mean much when a Russian railway follows our trail from Kiahta," says Alexsimevich; and André adds: "They will all be glad when the Cossacks come to Kalgan."

VII

RUSSIA IN EVOLUTION

New times have come to Russia with the events that have halted her armies. The Slav, looking and reaching outward, has been hurled violently back upon himself, and he turns to look inward. The stream of Slavic civilization still flows eastward. But now held back at the frontiers, its tide is rising behind the impounding barriers and is lifting on its wave the level of national life. Its scour is undermining here and there, its laden currents are depositing and filling in the interstices of the social fabric. The struggle is intensified to achieve representative government, to secure administrative reform, to relieve the distress of the peasantry. The people are in evolutionary throes and are sweeping forward in the arts of peace, in the science of government, and in the myriad lines of internal development.

The movements of empire-advance have been noted because they have been conspicuously visualized. But the economic and social growth have been only slightly regarded by our western world, intent upon great events, crises, conflicts lost and won. The seizure of a hamlet in Manchuria has obscured the founding of twenty cities in Siberia.

The continent-cleaving Siberian Railway has now revealed, in the Russian occupation of northern Asia, not an exploiting colonial enterprise, but a race-movement akin to the European invasion of our Aryan ancestors. The upward struggle of a people striving to find itself is embodied in imperial rescripts and armed revolts, in dumas and dynamite, where rival titans grapple for the throw. There is now therefore in the world a more earnest watching of this metamorphosing Russian people. What are the types of civilization, the beliefs, the manners of thought, the institutions that are to hold mastery over the largest area on the globe occupied by a single nation?

To comprehend a people and the course of its evolution one must pierce below the surface of ephemeral and contemporary incident, and probe the primitive racial elements. Russia is to-day iceberg-like. The crumbling, upper ice, honeycombed by eating waves, is exposed; but submerged and unseen is the massive blue block beneath. Because rotten surface-structures are obvious, many fail to appreciate what lies in the depths. There comes understanding for much when one sounds the ancient sources in race-history.

From the earliest times Russia lay across the path of incessant invasion from Asia. In 1224 the Mongols swept down upon the old Scythian plains. There were no mountain fastnesses in which the sparse population could defend itself. The followers of Genghis Khan, through the years that followed, destroyed town after town,--Bolgari, Suzdal, Yaroslavl, Tver,--devastated Volkynia, and Galicia, until all Russia, save Novgorod, was brought under Tatar rule. Their devastations cut off the population of whole provinces, and changed old Russian cities, such as Kiev, to hybrid towns of Asiatics. At Sarai on the Volga, for two centuries Tatar sovereigns ruled; and here from being pagan they became adherents of Islam. Russia's foreign master was confirmed in a religion as antagonistic as was his race. To these aliens Russia gave humiliating homage and paid tribute, and from their khans her czar received permit to rule. Thus in her infancy she had a foreign race, not as servile members of the humble labor class, but in the wild, fierce scourge of conquerors.

Throughout this period many Russian princes married into noble Mongol families, and Mongol officers formed alliances with the Russian boyars. The Muscovite aristocracy had already grown into strong Oriental proclivities from contact with its southern neighbor, the Byzantine, and these became confirmed under the Tatar. One czar, at least, Boris Godunov, was of Mongol birth. Incessant war harassed the people. Alexander Nevski, of Novgorod, beat back the Swedes; but, abasing himself, he went to the Tatar khan with the tribute of a country too feeble still to resist him. By and by Russia began to rally and to strengthen her centres, Novgorod, Kiev, and Vladimir. Moscow arose--that small destiny-city where Simon the Proud, even in vassalage, dared to dream of unity and nationality, and took the title of "Prince of all the Russias." His grandson made the first great stand against the Mongols and won in the field of Tula, which, with the fights of Alexander Nevski, gives to chroniclers and bards their early Russian ballads, or _bilinî_. Moscow, punished cruelly, was razed almost to the ground. But the Bear was aroused and goaded into desperation. Russia reeled to her feet, and for nearly a hundred years she fought, she lost, she fell; but she rose again and fought on, until at last the power of the Tatar terror was broken and the tyrant was driven over her border. Still, for a hundred years more, she was forcing back his inroads, and rescuing the winding trains of her children, toiling over the southern steppes to be sold as slaves at

Kaffa. This was Russia in the last quarter of the sixteenth century.

That Europe was spared this, she owes to the Russian. Through those crucial centuries when the Slav, weak, torn, anguished, beset with foes around and foes within, was standing grimly at the perilous portal of civilization, Europe, within the temple, safe by his grace, was privileged to work up into light, to cement her nationalities, to effect the liberation of her masses, and to develop her intellect into the magnificent promise of a printing-press, a people's Bible, and a Shakespeare.

But to the brave warden of that portal there was not the sweetness and the light. For him were the seams and the scars, the mutinous passions of the strife. Long after the clouds of the Dark Ages had cleared from the face of western Europe, they hung over Russia. The Slav was back in his Dark Ages yet, heir only to a barbaric experience. Here he must start, where Europe had started nearly a thousand years before, where America, in the favor of Providence, was never to be called upon to start. For him were the memories of subjection and the blood of contention; but also, in relief, to him were the stolid patience and endurance which were to serve him so well. He groped along in the shadow until the coming of the great Peter.

But now arose a man. He, too, had dreamed the dream of empire,--vast, masterful. He set about making his dream real. He found Russia a small inland state, torn by faction, barbarian, and Oriental. Though himself the descendant of a long line of Byzantine kings, half monk, half emperor, he saw with the insight of genius, and he knew that that way did not lie greatness. Therefore fully and fiercely he broke with the past and set himself to the future.

Between him and that future stood the Strelitz. The walls of the Kremlin, and the Red Square told the doom of their barring conservatism. He warred with the Turk, he fought the Cossack, he routed the Swedes, again and again, taking whole provinces on his Baltic outlet and securing the coveted Neva. He embroiled himself with Persia, and through Baku opened a way to the Caspian. Then, with a high hand, he swept out the customs that made for Orientalism. He broke the seclusion of women, the prostrations, banished the caftan, the beard, and the flowing robes. He lifted his people bodily and violently out of their past, and set them down face-front to a new order. The Russia he had received a province, he left an empire. The Russia he had received Asiatic, he left European, and already a force in Europe. And when arose one of his own blood--a reversal--who would undo the herculean labor of this master-builder, who would give back to Sweden those priceless, wave-washed Baltic provinces, and, restoring the capital to Moscow, return to an Oriental estate, the patriot was stronger than the father, and at the price of his son's life he bought the progress of Russia. Here in this man, who died in 1725, we can truly say that Modern Russia begins.

Through this skeleton history can be traced the structure of the modern state, as in the struggle for survival may be found the root and early warrant of her governmental system. Every element, physical and ethnic, was, and still is, a handicap. Russia is not protected by the ramparts of the sea; she is surrounded on all sides by nations with whom her history has been that of perennial conflict. In place of a compacted, well-peopled country, she has an empire extended gradually from frozen Nova Zembla to Afghanistan, from the Danube mouth to Behring's arctic sea. She is a land of many distinct peoples, as foreign to each other as Lithuanians and wild Kirghis; as alien in religion as Catholic and Mohammedan. She is divided into one knows not how many tribes, numbers of them completely barbarous. Her eastern and south-eastern frontiers call for defense across vast and vacant stretches. Her northern and western borders are occupied by Finns and Poles, unforgetful forever of their own days of sovereignty, naturally and rightly jealous for the memories and the prerogatives that are its legacy.

With the eastern problem living from the first on her immediate border, with her many tribes wayward, Russia early strove to fuse her empire into national unity. In old Poland had been seen the fearful price which feebleness and disunion pay to fate. How much greater was the menace to polyglot Russia, were her master-grip to relax! That she should hold a strong hand over the elements that ever threatened her disruption was the first national necessity. This supreme obligation to herself in her entirety compelled a firm, commanding, centralized authority. The mould that was to shape such metal had need of rigidity and unyielding strength. To meet these race-desires, not as a purposeless tyranny but as the fruit of a long evolving system, arose the autocracy.

The system reached its climax in the most absolute administration of modern times at the period of the American Revolution; the "Government Statute of 1775" meshed all things and all men into the institutions of despotism; Russia groaned under the iron rule of a Nicholas, yet rejoiced in the belief that strength was there, and sure defense from domestic disunion and foreign aggression; then, in the Crimea, came a revelation of the inefficiency of the bureaucratic juggernaut. Despite the stubborn valor of the defenders of Sevastopol, despite the gallant efforts of the aged autocrat, the glory of Russia went down in the blaze of her city and her fleet.

The old régime had failed. Even the Czar, before he died, could read the lesson but could not act. How pathetic the words of the failing monarch: "My successor may do what he will, I cannot change."

With the accession of Alexander to the throne in 1855, on the sudden death of Nicholas, came the first effective steps toward modern institutions. The young czar, a self-declared friend of progress, raised regally the standard of reform. All Russia rose to the hopes of his idealism. Corruption in office, which had before been rampant, was crushed out by the sheer force of public opinion. Pamphlets circulated freely, uncensored. Meetings were everywhere held to discuss the varied plans of a vivified government. With a whole nation become to a degree transcendental, the Czar began his reign and his reforms.

First of all for righting, as it was first in evil, came serfdom. Summoning commissions of his ablest advisers, seeking counsel of the proprietors and their coöperation in an act of self-abnegation, the Czar proceeded to the execution of his great task. For three years every side and every phase of the problem was studied. Then at length with a fundamental law which forecovered every detail of the situation, Alexander II put his signature, February 19, 1861, to the great Ukase of Liberation.

In Russia's past there is much to answer for before the judgment-bar, in omission and in commission. Yet, giving but justice to ruler and people, it must be allowed that the measure which freed the serfs ranks, with Magna Charta and the American Constitution, among the mightiest agencies of advance that mankind has ever known. A dependent population of nearly forty-six million souls was given liberty. The great act was accomplished peacefully, and the measures were executed without any trouble worthy of the name, in a spirit equitable to the old owners as well as to the serfs. Not alone were the latter released from bondage, they were provided, one and all, with land and livelihood. They were given, in everything that concerned their local administration, entire freedom from interference by their old masters or by the members of the Administration. The righteous deed that the American Republic achieved nearly three years later liberated but one ninth the number of the Russian bondmen. It did so at the cost of the deadliest fratricidal war of modern times, and the impoverishment of one quarter of its people. All the work of the Freedmen's Bureau through the Reconstruction period could not insure to a tithe of the Negroes the opportunity for a livelihood,--this that Russia provided inalienably for each of her liberated. To this day the American Negro in many places is under special civic disabilities more galling than those imposed anywhere in the Russian Empire.

The protection of the former serfs was skillfully arranged by grouping them in self-governing village communes, to which land enough was given on a long-term repayment basis. In each, by an assembly composed of all the heads of households, periodic allotments of the common territory were made to the individuals. Compact economic units, whose property could not be sold, were built up against alienation of the land or poverty-induced peonage. The rendering of justice in local disputes was delegated to the peasant courts,--the only tribunals in Russia, save the National Senate, from which there is no appeal.

The Mir, complete within itself, was responsible to the Imperial Government for good order and the taxes, and was secure from molestation provided these duties were fulfilled. Its inhabitants, united and independent, were able to resist any encroachment by their former masters or by neighboring landlords.

[Illustration: THE KREMLIN, MOSCOW]

It is not unworthy of note that up to the present time the liberties in economic matters thus granted have rarely been infringed by the authorities, nor have the village assemblies been exploited as a play in politics or to attain personal ends. While agriculturally and industrially the communal land provisions have become insufficient, cramping, perhaps baneful, and no longer necessary now that society is in equilibrium, nevertheless the germ of free institutions fecundated in the Mir, when dissociated from its communal features, is admirable still, and is capable of becoming the foundation for real self-government.

Plans for provincial assemblies as a further extension of local home rule had been under consideration since 1859. On January 1, 1864, an Imperial Ukase was promulgated instituting Semstvos in thirty-three governments. To this assembly, proprietor and peasant, rich and poor, elected their representatives. Each Semstvo was to appoint its own executive to carry out the laws it decreed.

The jurisdiction of this assembly, though confined to local and non-political matters, was wide. Rates, streets, convocations, posts, sanitary measures, famine-relief, fire-insurance, schools, agricultural improvement, all land, house, and factory taxes (those upon imperial as well as those upon private domains), were given into the Semstvo control. It was granted partial powers over various other minor matters. It exercised practically all the economic and social functions of local governmental activity save what fell to the Mirs. It was welcomed as an epoch-making institution. The liberal press of the period hailed it as a living guidon of the upward way,

as the blessed daylight of a constitutional government.

So indeed it might have become. In the new Emperor's mind there germinated a whole peaceful revolution. He had plans for new courts of justice, reorganization of the army, reform of the civil administration, and popular representative government, with an elected national chamber.

But in the midst of his reforms broke out the Polish insurrection. The Czar had granted to the Poles elective councils in each district of government and in the chief cities; he had appointed a Pole his Minister of Public Instruction, and had made many concessions to their old language. Iron and blood crushed out the insurrection, but it had brought to the great Czar Liberator the conviction that liberty spelled disunion for Russia, and this belief was never to be dispelled.

Upon the Semstvo assemblies, no longer uplifted by the old generous enthusiasm of the sovereign, pressed little by little the dead weight of executive officialdom. One by one their functions were lopped away. More and more the selection of delegates was transferred to the administrative officials. The marshals of noblesse became chairmen, the governors vetoing overlords. Before the death of Alexander II, his once-cherished creations had lapsed from independent state legislatures into anomalous, semi-advisory councils, discussing roads, land-taxes, agriculture, and schools, and controlled by the land-owning nobles and the governors. Semstvo and Mir and Assemblies of the Noblesse became ornamental trimmings to the colossal edifice of the bureaucracy.

The assembling of all the functions of government into the hands of the executive became again the guiding principle of this system. "The Council of State," whose office was that of discussing the budget and law-making proposals, was the simulacrum of a parliament. The Senate, which gave decision on special points appealed from the lower courts, and whose promulgation of all enactments was the hall-mark of their legality, was a form of supreme court. But both hung from above rather than rested on a substructure. They were substantially cut off from popular influences, their function was secondary action following origin in the executive bureaus. The Imperial Autocrat, deriving his right from Divinity alone, exercised, in addition to his executive functions and his duties as supreme commander of the armed forces of the State, those powers which by a segregation of functions would have fallen to the legislative bodies and the judiciary. In this, the ten ministries were his main agencies.

Under this system, legislation was inaugurated through the presentation of a project to the Czar by one of his ministers, or by outside petition, or perhaps by the imperial wish.

The proposed enactment, if the Czar ordered it to be further examined, was referred usually to an Imperial Commission of Study. Debates followed in the Advisory Council of State, and the completed bill, as framed by this body, was signed by the Emperor and became a ukase, to be formally promulgated by the Senate and enrolled as part of the law of the land. Interpretations of law were made by the Ministers, which none might gainsay. Thus was the legislative function absolute.

In the provinces the three functions of government were equally centralized. A governor (almost invariably a general or an admiral) through his subordinate executive officers duplicated in microcosm the system of the capital. The dependent Semstvo was his Council of State, the dependent judges composed his Senate, the dependent Semski Natschalniki, his executive ministers. Into his bureaus came the details of provincial government save such matters as the villagers settled in their own Mirs. The troops of the district were at his call, the gendarmerie under his orders carried out the judicial arrests and the drumhead condemnations that sent so many thousands along the road to Siberia.

In the placing of these proconsuls and their sustaining soldiery was applied the Roman rule, "Divide et impera." The head officials of the provinces were from distant parts,--the Governor of Warsaw from Tiflis, the Governor of Odessa from Samara, the Governor of the Amur from the Baltic. The Orthodox Cossacks of the Don were in force among the troubled Poles and Jews of the western governments; the drafts from the peasantry of Little Russia garrisoned Tiflis and Turkestan, and Siberian regiments watched the Austrian frontier. Even the popes sent to petty village congregations were generally of far-off origin.

Though power was thus alienated from the people, the bureaucracy, by other agencies rooted deep in human nature, had twined itself around the daily life of society.

Every ambitious man in his profession, as he succeeded, was marked for promotion. Not only to office-holders and soldiers, but to everybody, throughout the whole social fabric, were "chins" or graded ranks given. Here for example is a selection from one of the lists of the Czar's Christmas announcements:--

Appointed members of the Council of State: Privy Councilor Kabylinski, and Von Kaufman, Senator, Minister of Public Instruction, President of the Supreme Court.

Decorated with the St. Stanislaus Order, First Class: Major-General Hippolyt Grigerasch, Director of the Department of Physics and Electro-technology at the Nicholas Engineer Academy and School.

Decorated with the St. Vladimir Order of the Third Class: Major-General Michael Hahnenfeldt, on the staff of his Imperial Highness the Supreme Commander of Guards in the St. Petersburg Military District.

Valentin Magorski, Doctor of Veterinary Medicine, Chief of the Veterinary Staff.

Alexander Pomeranzev, Professor of Architecture.

Dimitri Sassiyadke, Governor of Radom.

Michael Mardarjev, Censor of Foreign Papers and Journals.

Advanced to the ranking Chin of actual State Councilor, hereditary "honorable citizen" Constantine Popov, founder and director of the Tea Emporiums.

Raised into hereditary "honorable citizenship" of the 3d gild, the Archangel merchant Emil Brautigam.

Given personal "honorable citizenship," Vladimir Ritimoun, Proprietor of the Wollner Typographical Establishment; Karl Volter, Captain of the steamer _Emperor Nicholas II_, of the Riga Navigation Co.

When a professor from his books was called up before the highest provincial dignitary to have pinned on his lapel for honorable service to the Empire the Order of St. Stanislaus, it was hard for him not to have a warm sentiment for those who had so signally recognized his talents. When on the document which recorded the promotion of a royal prince to a colonelcy was enrolled the name of a tradesman; when a neighboring doctor was raised his step in civil rank, each felt the touchstone. All who had served well in their respective positions might hope to be on the honor list, and this was the most effective tribute to the weakness, the worth, and the ambition of human nature.

In Russia, as in France under Napoleon's iron yoke, there was a welcome to every sort of ability, and its elevation to posts of the highest trust. The aristocracy sought for was one of power, not that of a small birth-caste. A fundamental democracy ran through society. Save for a few of the Guards regiments, the army was officered by poor men. The Cossacks' officers were chosen from among their own people and were state-trained. In the knapsack of every soldier was Skobelov's baton; in the desk of every chinovnik, Witte's portfolio.

So stood the bureaucratic edifice, complete in itself. Here and there a popular embellishment was added, perhaps to strengthen, often to conceal; but in grim reality it formed no part of the structure. Thus the Russian Empire finished out the nineteenth century. With the twentieth the system had come to trial for its stewardship.

In the great reckoning are elements both of good and of evil. The liberation of the serfs and all that went with the emancipation stand as a credit. It is a further vast credit that Russia has made, held together, and civilized an empire of over eight and a half million square miles, with a population of over one hundred and forty million souls; that to the internal development of her splendid resources the Government has vigorously set its hand, seeking for her rivers unhampered navigation, for her canals larger passage, for her deserts great irrigation works. Already the Siberian Railway links the Baltic and Pacific; already on the southeast the tracks creep to the threshold of Kashmir, where some four hundred miles separate the Russian lines from those of British India. This gap once crossed, Calcutta becomes but eleven days distant from London. It is still another credit that, despite Slavic limitations and financial loss, in the face of Western invention and competitive leveling, the country of the cheapest telegraph and the cheapest railway rate was until recently not America but Russia. It is a credit that the public land has been put so efficiently and generously at the disposal of the people, that any emigrant expressing a genuine purpose of settling will be given, wherever he may select it in Siberia, a liberal homestead, and he will be conveyed to it over the Trans-Siberian Railway for a sum less than the cost. He is not only allotted his homestead, but he is supplied with seed, grain, tools, and advances for his first years of marketing.

It is again a credit that the governmental attitude to the industrial classes has not been one of oppression. True, work-hours are unrighteously long and certain strikes have been put down arbitrarily. Still the Russian labor laws and arrangements for the settlement of labor difficulties are in many features conspicuously statesmanlike and just. Some years since, a body of Belgian

miners, fifty or more, with their families, were transferred from the collieries of the Meuse to the Donetz Basin. Recently these miners, at a meeting of the directors' board, presented a memorial to this purport: "How happy are we who are no more in Belgium, but who live and work in Russia! No longer must we support the socialistic committee. On the day of pay we put our hands in our pockets and have it for our wives and children."

The other side of the ledger is, however, not without weighty items. While no system of government can legislate prosperity, the public welfare is rightfully the first test, as it should be the first consideration, of an administration. Despite her immense territories, her vast mineral deposits, her fertile soils, her navigable rivers, her abundant timber, all the natural sources of national wealth, Russia is very poor. The peasants have more than doubled in number since the allotment of communal fields that followed the emancipation, and they are in general want. Vast stretches, whole provinces, are subject to periodic famine. Millions of the people are constantly on the brink of starvation. Manufacturing is, as a rule, desultory, undeveloped, and, in general, unprofitable.

The per-capita wealth of Russia is estimated at but two hundred and seventy-five dollars, as compared to Germany's seven hundred dollars, France's eleven hundred and twenty dollars, and England's twelve hundred and thirty-five dollars. The savings-bank deposits reported for all Russia average but $2.75 per man, while in France they average $20.82, in England $15.00, and in Austria $15.68.

The degree of administrative responsibility for this condition is of course not to be definitely laid down. Much manifestly is due to natural conditions, national character, and historic handicaps; and some of the resultants would be the same under any administrative policy. Russia in her great area has had a sparse population. She has not, like her sister nations, and preëminently America, been able to lay the rest of the world under teeming contribution to her citizenship. She has had only her natural increase, and no such record as that of the United States has been possible. The Slav is not commercial, but agricultural. He has remained poor, and has had relatively very small resources to devote to what have proved our two greatest developing forces--internal improvement and education.

It is, however, a matter directly involved in government that, with this low standard of national living, there is the correlated fact of extremely high national expenditure. An immense budget of two billion roubles, ordinary expenditure, is annually met, which the war-loans raised to a total, for some years, of over three billions.

[Illustration: DRAGOON CONSTABLE RUSSIAN TYPES]

It is the general belief that a large part of the public funds is frittered away in needless waste, with multitudes of idling clerks and sinecure officials. Granting the benefit of doubt, assuming that the Administration's corruption and inefficiency are exaggerated, and supposing that the public money is in the main honestly and productively spent, it is still a very serious question if any public service rendered by the agents of Government can correspond to or justify the immense burden of taxation heaped upon a people whose economic distress is so terrible.

The weight of the tax-levy crushing the peasants, whose improvident habits aggravate their want, is, for most, unescapable unless they follow the emigrant's road to Siberia. The rate-gatherer can take anything the mujik has, save his last coat, his last horse, his seed-grain for next year. He is, with fateful frequency, forced to hire himself out to whoever will use his services, and this during the brief summer season which is so supremely essential if he is to attend to his own crops and fields. One landowner relates that he has seen paid an average of five roubles ($2.50) a month for farm-laborers, including men, women, and children, during June, July, and August.

Under the old system the method of rate-levy on the "souls" in a family weighed inequitably. Census revision was delayed in one instance, personally related, by over twenty-three years. A family taxed, twenty-three years before, on a father, four brothers, and two adult sons,--seven souls,--was still assessed for seven males, whether the family had increased to twenty, or been reduced to one. Each member of the household was responsible for the total.

It is related that whole families in Samara, reduced by the fearful cholera epidemic of some years back from scores of men to a dozen or ten, had to leave their home-country for Siberia to escape the load of their dead brothers.

Discussing the economic loss of the years of military service, one of the country nobles related an incident. He told of ordering the dead leaves and branches cleared out of his lake. Ordinarily, he said, he did not go near the work or let the peasants come near his château, for there was a good deal of class-hostility where he lives. But he was interested in the lake because the branches were killing some specially cherished fish, so he went down through the woods and was surprised to see nobody working. All the men

were crowded round a peasant whom he had cited as an example of those who, though unlettered, had great capacity. This man had served seven years in the navy and could neither read nor write, a commentary upon what the service training was. He was declaiming on politics, and the squire stepped behind a tree, for the peasant spoke musically and well. The man was telling about his naval service: "Seven years on the boats I have been, brothers, and every three months I got ninety kopecks to buy a string for the crucifix and to cut my hair. I had no money for tobacco, none to send home to my wife in all this time, and I came home without a kopeck. Seven years of my life I have given to the Czar. What has he given me? What has he given you?" The landowner stepped from behind the tree and faced the group of startled peasants. "You have heard, your honor? Well it is true, it is true!"

The measure which under existing land-conditions would most directly raise the standard of life is the improvement of the mediæval agricultural system, and this depends upon the intelligence of the people at large. Scientific farming needs technical knowledge, yet of the great sums collected, a very small portion goes to education. The Nation spends for it but forty-three million roubles, the Semstvos but twenty million roubles, or together one eighth of the military budget.

A tedious, inefficient course in Slavonic, with the prayer-books as text, a smattering of modern Russian, sometimes mathematics as far as multiplication and division,--this is the state education of the privileged few of the peasants' children. Whatever small amount of real knowledge is gained is quickly submerged in the ocean of ignorance at home. The percentage of illiteracy is very great. The record gives Switzerland five, Germany seven, Great Britain ten, France fifteen, Russia eighty-four.

It is argued that for the bulk of the population, under existing material conditions, schools are of small use. The lack, in the general poverty, of the very primary materials,--paper, pencils, books; of proper shoes and clothes; the unsuitableness of the houses of the peasants as places for the children to prepare their lessons in, with no spot to put their books or to do their tasks and with no available light--all these things strike at the very root of education. The population must be raised economically to the point where the elementals of existence are assured, before the incidental costs of schools can be met by the peasantry. However, there has been coming to Russia during the last generation, in a great wave, the kind of education that made the American West--the education of expansion, of the founding of towns, the planting of new industries, the building of new railroads, the opening of better navigation-routes, the enlistment of foreign capital; all the intelligence and enlightenment that attends a real industrial, commercial, and material quickening.

Beyond these social and economic factors a large count is set against the bureaucratic system for the conduct of administration. The suppression of personal liberty, of freedom of speech, the abuse of power by arbitrary officials, remorseless repression, ruthlessly carried out, racial oppression, frightful cruelty in the prisons and exile stations;--it is a terrible indictment that has been drawn. The close of the Japanese War opened a new "Smutnoe Vremya," or time of trouble. Industrial wars, riots in Baku, uprisings in the Caucasus, seizure of cities by Social Democrats,--so went the disturbances throughout Russia, the white terror above grappling with the red terror beneath.

The situation which the forces of order were required to meet was extraordinary. The balance-wheel of the human mind, and all sense of proportion among classes of the people, seemed at times to be lost. Barbaric as the administration condemnations undoubtedly were, the individuals were not infrequently innocent only by curious standards. In a broad view one must confess that on both sides were rights and wrongs. The system, far more than individuals, was at fault. But while a system so linked to violence and oppression could not longer be suffered, the way out could not come through yielding to men in insurrection.

Salvation lay along the path that the Emperor opened. His rescript of October 17, 1905, proclaimed a National Duma.

The pregnant clauses in the summons to a national legislature were these:--

We direct the Government to carry out our inflexible will in the following manner:--

1. To grant the population the immutable foundation of civic liberty based on real inviolability of the person and freedom of conscience, speech, union, and association.

2. To call to participation in the Duma those classes of the population now completely deprived of electoral rights.

3. To establish it as an immutable rule that no law can come into force without the approval of the State Duma.

The ebullition of sentiment that followed these decrees was extraordinary. All the bitterness and discontent that had weltered through the years of distress were metamorphosed into a glowing hope. Ambition and aspiration became a fervor. The delirium went electrically through all classes during the few following weeks of uncensored press and unfettered meetings. The educated

were fed with every sort of essay upon what would be the result of the new order, and exhortation to keep spread the young wings for national ascension. Among the unlettered peasants, pictures circulated showing glorified cartoons of the risen Russia. One of the most widely distributed of these celebrated the Imperial Svoboda Manifesto. The genius of the Slav stood forth: one hand rested on a tablet marked "Zakon" (Law), the other unfurled a banner inscribed in blazing red letters, "Svoboda" (Liberty), below which followed freedom of speech, of forming associations, of holding meetings, of religion, the inviolability of the home, and amnesty for political prisoners. Peasants and workmen were grouped around, and above them stood an heroic figure representing the Duma which was to halo all national activity with law. The rising sun, illumining the Tauride Palace, cast its glow and glamour over the prophecy.

The ukase had gone forth to give the widest representation at the polls. The command was followed out in a system by which every class had its own deputies in the nominating colleges that elected the Duma members. Among the peasantry each _volost_ had two deputies; every thousand industrials had one, the nobility, the salaried clerks, the bourgeois in the cities, the Cossack stanitzas, the boards of trade, the universities, the Holy Synod, the aboriginal Buriat tribesmen,--each had special representation. Uninterfered with for the most part by officialdom, all Russia crowded to the polls, every man believing that his ideal was now, at last, on the eve of realization. The peasants who called for land, the workmen who wished for higher wages, the Intellectuals with their slogan of universal education, the submerged races with dreams of reborn nationalities, the ambitious with visions of power, the venal with hopes of plunder, each and all thought their hopes were to spring at once into the actual and the visual.

In such a fever-time the men to whom official service meant the slow toilsome improvement of conditions by self-sacrificing devotion to the routine of administration, who could offer as pre-nomination pledges only earnest study and conscientious action on the legal matters presented, were passed by in the hot aspiring canvass for delegates. Those who believed all things and promised all things, whose fervency of expectation fed the universal hope, whose preaching held that, the way once cleared, Russia could at a bound reach the plane to which other countries had so long and toilsomely struggled, those of fiery faith which would consume every obstacle--these were the men whom the people ratified and whom the nation sent to St. Petersburg for the first Duma.

It was a band of hot heads and eager hearts that assembled, echoing their constituents' desires, crying for all things and at once. They were saturated with the history of the French Revolution, they felt confident that their coming meant the end of the old régime, and belief in their own power was the pledge of the future. Their first official act threw down the gauntlet to autocracy. In the reply to the Crown, passed during their first day's session, the final paragraphs read:--

The most numerous part of the population, the hard-working peasants, impatiently await the satisfaction of their acute want of land; and the first Russian State Duma would be recreant in its duty were it to fail to establish a law to meet this primary want by resorting to the use of lands belonging to the State, the Crown, the Royal family, all monastic and state lands, also private landed property, on the principles of eminent domain.

The spiritual union of Russia's different nationalities is possible only by meeting the needs of each one of them, and by preserving and developing their national characteristics. The Duma will try to satisfy these wants.

Sirs, the Duma expects of you full political amnesty, as the first pledge of mutual understanding and mutual agreement between the Czar and his people.

It was apparent that if these clauses did not contemplate the confiscation of private property, which was openly advocated by the peasant deputies, and the substitution of a "spiritual union" of Russia's subsidiary peoples for the real hegemony, there was fair _prima-facie_ evidence for thinking that they did. While a general amnesty would render less than justice to a large number of citizens, it would cover as well the bomb-shell anarchists, whose imprisonment was as necessary to the protection of society as that of any other dangerous criminals. The tenor of these demands, the speeches of the deputies, and the avowed desires of their majority, brought matters to a crisis. Not alone the autocracy, but national unity, and the jurisdiction of the courts, were called openly and violently into question. When such a challenge is offered a government, it must answer or abdicate.

Unostentatiously, the Imperial Administration poured troops into St. Petersburg from Kronstadt and the northern garrisons. The governors at Moscow, Odessa, Warsaw, and the big industrial centres were notified to concentrate their loyal regiments. The whole country was mapped out like a checker-board. It was now only a question of when the authorities would act.

On the night of July 8, the troops in St. Petersburg were called to arms. They marched with machine-like precision to appointed stations throughout the city. With the dawn every strategic point was held by the soldiery, and a battalion ringed about the deserted

Duma hall. In the silence was read the imperial rescript. The first Duma had ceased to exist.

The dissolution of this national parliament had come as a stroke of lightning. The venerable representative Petrunkevitch told how he was awakened at five in the morning with the news that the city was under martial law and that soldiers with fixed bayonets were at the Duma doors. Hurried consultations were held with groups of colleagues, and finally the word was passed to meet at Viborg in Finland. At the little inn there, the pressing crowd of one hundred and sixty-nine fugitive deputies signed their manifesto. It called for the cessation of tax-payments, the refusal of conscription, and reclaimed the freedom of Russia. But the insurrection, the uprising in their support! Not a regiment came to assist them, not a city rallied to their call, not a Mir responded. For a few weeks the signers were free. Then the police took them, one by one.

Dully unprotesting, the public received the news of the dissolution of the Duma and the arrest of the deputies. The majority of Russians did not want disunion, did not want the overthrow of vested rights. Each wanted some specialty of his own. Yet here was the resultant of each constituency's crystallized desires. The people had accepted the leadership of those who had held out great hopes, impotently. The Government had crushed the men whose power meant social and economic, as well as administrative, revolution. In the blow it had perforce shattered the dreams as well.

[Illustration: THE TVERSKAIA GATE LOUBIANSKAIA PLACE STREET SCENES IN MOSCOW]

Humiliated by the contemptuous condemnation of their chosen representatives, bitterly disillusioned, the people at large stolidly acquiesced in the extinction.

The voting for the second Duma, which followed some months later, was almost perfunctory. Those who had chronically wished to agitate, and those put forward by the Administration in an effort to pack the membership, composed the bulk of the deputies. Moderates, hopeful of progress with order, stayed at home, disgusted with both sides. The result was a second violent, wrangling Duma, offending like the first, and in its turn ignominiously snuffed out.

The year 1907 saw universal disappointment, cynicism, and skepticism. In the literature, the lassitude of the nation was shown, and morbid despair reflected the thwarted hopes, the agonies, the confusion of the people. The bitterness in the _Lazarus_ of Andreyev, the decadence in the _Sanin_ of Artzybashev, mirrored the people's mood, and the shadow of a dark destiny brooded over all. To fill the cup, the reaction, coldly triumphant, was able to bring the members of the first national parliament before the bar for high treason in signing the Viborg Manifesto.

In the stifling Hall of Justice in St. Petersburg, like a resurrection of the first Duma, sat the hundred and sixty-nine signers, grouped as of old by party affiliations. Each man was called upon to justify his actions. Many had signed the Viborg document in the belief that the people would rise in bloody rebellion, and they issued what was, to their fevered view, advice of moderation. One deputy after another stood erect to answer for his deeds. If the men had been carried from liberty into license, at least they had been fired by intense belief in themselves and in their mission. Impressive were the solemn declarations of those who expected nothing less than long imprisonment for speaking out, now, a defiance to the ruling power. It was currently rumored that should the former President of the Duma, Dolgoroukov, justify his action, his penalty was to be three years' imprisonment; the others would serve one; while liberty was reported to be the bribe for any who would confess a fault. Yet almost to a man these old deputies rose to declare that they still stood by all that they had done.

"I did not care, and do not care if our action was unconstitutional. We found that we must rely," said Nabokov, "on the highest law, the will of the people."

Kakoshtin, of the Cadet Party, and a professor in Moscow University, declared: "Whatever fate awaits us, it will be nothing compared to the sufferings of our predecessors who have fallen in the fight for liberty."

Three members of the "Group of Toil" declared that the first Duma would be an encouragement to the people to overthrow the present system.

Mourontzev, and Prince Dolgoroukov were there, leading members of the first Duma. Petrunkevitch ended his speech: "If you open for us the doors of the prison, we will quietly enter with the knowledge that we have fulfilled a duty to the Fatherland."

Burning words these, but they waked not an echo. The Administration was in complete control of the situation. Repression was the order of the day, repression as widespread and efficient as in the days of Nicholas I; the autocracy, buttressed by an army which, however lacking in discipline and supposedly honeycombed by disaffection, nevertheless rallied still to the command and service of

the master.

At this time there was issued the call for a third Duma. As Prime Minister sat cold Stolypin, whose reputation as a governor-general was the reverse of liberal. He had risen by virtue of rigid efficiency. His best friends did not know his beliefs. He had dissolved both the first and second assemblies, and had done his best to pack the third. "I want a Duma that will work, not talk," he declared.

The murmurers said that the Russian Parliament had become a farce; that the administrative officers were following to the best of their ability instructions from St. Petersburg to deliver a roster of safe men; that those who had agitated unwisely were being removed from the likelihood of candidature; that the Senate, with its membership of retired officials, had so construed each provision of the election law that the unquiet classes were as far as possible disfranchised; that every influence was being used to make the third a "dummy Duma," hopelessly manipulated into the reactionary camp.

Throughout this time of shattered ideals and discouragement, a very small band of real believers still held high the torch of faith. Most prominent among them was Alexander Goutchkov, he who among the Moscow Constitutional Democrats (the "Cadets" of the earlier times) had in a critical Polish debate of the party spoken and voted alone for a united Russia.

When at length the third Duma had assembled, the so-called Octobrists or Moderates, who had a small plurality, prepared a reply to the Speech from the Throne. Very respectful it was, with no demand for general amnesty or suggestions of confiscation or national devolution. It read in part:--

We wish to devote all our ability, knowledge, and experience to strengthening the form of government which was given new life by the Imperial will; to pacify the Fatherland, to assure respect for the laws, to be a buttress for the greatness and power of indivisible Russia.

Unexceptionable, this, to the higher powers, save that in the preamble in the original draft, the Czar's historic title of "Autocrat" had not been given him. A debate followed, and brought about the declarations which defined the parties of the third Duma. Bishop Mitrophane, of the Right, or reactionary party, rose. He said in the name of his group that the Address to the Throne must contain the phrase "Autocrat of all the Russias." Lawyer Plevako seconded, threatening to secede if the proper title were not incorporated. Paul Milyoukov spoke hotly for the opposing Cadets, asking whether the country was or was not under a constitution. He declared the new election law to be contrary to the original ukase and an act of force. Others of the Left, among them orator Maklakov of the Cadets, declaimed against the election law by which this Duma was constituted. They were not politic, these spokesmen, but harsh and dogmatic, yielding none of the courtier-respect that makes up for so much absence of real yielding. For the Octobrists, Alexander Goutchkov led the debate. His speech revealed that they operated, not with the bludgeon, but with the Damascus blade. They were of flexible obstinacy and opportunism, stirring up no sleeping dogs, bending to rise again. Goutchkov slipped adroitly into his speech the disputed word constitution, thus: "We do not believe that the Czar's power has been diminished. The Emperor has become free, for the Constitution has delivered him from court camarillas and the hierarchy of chinovniks." Thanks largely to his tact, the Octo brists won. The Address, without "Autocrat," was passed by a vote of two to one. But it passed at the cost of self-separation by the right wing of the reactionaries, who withdrew.

The answer of the Administration came sharply from Prime Minister Stolypin:--

The manifesto of imperial power has borne witness at all times to the people that the autocratic power, created by history and the free will of the monarch, constitutes the most precious benefit of the political state of Russia; for it is this power and this free will that are alone capable, as the tutelary source of existing constitutions, of saving Russia in times of trouble, of guaranteeing the state from the dangers that threaten it, and of bringing back the country to the way of order and historic truth.

He called upon the Chamber to incorporate the recognition of the "Autocracy."

A hundred members protested. Many of the Cadets walked out. To the Octobrists, barely a quorum, fell the humiliating duty of recalling their own address and of inserting, despite the scorn, the fateful word. So shaken was the group itself by the conflict that of its one hundred and sixty members but ninety-five united in the caucus that elected officers and committee members. Alexander Goutchkov was chosen chairman, Baron Meyendorf, Priest Bjeloussov, and Radsjauko, officers. Among the heads of committees were Prince Wollanski, and Peasant Kusovkov. In spite of the stigma of reaction popularly imposed upon them, these were not unrepresentative men.

The distracted Duma got slowly under way, and the Prime Minister brought before them his proposed policy of administration.

M. Stolypin's address to the Duma, November 16, 1907, stated that:--

1. The destructive movements of the party of the extreme Left have resulted in brigandage and anarchy. Order will be the first duty of the Government.

2. Agrarian relief is the first necessity, and this by a system of small proprietors.

3. Local self-government and administrative reforms will be formulated and presented to the Duma.

Business got centred on these practical subjects. Discussions as to whether or not there was an autocracy gave place to famine-relief measures and railway-rate studies. The absenting delegates of the Left and Right, who had retreated to their tents in the wrangle over the Czar's titles, and had left the forlorn little band of constructive Octobrists to carry on the work of legislation, now returned. The proceedings began to take parliamentary form.

The Budget came on, the Ministers of the Government presenting their projects for discussion. In the heat of debate, the Minister of Finance, M. Kakovtsev, exclaimed, "Thank God, we have no parliament yet!" The fact that an Imperial Minister was presenting his budget to an elected assembly showed the reality, but the war on names rose up afresh. The Duma officially declared the Minister's expression unfortunate. He threatened to resign unless the house apologized. The Left again exploded in outcries, called out that the Duma was a farce, threw in their votes as more fuel for the flame of discord, and deserted the hall when they were in the minority. Still the little band of moderates chose the self-abnegating, unspectacular part, and gave the apology that avoided a crisis.

But now came up a matter wherein the dispute was not over a name or a title, but a reality. The Government, upheld by the Czar, the Court, and much public sympathy, proposed a programme for a new navy. It called for the immediate allocation of one hundred and eleven million roubles, and the expenditure in ten years, of over a billion roubles. In the state of the country this entailed a fearful burden, perhaps the loss of the gold standard. The outwardly supine members, in rows like grenadiers, voted against the project. By 194 to 78 it was lost.

The Minister of Finance shortly afterwards undertook to issue railway bonds without the Duma's consent. With a rebuke, for which this time no apology was asked or given, his estimate was cut down by one rouble, and voted. The Amur Railway was authorized, though three hundred million roubles are its prospective toll. The sole remaining Pacific port of Russia, Vladivostok, is thereby linked with the Irkutsk and Trans-Baikal districts of Siberia, and so doubly insured against an eastern enemy.

After a lengthy session the third Duma adjourned, but not by violence. It could show as results two hundred bills passed, a budget thoroughly scrutinized and ratified, and much faithful work in committee. More important still, the Parliament, by forbearance and patience, had made itself a part of the machinery of government, and had shown that a national legislature did not mean expropriation, and a partitioned Russia.

At the end, fiery Maklakov of the Cadets, he who early in the session had cried out that all was a farce, admitted that "the third Duma has lost none of its rights, it is systematically extending them." All honor to those whose self-suppression and patience won.

The thin edge of the wedge had been driven in under absolutism by the third Duma, but little could one foresee that a half-dozen quiet blows would, during the fourth Duma's session, bring autocracy to the greatest crisis it has encountered since it decreed a legislature. The heart of the situation lies in a naval bill submitting to the Duma matters which the Constitution reserves to the control of the Emperor. Strangely, too, the Czar is himself the abettor, if not the originator, of the supplanting.

In May, 1906, the Czar decided to create the "Naval General Staff." One hundred thousand roubles a year were needed, and the money must be sought of the Duma. The first two assemblies being so violent, the measure lay in abeyance, to the great injury of the service. Since the regeneration of the navy was one of the measures made painfully necessary by the Japanese War, M. Stolypin had a bill drafted, in three clauses: one ratifying the creation of the "Naval General Staff," a second furnishing an annual sum for its operation, a third supplying a fund for contingencies. No feature of the creation, save the financial aspect, came at all within the legal jurisdiction of the Duma. Yet the Premier had the organization itself brought before the Assembly.

The deputies criticised the institution, modified it, sliced the estimates. Assuming the judicial functions of a court of last appeal, they voted the money and passed the bill, which M. Stolypin then submitted to the upper chamber. In view of the overstepping of domain, the bill was, after a lucid exposition of the law by the ex-Controller-General, thrown out.

The matter was next submitted to the Czar himself, who authorized its reintroduction in the Duma. A second time the measure was passed and sent to the Council. M. Durnovo, ex-Minister, ablest of the Conservatives, and candidate for the Premiership, made a notable speech. He proved clearly the trespass upon the rights reserved to the Crown, showed that such precedents would build up an artificial claim which could not later be combated, while the allowance of participation in one instance gave a warrant for demanding interference in any and every proposal. The bill was a blow at the very heart of monarchical government, and a degree of democracy not allowed even in republican France. But, defiantly, M. Stolypin held his ground. The anomaly was presented of Conservatives decrying the Premier for undermining the dynasty, with the Emperor himself supporting the culprit. Thus has the former government minority been converted into a majority,--the measure passed by the small margin of twelve.

The reactionaries have bitter feud with this Premier. He has, it is allowed, so enlarged the functions of the deputies by handing over to them, one after another, the vital prerogatives of the autocracy, that no later action can ever disestablish the Duma. The Empire is now governed through a unified cabinet; the important prerogative of appointing the governors-general has been exercised by the Premier, rather than by the Czar, since June 16, 1906. Russia has marched far on its upward way.

Great, however, is the task ahead. Of all that the Duma can achieve the country has supreme need. The agrarian question calls aloud for solution, and the peasants' future depends on land-relief. The Emperor has given instructions for the sale of most of the Crown domains and those of the Imperial Family. The nobles are being encouraged to sell to the tenants, on notes guaranteed by the Imperial land bank. Firm and able hands must guide this improvement, promoting the division of estates left to run wild, but avoiding the pitfalls of threatened property-rights.

Individual enterprise must be awakened, which will in the end bring about more scientific rotation and intensive farming. The old system leaves fallow thirty-three per cent of the arable land--an area equal to the whole ploughed acreage of the United States. In western Europe but seven per cent is fallow, and the value of the harvest per acre in Russia is less than a third that of Germany. The policy adopted in the Agrarian Law of November 9, 1906, for the gradual breaking-up of the communistic Mirs, and the division of the common lands, at the villagers' option, into freehold plots, is a wise one. In 1907, the year following the law's promulgation, 2617 peasants, in the government of Ekaterinoslav had become individual proprietors. Under the Land Act of 1909 one million farms had been taken up for private ownership in the first six months of the law's operation.

Emigration to the vast untilled fields of Siberia should be carried on with all the efficiency of which the Government is capable. That this is in progress, the figure of four hundred and ninety-one thousand emigrants for the first seven months of 1908 attests. Fifty-nine thousand homeseekers were sent by villages which wished to emigrate thither _en masse_. But care and providence must follow the movement, and insure that the settlers are equipped with the means for safe and permanent establishment.

The race-question calls also for a righteous solution. The future must bring the repeal of the old bureaucratic laws of Jewish exclusion, and end the vicious circle of oppression and terrorism against this much wronged people. The chaotic finances of the Empire must be regulated by years of patient work, such as that of the last Duma, through whose agency there is now, for the first time in twenty-two years, a budget surplus.

The Duma members, to whom these all-important tasks fall, must plough the fields in all their armor. The autocracy is not their greatest enemy. The history of parliamentary government demonstrates again and again that in an ordered community authority gradually reverts to the national representative assembly. Little by little power slips away from the throne. In England, in 1686, the reign of James II could show Jeffreys' Bloody Assizes; yet five years later the Parliament was in full and permanent control of the government.

The preservation of the country from the nether chaos is, however, a mightier problem. Before the ship of state rides safe in the harbor of true representative government there must come a critical period when the administrative powers are not firmly clasped by the hand of either autocracy or duma. This hiatus-time, when iron repression ceases and sober self-rule begins, is yet to come. Those who must tide the nation over it are such as those pathetically few Octobrists, unpopular because of their bending, craven-seeming policy, and because of the unfree elections that gave them place. Will such a group, when the crucial hour strikes, be allowed peaceably to pilot the vessel? Or will red-handed revolution wrench from their grip the tiller, bereft of the guidance of autocracy? Is it to be evolution or revolution?

One cannot deny that a free election to-day would throw out the toiling Octobrists and put in a membership like that of the first Duma. These constructive, unvisionary men are not loved, nor is their progress likely to make them so. They exist as the ruling factor only by virtue of election manipulations and legal interpretations. With this essentially temporary support taken away, the

group would be powerless, for every indication shows that the people would not support them or their policies.

[Illustration: PEDDLER POLICEMAN RUSSIAN TYPES]

Even Moscow, their former stronghold, fell away in the 1909 elections. There is throughout the country an undercurrent of fierce demand for an immediate millennium, with Liberty as the guiding grace and some particular party as its escort. A song that has become almost an anthem, "Spurn with us that ancient tyrant," chanted softly by the school-boys to the tune of the _Marseillaise_,--this tells the tale of what is in the air, and in the blood of the people. The most poorly-suppressed desire is insatiate to hack away with one blow the abuses that have, through the centuries, rooted themselves deep in Russian society. The experience of the various revolutionary and terrorist movements proves that their votaries are capable of daring any death for their creeds, and of swimming to their imaged goal in a sea of blood. Let the conservative Octobrist group once succeed in concentrating power in the Duma, and then let a free election substitute for them such men as were in the first Duma, and the Russian Revolution has become a fact.

It is a commonplace to compare the situation with that of France in 1790. There is, however, one fundamental difference. France possessed a numerous and economically powerful bourgeoisie, from whom political rights had been withheld. This class included many strong men moved to a unity of political desire. They were able in the first place to work up into a place of dominance. After the interval of supplanting terrorism, they retook by their own efforts the power which, save for the periods of despotic militarism, they have since maintained. In Russia the conservative middle-class is numerically very weak, and its representatives are unable to seize and hold control themselves. They possess it now only precariously, by the external propping of weakening absolutism. Will Russia's Octobrists, after performing the function of filching power from the autocracy, meet, at the hands of a new Robespierre, the fate of the high-idealed Gironde?

One cannot yet answer. But whatever the harvest, the work of the third and fourth Dumas, carried out in harmony with the Imperial Ministers, has shown that the last dread arbitrament of social war need not come. Revolution is the final recourse, to be undertaken only if a political and social situation is so desperate that all other means must fail. Such is not the case in Russia. There are administrative abuses there. But governmental restrictions press rather less than one might imagine upon the plain workaday people; and compared to those of other nations, they are not exceptional save in degree. It is the educated and so-called upper classes who complain. Taxes elsewhere than in Russia are burdensome and sure as death. Emigration to Siberia will give any peasant the legal privilege of escaping taxation, which in America is the prerogative of her absentee plutocracy alone. The exile system, dwindling for years past, has now been in effect abolished by the refusal of the Duma to make an appropriation for its continuance. The press-censorship is only the open operation of influences tacitly accepted elsewhere--such as in the United States left the Tweed Ring so long uncriticised. The much-condemned passport is actually of no more inconvenience than showing a railway ticket, and it does not come within "forty _sagenes_" of the custom-house inquisition which faces every American citizen on his return home.

It is not an error to say that in many matters of individual liberty the Slav enjoys more than the American. In the treatment of subject nations, reliable and neutral witnesses declare that Russia does not approach the rigor of the Prussian bureaucracy in Alsace. Many of the Empire's restrictions are those which obtained throughout Europe fifty years ago--abuses common to a certain stage of civilization, and of public opinion. These melt away in newer customs, for time is curing much. Once the chariot of progress is started, many evils right themselves in the natural and inevitable upward pressure, and many slough off unnoted. It is not so many years back that in America a black man could be deported to malarial lowlands more deadly than Siberia's steppes; not so long ago that the English Parliament passed an act requiring all railway-trains to be preceded by a man carrying a red flag. Like the seignorial rights of Germany's feudal states, anachronisms become outgrown, and fall away.

In Russia, unfortunately, the onslaught against iniquitous human laws is overcarried into a blind charge against Nature's laws, which no revolution can repeal. The protest against dire artificial abuses is mixed with a rebellion against the curse of Adam. It is the fearful fact of life that the destiny of the majority is anxiety, dependence for daily bread on other men, grinding incessant toil remunerated by a bare livelihood, a barring-back from the fullest personal capacity and possibilities through poverty, parentage, environment, and lack of opportunity. The forces of Nature and primal competition put so many limitations upon every one's action that it is hard to say which are due to the tyranny of men, which are the handicaps born of the nature of things. The cry for deliverance is rising equally in the workhouses of Scotland, in France, where thirty-five per cent of the land is owned by great proprietors, in the slums of New York City, and in the rice-fields of Japan. A government under the present system can but do its best to develop men's capacities, and to give them a fair deal. All that the best of modern societies has succeeded yet in securing

to the mass of mankind is the chance to get their sons the education which will enable them to vanquish some of the limitations, security for the person, and protection from robbery of the cruder sort.

Capacity and opportunity can come but by slow degrees. When one sees the numbers and the types in the villages, men of latent capacities undoubtedly, but swamped by the spirit of _nietchevo_ and with all their enterprise sapped in the stagnant communism of the Mir, he realizes the futility of a sudden change and the hopelessness of germinating by political pellet the leaven of progress in the hundred and forty millions.

Rulers may be changed by revolution. But the real quickening of the people to their great future must come and is coming by the slow, sure way of evolution.

VIII

THE STORY OF THE HORDES

Among people so peaceful and subdued as are the latter-day Mongols, it is hard to realize that the race has had a past which in tradition at least goes back to the infancy of history. According to legend, the Chinese, the first reputed offspring of the Mongols, preceded by three hundred years Egypt's earliest dynasty. They antedate Abraham's assigned epoch by twenty-six generations. They claim to have continued before Marathon a longer time than has elapsed from the foundation of Rome to our own era. Yet they yield not even to the Romans preëminence of arms, for they won and ruled an empire in extent and population the greatest that has ever existed. Mongols have led the world's mightiest armies; their hosts have carried the ox-hide banners over every great European state but Spain and England, and into every Asian country except Japan.

That the march of Mongols down the long way of history has been so little appreciated is the sword's obeisance to the pen. Save for the mendacious memoirs of Tamerlane, and a few Ouighour inscriptions in Central Asia, chronicles there are virtually none. So story has found a peg for the clipped tails of Alcibiades' dogs, but scarcely a word for the deeds of those who won the world from the Yellow Sea to the Baltic, from the Persian Gulf to the Arctic. Only where the annals of the race have been written in the blood of the peoples they conquered are the events to be traced; only by assembling the alien and hostile evidences of the encircling nations can one shape the outline of Mongolia's mighty past. History takes from the Confucian Book of Records the story of the earliest emigration to the east; from Herodotus the descent upon Mesopotamia and the struggle with Persia on the west. It gleans from the Chinese archives the doings of the Hiung-nu--the Huns; from the documents of the Byzantine Empire the descent on Europe of the same Mongolian "Scourge of God." It culls from Arab historiographs the facts of the southern conquests of Genghis Khan; from Russian monasteries the tale of the northward march of his lieutenant Batui.

The outlines of Mongolia's career are patched and gathered from her frontier lands, yet silhouetted against the far recesses of time they grow steadily clearer and more colossal.

In the year given by most as 2852 B.C., a tribe, whose earliest folk-lore and traditions point to an origin in the cradle of the Hordes near Urga, was pushing seaward down the valley of the Yellow River. Like the children of Israel, they were in constant conflict with the "barbarian" aborigines. This tribe became in due time the Chinese nation.

Through fifteen hundred years the descendants of the invaders wrought out a dimly comprehended civilization on the banks of the Hoang-ho. Behind the imposing national legend, hallowed by the mist of centuries and focused by images of their five Hero Kings, one may see the fact of strong, brave rulers striving for their people's advance. A real statesman was the original of the demigod Shinnung, "holy husbandman," the introducer of agriculture, in whose honor every spring a furrow is ploughed in the soil of his temple courtyard by the Emperor of China. A father in the flesh was that "Nest-builder" who watched the birds construct their homes, and on that model taught his people to make the wattled and plastered huts one sees to-day. The mystic queller of disastrous inundations, Ta-yu, founder of the house of Hia, was the first hydraulic engineer, the dykes of whose successors embank the treacherous Yellow River. He it was who hung at his door a bell which any of his subjects might ring, to obtain immediate attention, and who would leave his rice to answer a call to secure justice. Kie likewise wears human lineaments, he who made a mountain of meat and a tank of wine, and then, to please a frail companion, had his courtiers eat and drink of them on all fours like cows. There is an historic background to the rising against the tyrant under Shang, who later offered himself as a human sacrifice for rain in time of famine, and a kindred note in the story of Chou-siu, sold to misfortunes by a woman whom he loved and immolating himself in his royal robes when the rebellious vassals were closing in around him.

As the years pass, the histories become clearer and more direct, and the legendary aspect of exploits falls away. The Commentaries of Confucius deal with events as tangible and exact as Luther's Reformation: they give the records of kings, and their daily doings two thousand years before our era.

In 1122 B.C., with Wu-wang of the dynasty of Chu, the Chinese nation emerged as a civilized state. It was organized on a feudal system, not dissimilar to that built up by Japan's powerful Daimios. Under this single dynasty the Celestial Kingdom began a period of 873 years of development, marked by the writings of the great sages. Lao-tse, founder of the Taoist religion, with its watchword of "Tao" (reason), but its quick degeneracy to forms and idol-worship, was the first of the Chinese philosophers in point of time. He was at the zenith of his repute around 530 B.C. He had a young disciple struggling through poverty to an education, "Master Kung," known to us under the Latinized nomenclature of Jesuit missionaries as Confucius.

The youth eagerly conned and meditated upon Lao-tse's abstract speculations; but, unsatisfied, he began the studies and compilations from the ancients which to this day constitute the foundations of Chinese literature, etiquette, religion, ceremonial, and policy of government.

Confucius was at once the world's greatest college professor and its most influential editor. His school instructed three thousand pupils in ethics and etiquette. His writings have influenced more minds than those of any other human individual, and his supremacy is the triumph of uninspired work. His moral tone is lofty,--as witness his "Do not unto another what you would not have done to yourself,"--but his life brought no great new message.

"I am a commentator, not an originator," he said of himself.

Mang-tse, "Master Mang," whom we know as Mencius, followed "Master Kung" by one hundred years, applying, as a practical reformer, to the society of the day, the maxims of his enlightened philosophy, rebuking princes and giving to the Chinese world the last of its classics.

In the glories of the Chu Dynasty, China, the earliest offshoot of the Mongol race, reached its literary and philosophic climax.

In Turan, now called Turkestan, and in Mesopotamia, a western division of the Mongols appears about 640 B.C. It is making an incursion into the declining Empire of Assyria, over which Nebuchadnezzar is soon to rule. Nothing of detail remains, only the record of the devastating inroad over the mountain; but it locates at this date the southwestern frontier of Mongol dominion.

Scythia, north of the Black Sea, reveals them next. The sketch is drawn by the master-pen of the Greek father of history in his description of the expedition of Darius, 506 B.C. "Having neither cities nor forts, they carry their dwellings with them wherever they go," Herodotus writes, describing the nomad foes of the Great King. He relates that they are "accustomed, moreover, one and all of them, to shoot from horseback and to live not by husbandry, but on their cattle."

This was the enemy against whom Darius planned a campaign, whose object was to free from the menace of the Scythians north of the line of advance his prospective expedition for the conquest of Greece. From the bridge of boats over the Hellespont, beside which Miltiades watched, the great Persian marched to the Don River, the nomads always retreating. Darius finally challenged the Scythian king to stand and fight, or to accept him as suzerain. To this message Idonthyrsus replied: "This is my way, Persian. I never fear men or fly from them, nor do I now fly from thee. I only follow my common mode of life in peaceful years. We Scythians have neither towns nor cultivated lands, which might induce us, through fear of being taken or ravaged, to be in any hurry to fight with you. In return for thy calling thyself my lord, I say to thee, 'Go weep!'"

All the Asian steppes were open to the ever-retreating nomads: Darius was obliged to halt. Hereupon, the Scythian prince, understanding how matters stood, dispatched a herald to the Persian camp with presents for the king. They were "a bird, a mouse, a frog, and five arrows."

Darius was at liberty to deduce whatever explanation he chose. He retreated, the Scythians hounding his army on. He found his bridge over the Bosphorus safe, and returned to Persia to prepare the Athenian expedition that ended at Marathon. The Scythians remained: they were left leading their flocks as of old over the unconquerable steppes.

By these echoes of clashings with other nations, the first-known streams of Mongol outflow are dimly followed to the Caucasus Mountains and the Black Sea on the south and west, bounding Scythia; to the Hoang-ho Valley, in which were living the metamorphosed Chinese.

But the rolling hills south of Lake Baikal, the source of the race-stream, still poured out fresh hordes, which periodically overflowed in roving nomad bands, harrying the plainsmen. While the feudal states of China struggled and fought among themselves, now coalescing under the "Wu-pa," the five dictators, now uniting under a Prince Hwan of Shan-tung into a temporary Chinese Shogunate, there came down upon the fertile lands and populous cities wild horsemen, sparing none, burning, looting, riding away. "The Hiung-nu descended on us," appears again and again in the history.

At length, about 246 B.C., arose the short but glorious dynasty of Ts'in, under China's king, Shi-hwang-ti. He was a man of action. He compacted a centralized monarchy from the many princedoms, drove back the nomad Hiung-nu beyond the Yellow River, built the Great Wall, and by his glorious exploits blazoned into Europe's vocabulary, the word China--Ts'in.

In Sz-ma Ts'ien's history, a striking incident, revealing the Great Emperor's limitations, is graphically told.

"Li-se, the councillor, said, 'Of old, the Empire was divided and troubled. There was nobody who could unite it. Therefore did many lords reign at a time. For this, the readers of books speak of old times to cry down these. They encourage the people to forge calumnies. Your subject proposes that all the official histories be burned. The books not proscribed shall be those of medicine, of divination, of agriculture. If any want to study laws, let them take the office-holders as masters.'"

The decree was "approved." The old books of annals, the Confucian Commentaries, the Odes and the Rituals, to the suppressed execration of the learned, fed the flames. The literati who protested were warmed, themselves, over the same fires.

But despite Shi-hwang-ti's signal defeat of the five coalescing tribes, and the eighty-two thousand severed heads; despite the victories in 214 B.C., the Hiung-nu Empire grew in power, until it extended from Corea to Tibet.

The Chinese "Han" Dynasty, even under the peasant-founder, Lin-pang, who had proven himself a thorough soldier, was constantly harried. The loss of the old literature continued to be mourned, which argues some plane of general appreciation. The Minister urged the recall of the Ts'in philosophers and the reproduction of the burned books.

"Why have books?" said the Emperor. "I won the Empire on horseback."

"Can you keep it on horseback?" the Minister asked.

The literati were eventually recalled. Their support was secured for the throne, and the Hiung-nu were kept back by art as well as by arms.

At the Emperor's death, his widow, the Dowager Empress Lu, of Borgian repute, was still harder pressed by the nomads. Meteh, the khan of the invading hordes outside the Wall, ventured to send to her a proposal of marriage and tariff-treaty couched in Rabelaisian poetry. "I wish to change what I have for what I have not." He followed the verses with gifts of camels and carts and steppe ponies. In return his messengers insisted on a tribute of wadded and silk clothes, precious metals and embroidery, grain and yeast, as well as the intoxicating _samshu_. These royal presents and tribute were really a trading of goods, a barter, and citizens of lower rank, in the fairs beside the Wall, were carrying on an equivalent.

More and more oppressive became the demands of the Mongols. A band of beautiful maidens, a very toll of the Minotaur, was exacted yearly. In one of the ancient Chinese poems a princess laments the fate that condemns her to a barbarian husband, a desolate land where raw flesh is to be her food, sour milk her drink, and the felt hut her palace.

In 200 B.C., Sin, King of Han, marched against the Hiung-nu, only to retreat after heavy losses, with a third of his soldiers fingerless from the cold. Again, in 177 B.C., the Hiung-nu broke a treaty and raided across the Wall. A speech of the Emperor, in 162 B.C., is quoted in the Chinese chronicles: "These later times for several years the Hiung-nu have come in a crowd to exercise their ravages on our frontiers."

In 141 B.C., Nu-ti, the fifth of the House of Han, assembled a great army of one hundred and forty thousand Chinese, and marched against the Confederacy. This army, like that of Darius, penetrated far up into the nomad's territory. Scarcely a quarter of them returned. But the invasion was not fruitless: the Hiung-nu gave allegiance to China. Later, in 138 B.C., largely to turn the left flank of the Horde, the Chinese advanced into Corea. In 119 B.C. another march to the district north of Tibet turned the nomads' right flank. At length, in 100 A.D., a more northerly Tatar clan, the Sien-pi, came down on the broken remnants of the Hiung-nu. After thirteen hundred years of power this tribe was destroyed. Of the scattered nomads some remained to unite with their victorious conquerors; some went south to Turkestan; a third group trekked north, and went over the great steppe. Subsequent to 100 A.D., they are found

on the east bank of the Volga, where during two centuries they temporarily disappear from history.

The great Empire of China now existed unmolested by the Hordes, and after a few hard fights ruled Asia as far as the borders of Persia. Its outposts almost met those of the Empire of Rome. Both realms were, about this date, in peace and prosperity. There is even a record of trade between them, the Chinese annals telling of an expedition of King An-tun, or Antoninus, in 166 A.D., to Burmah, from which his factors reached the Middle Kingdom; and of glass, drugs, metals, and game obtained overland by way of Parthia from Ta-ts'in, the Great Empire. Pliny writes of silk, iron, furs, and skins, caravan-brought from China. So moved the two empires until 376 A.D., when Valens the Irresolute reigned in Byzantium. To him came messengers bringing word of great alarm from the Danube. The whole nation of Goths were on the bank, begging a refuge in Roman territory.

"Wild enemies, from where we know not, are upon us!" they cried.

The Goths, who were to subvert the declining empire, were escaping from before the western division of the old Hiung-nu. Valens had the Goths ferried over the Danube, and the Huns established themselves in the vacated places of what is now Austria.

[Illustration: THE MIRACLE OF ATTILA'S REPULSE (From a painting by Raphael in Vatican)]

Amid those hordes arose a leader destined to leave a memory in the sagas of the Scandinavian bards, in the Niebelungenlied of the Teutons, and a lurid trail in the annals of the Cæsars. He called himself a descendant of the great Nimrod, "nurtured in Engaddi, by the grace of God, King of the Huns, the Goths, the Danes, the Medes; the Dread of the World,"--Attila.

A profound politician, he alternately cajoled and threatened the peoples whose conquest he undertook; a true barbarian, no food save flesh and milk passed his lips. He and his men worshiped the mysteriously discovered scimitar of Mars, and from Persia to Gaul, from Finland to the walls of Constantinople, his armies ranged. Ambassadors went from his Court to China. The great battle of Chalons, in which, aided by the Goths, the dwindling forces of Rome's Western Empire won their last victory, alone preserved Europe from his yoke. His descendants, mixing with succeeding conquerors, have remained until this day in the land that is called, after their dreaded name, Hungary.

Back to the history of Sz-ma Ts'ien one must return for the next harvest of Mongolia's dragon-teeth. The Tung-hu, whose descendants are now the skin-clad Tunguses that live far to the north, even up to the Arctic Ocean, came down between 309 and 439 A.D. upon Manchuria. This occupation separated China from Corea, which, thus isolated, preserved for centuries the old Han dialect. The Tung-hu conquerors established a great kingdom extending from the Japan Sea to Turkestan. From 380 to 580 they ruled the northern kingdom of China proper. The leading place among those who composed their empire was held by the tribe of Juju, or Geougen, whose descendants are now the Finns. Subject to the Juju was a Mongol clan descended from the old southern Hiung-nu, who lived hard-by Mount Altai. They were blacksmiths and armorers for the Tung-hu army, and were called Turks. Their crescent power gradually supplanted that of their masters.

In 480 this people appeared on the border of China. By 560 the Turkish Empire had become supreme in Central Asia. They pressed upon the nation of Avars on the Altai borderland of the steppe, until twenty thousand of these, refusing to submit, moved westward. Justinian received the envoys of the fugitives in 558. They offered to serve him, and threatened, if unaccepted, to attack his Eastern Empire. Anxious only to keep them away from his own domains, and indifferent as to which should survive, he sent them to attack his German enemies. The Avars, conquering a place in Europe, established a powerful nation between the Danube and the Elbe, biding their time till with the other barbarians they could descend to the spoil of Rome.

After their rebellious vassals came the Turkish envoys, with richer presents to the Eastern Emperor Justin II, and more alarming menaces. The military alliance of the Turks was accepted and that of the Avars renounced. Kemarchus carried the ratification of Rome's treaty to Mount Altai in Central Asia. For many years there was friendship between Mongol and Byzantine, mutual alliance and trade.

In 618 the great T'ang Dynasty arose in China, whose fame is suggested in the fact that the only Cantonese word for a Chinese nationality is "Man of T'ang." The energetic Li-shi-min subdued the Manchurian Tunguses, and in 630 a great battle broke the Turkish power. China once again was supreme from Corea to the borderland of Persia. During the T'ang Dynasty, Kashmir in India, and Anam were captured by the Chinese.

There followed now a period of centuries when the breeding-place of the Mongol's wolf-born hordes ran barren. In unchronicled obscurity the skin-clad herdsmen lived out their generation. To the feeble Ouighour confederacy fell the sceptre of the steppes. The

old territory of the Hiung-nu khans and the Turkish Supreme King was split into little chief-governed principalities. Manchus and Tung-hus, rallying again, alternately ruled and harried China. Avars and Huns occupied their distant conquests. But in the vast stretch between, the tribes were in a bewitched sleep. The people and the qualities that made the old armies were there; the breed of shaggy ponies which they rode was there; iron reddened the hill-slopes, waiting to be hammered into spears in the Altai forges; China and Europe were as ripe for the spoiling. All that the Mongols needed was a leader.

In a quaint chronicle of the Middle Ages we read of how he came. When the French took Antioch from the Turks, one Can Can ruled over the northern region out of which the Turks had originally come. To the old kindred in this hour of need they sent for aid. Can Can was of the Cathayans, a people dwelling among the mountains. In one of the valley stretches lived the Tayman tribe, who were Nestorians. After Can Can's death a shepherd, who had risen to power among the Taymans, made himself ruler as King John. King John had a brother named Vut. Beyond his pastures some ten or fifteen days' journey was Mongol; the latter described as a poor and beggarly nation, without governor or law save their soothsayings so detestable to the minds of the Nestorians. Adjoining the Mongols were other poor people called Tatars. When King John died without an heir, Vut became greatly enriched. This aroused naturally the cupidity of his needy neighbors. Among the Mongols was a blacksmith named Cyngis. Ingratiating himself with the Tatars, he pointed out that the lack of a governor left both peoples subject to the oppression of the surrounding tribes. He got himself raised to the double chieftainship, secretly collected an army, and broke suddenly upon Vut. Cyngis sent the Tatars ahead now to open his way, and the people everywhere cried in dismay, "Lo, the Tatars come! the Tatars come!"

While the Turks sought aid of their kinsmen for the defense, the French King sent to King John's reputedly Christian kingdom for help to his crusade. But Cyngis "Temugin," the Man, had come. As Genghis Khan he was to open up the vastest empire the world has ever seen.

In 1200 the young Temugin, in a great battle near Urga, defeated Wang Khan, whom modern research, vindicating the basis of truth in the old Friar William de Rubruquis tales, has shown to have been a Tatar prince of the Nestorian Christian faith, King of the Kitai or Cathayans, in all probability the ruler known to the princes of Europe, through his letters to the Roman Pope, as the Christian potentate of the Orient, Prester John.

Wang Khan's skull, encased in silver, graced the conqueror's tent as a first trophy. In 1206, summoning all the Mongol chiefs, Temugin took the title of Genghis Khan, "The Greatest King."

His armies were turned next to the reduction of his own people, the nomad tribes of the Central Asian plains. As one after another was defeated, its warriors were incorporated into his growing army. When all these myriad shepherds and soldiers were gathered in, he directed his march towards China.

The Great Wall was as paper to his host. Ninety cities were taken by storm, never one surrendering. For while to the kindred races which he had conquered, and which furnished further recruits for his armies, Genghis was most merciful and humane, to a foreign foe he was indeed the Wrath of God. Once he was bought off from the invasion; but again he returned to the prey. A way into Peking was opened by means of a mine dug under the walls to the centre of the city; through it a picked body of Mongols entered, marched to the gates, and opened them. The savage host rushed in to sack and slay. For sixty days Peking burned, and five desolated provinces of North China were added to the Mongol Empire.

Mohammed, Sultan of Carizme, who reigned from India to the Persian Gulf, was the next objective for the Mongols. In the field, by valor and numbers, the Khan's troops defeated all the Sultan's armies. The walled towns were besieged and taken, largely through the skill of Chinese engineers. The whole great Persian district was harried after the custom of the Mongols through four years; for hundreds of miles the country was so ruined that to this day the old populousness and prosperity have never been recovered.

The army of one of the Khan's generals marched north into Turkestan, and subduing many Turkish peoples, entered beyond the Caucasus the territory of the Polovtisni, themselves Mongols of an earlier invasion. The conquest of Russia had begun. A Muscovite chronicle of those days illustrates the utter consternation and surprise of the inhabitants at this formidable and sudden incursion: "In those times there came upon us, for our sins, unknown nations. No one could tell their origin, whence they came, or what religion they professed. God alone knew who they were." The people generally believed that the time had come foretold in Revelation when Satan should be let loose with the hosts of "Gog and Magog to gather them together in battle; the number of whom is as the sand of the sea." Indeed, in the old map of Tatary, by Hondius, the territories of these two fabled worthies are carefully outlined in what is now Manchuria.

Despite the Tatarean theory of the Mongols' army, the Russian chivalry gathered to the aid of the Polovtisni, and collected an army by the lower Dnieper. Defiantly they killed the ambassadors whom the Mongols sent. The wrathful nomads advanced into the Crimea near the Sea of Azov. The two hosts met in the fatal battle of Kalka. It was the Crécy of Russian chivalry. Hardly a tenth of the army escaped. Ten thousand of the men of Kiev fell; of the princes, six, of the boyars, seventy, died on the field of battle. Matislaf the Bold alone made front, and he was treacherously betrayed and slain.

The way into southern Russia was now open; yet, after their victory in 1224, the Mongols disappeared as suddenly as they had come. The hordes had been diverted to complete the conquest of China. For thirteen years they were swallowed up by the steppe. The son of Genghis, "Oktai," had succeeded the dead conqueror, and had appointed Batui General of the West.

Again there was heralded an invasion, this time by one of the outlying tribes of Khirgiz on the eastern border. The blow was aimed at the very heart of Russia. The old Slav ballads, or "_bilinî_," tell how Oleg the Handsome fell at Riszan. The Tatars entered and burned Moscow in 1237. Onward into the north rolled their conquest, town after town falling. At the Cross of Ignatius, fifty miles from Novgorod, the torrent turned, and, sparing for the time being the ancient republic, swept to the south.

Against the cradle of the Russian race, the white-walled many-towered city of Kiev, Mangu, the grandson of Genghis, now marched. By multitudes the Tatars carried the walls. Fighting to the end, the last defenders went down in a ring around the tomb of the great Yaroslav.

Russia was prostrate at the feet of the nomads. Her princes became vassals, some to journey as far as the Amur to pay their homage to the Great Khan. Without the Tatar Emperor's letters-patent, no prince could assume his inheritance. When the envoy presented the documents, the nobles had to prostrate themselves and accept them kneeling. Each Russian city gave its tribute, even the still uninvaded Novgorod. Every peasant in Muscovy paid his poll-tax. Indeed, the supremacy of the czars of Moscow, when the Tatar yoke was at length thrown off, was largely due to the wealth which the Romanov family had managed to acquire and to hold during their term as tax-farmers of the Great Khan. Russian troops, supplied as part of the tribute, engaged in the Tatar wars, getting in one instance of record their share of the booty--after the sack of Daghestan. They were drafted on account of their great size and valor into a body-guard for the Mongol Emperor in Peking, corresponding to the Swiss Guard of Louis XVI.

While the conquest of Russia was being consolidated into a permanent Mongol dominion destined to endure for nearly two hundred and fifty years, Batui led his army on into Poland and Bohemia. He took Buda-Pest and devastated the country far and wide. The most alarming accounts preceded him, which are still to be read in the monkish annals of the time. "Anno Domini, 1240, the detestable people of Satan, to wit, an infinite number of Tatars, broke forth like grasshoppers covering the face of the earth, spoiling the eastern confines with fire and sword, ruining cities, cutting up woods, rooting up vineyards, killing the people both of city and country. They are rather monsters than men; clothed with ox-hides, armed with iron plates, in stature thick and short, well-set, strong in body, in war invincible, in labor indefatigable, drinking the blood of their beasts for dainties."

The Holy Roman Emperor, Frederick II, who undertook to gather the powers of Europe to meet the danger, wrote to Henry III of England:--

"A barbarous nation hath lately come called Tatars. We know not of what place or originall. A public destruction hath therefore followed the common desolation of Kingdomes and spoil of the fertile land which that wicked people hath passed through, not sparing sex, age or dignity, and hoping to extinguish the rest of mankind. The general destruction of the world and specially of Christendom calls for speedy help and succour.

"The men are of short stature but square and well-set, rough and courageous, have broad faces, frowning lookes, horrible cries agreeing to their hearts. They are incomparable archers.

"Heartily we adjure your majestie in behalfe of the common necessitie, that with instant care and prudent deliberation, you diligently prepare speedy aide of strong knights and other armed Men-at-arms."

Throughout Europe the dread was universal. In 1248 Pope Innocent IV sent to the Tatars an embassy with money, begging them to cease their ravages. Failing, he summoned Christendom. Louis IX of France prepared a crusade. The fishermen of England could not sell their herrings because their usual customers, the Swedes, had remained at home to defend Scandinavia. Fortunately, the tide of western Mongol invasion had spent itself. After wasting the Danube district, the death of the Great Khan recalled Batui in 1245.

[Illustration: ON THE ROAD TO THE MING TOMBS]

Syrian archives reveal the Mongols' next appearance. In 1243 Hatthon, King of Armenia, sought Mangu Khan at Cambaluc (Peking), praying him to fight the Saracens and recover Jerusalem. Mangu sent his general, who speedily took Antioch, spoiled Aleppo, and sacked the city of Bagdad.

When the latter was stormed, Haloon, the Mongol general, ordered that the Caliph be brought alive into his presence. There had been found in the city a quite surprising booty in treasure and riches. Haloon asked why the Caliph had not used his wealth to levy mercenaries and defend his country. The Caliph replied that he had deemed his own people sufficient to withstand the Mongols. Then the Khan announced that the precious things which had been so cherished would be alone left to the miserable man, who was shut into a chamber with his pearls and gold for sustenance and perished in torments. There was no Caliph of Bagdad after him.

Thus, almost simultaneously, there were conquered by the Mongols, northern China, Syria, Russia, Hungary, and Poland. The stream of human blood that it cost is immeasurable.

Of the first conqueror, Genghis Khan, an Arab poem says:--

On every course he spurred his steed He raised the blood-dyed dust.

The lives of four and a half million people are reckoned as his toll on humanity. He had proposed to raze every city and destroy every farm of the five northern Chinese provinces, to make pasture for his nomads, and was only dissuaded by a minister, who ventured death in opposing him. It was he who ordered the million souls of Herat to slaughter. Batui, subduer of Russia, called "Sein Khan" (the Good King), is said after the Moscow massacre to have received 270,000 right ears. Following his fight with the Teutonic knights, near the Baltic, nine sacks of right ears were laid at his feet. "Vanquished, they ask no favor, and vanquishing, they show no compassion." "The Mongols came, destroyed, burnt, slaughtered, plundered, and departed," summarizes an Arab; and the unimaginative chronicles of the Chinese tell without comment of city after city taken, and their inhabitants put to the sword.

Utter ineradicable barbarity would, on the face of things, seem to have been the inmost nature of this people. Yet only a few years later, when Mangu Khan was ruling at Caracorum, the Court had become civilized. Forty-one years after Genghis Khan's death, when the great Venetian traveler Marco Polo arrived at Kublai's Court, the palaces and the organized statecraft at Peking had become a model of efficiency. The Mongols, not as a race, but in the sphere of their leaders, had become a real nation, not unworthy of its success.

It is interesting to reconstruct the Tatar capital and note its development in half a century. The Minorite monk, sent to beg aid from the supposedly Christian Mangu Khan for the delivery of Jerusalem, wrote a detailed description of the city, Caracorum. It had a circuit of three miles and in dearth of stone was rampiered strongly with earth. It had two main streets: one of the Saracens, where the fairs were held and where many merchants assembled, attracted by the traffic with the Court, and with the continuous procession of visitors and messengers; the second chief street was occupied by Chinese, who were artificers. The town had four gates. In the eastern section grain was sold, in the western sheep and goats, in the southern oxen and wagons, in the northern horses. Beyond were large palaces, the residences of the secretaries. The Khan himself had a great court beside the city rampart, enclosed not by an earth but a brick wall. Inside was a large palace, and a number of long buildings, in which were kept his treasures and stores of supplies.

Twice a year the Khan held high festival, with drinking-bouts whereat Master William, a captive taken in Hungary, served as chief butler, officiating at the tree which he had devised to pour forth intoxication. The ambassador of the Caliph of Bagdad came in state, carried upon a litter between two mules. Before the Khan, rich and poor in multitudes moved in procession, dancing, singing, clapping their hands. The guests brought gifts to the monarch. Those of the ambassador of the Turkish Soldan were especially rich, but for quaintness the Soldan of India scored. He sent eight leopards, and ten hare-hounds taught to sit upon the horses' buttocks as do cheetahs. Manifestly it was no raw encampment of barbarians, this Caracorum of Mangu Khan.

If the Mongol's Court could, in 1253, show this degree of "pomp and pageantry," how much was it exceeded by that of Kublai the Magnificent, visited and told of by Marco Polo.

Kublai had established a second seat at Shang-tu, and had built not merely a court, but a city. His palace was of marble, its rooms aglitter with gold. Art had come, and the ceilings were painted with figures of men and beasts and birds. Trees of all varieties, and

flowers, were executed with such exquisite skill as filled the traveler, familiar with the best products of Italy, with amaze and delight. Sixteen miles of park, enclosed by a wall, embosomed the palace. Rivers, brooks, and luxuriant meadows diversified the landscape, and white stags, fallow deer, gazelles, roebuck, rare squirrels, and every variety of attractive creature, lent gayety and charm.

The Khan rode weekly with his falcons. Sometimes a leopard sat a-croup behind him, and was loosened at the game that struck his fancy.

The tale runs on of the Khan's silk-corded pavilion in the grove, gilt all over, and having lacquered, dragon-pedimented columns; of cave-born rivers running deep below the ground; of treasured gems and gold.

No wonder that Coleridge's imagination was warmed to his dream poem.

In Xanadu did Kublai Khan A stately pleasure dome decree, Where Alph the sacred river ran, Through caverns measureless to man, Down to a sunless sea.

London's tortuous streets were to wait two hundred years for their first pavement, when Cambaluc's were so straight and wide that one could see right along them from end to end, and from one gate to the other. In the Khan's parks, the roads, being all paved and raised two cubits above the surface, never became muddy, nor did the rain lodge on them, but flowed off into the meadows.

In addition to civilization's wealth and magnificence, the Mongols had developed a well-organized government. The Khan's twelve barons exercised his delegated authority, as does a modern cabinet in behalf of the national executive. Cambaluc was policed by a thousand guards. The city wards were laid out, for taxation and government, in squares like a chess-board, and all these plots were assigned to different heads of families. The military roads were constantly kept up by a large force. The Emperor had ordered that all the highways should be planted with great trees a few yards apart. Even the roads through the unpeopled regions were thus planted, and it was the greatest possible solace to travelers.

The post, too, was as thoroughly organized as Napoleon's. The messengers of the Emperor, bound in whatsoever direction from Cambaluc, found, every twenty-five miles of the way, a relay-station. Where the route lay through uninhabited deserts, the relay-posts were made houses of sojourn. At all stations express messengers were in readiness, as links in the system for speeding dispatches to provincial governors or generals: they were equipped with the fastest horses, which stood fresh and saddled, ready for an instant mount. The men wore girdles hung with bells; when within hearing of a station came the sound of jingling and the clatter of hoofs, the next man similarly provided would leap to his horse, take the delivered letter, and be off at full speed. The post covered a full two hundred miles by day, and an equal distance by night. Marco Polo states that, in the season, fruit gathered one morning at the capital, in the evening of the next day reached the Great Khan in Shang-tu--a distance of ten days' journey.

Organized charity was instituted by the Mongol Khan for Cambaluc. A number of the poorest families became his pensioners, receiving regularly wheat and corn sufficient for the year. The nomad levied as tribute a tenth of all wool, silk, hemp, and cloth stuffs, and had therefrom clothing made for the indigent of his capital. He had a banking system, paper money, a wonderful military discipline, advanced astronomy; and he opened the Grand Canal to the commerce of the ages. When one recalls the epoch at which all this existed, and realizes that at that time wolves and robbers disputed mastery of the streets of Paris; that the Saracens were lords of half of Spain; that Wycliffe had not yet published his Bible, and that French was the language of the English law courts,--the advance attained is hardly short of marvelous.

In nothing whatsoever is the Mongol civilization more remarkable and contrasting than in its religious toleration--the last acquisition of a civilized state.

While the Christian King of France was engaged in earning the title of "Saint Louis" by extirpating a people of whose creed he disapproved, his envoy, the friar, came to a country which had attained complete religious liberty and toleration. There were "twelve kinds of idolatries of divers nations." Two churches of Mahomet preached the law of the Koran, and one church of the Christians proclaimed the gospel of the Christ.

He found his own creed treated with especial courtesy, the Great Khan subscribing two thousand marks to rebuild a chapel on the behest of an Armenian monk. He relates that the privilege was accorded to the Church of trying any of their number accused of theft; that the Khan's secretary and his favorite wife were Christians; that a chapel was allowed them within the court enclosure;

and that the Nestorians inhabited fifteen cities of Cathay and had a bishopric there.

Marco Polo found the same indulgent tolerance of his religion. In Calaci, the principal city of Tangus, the inhabitants were "idolaters," but there were three churches of Nestorian Christians. In the province of Tenduch, formerly the seat of Presbyter John, King George was a Christian and a priest, and most of the people were Christians. They paid tribute to the Great Khan.

Indeed, if the Mongolian attitude toward armed nations combating in Christ's name has been implacable hostility, toward those of the faith who worshiped peacefully in their midst it has been uniformly tolerant, even favoring. The Nestorians, who brought their creed from Khorassan in the fourth century, had by 500 A.D. bishoprics in Merv, Herat, and Samarcand. The Perait Turkomans as a tribe accepted Christianity, and were unpunished. That the Faith was liberally treated in 781, under the Chinese, is self-acknowledged, on the ancient Nestorian stone of Si-an-fu. Headed by a cross, there is graven in Syrian and Chinese the Imperial decree of 638, ordering a church to be built: it gives an abstract of Christian doctrine, and an account of the "introduction and propagation of the noble law of Ta-t'sin in the Middle Kingdom." In Si-an-fu at this time there were four thousand foreign families, cut off from return by a northern inroad of fanatical Tibetans into Turkestan.

Another monument of 830, found near the site of the old Ouighour capital on the Orkhon, and carved in Chinese, Turkish, and Ouighour characters, mentions the Western religion. A strange sect of Hebrews of unknown origin found as well an unpersecuted home at K'ai-feng-fu, where the Mosaic rites could be performed. To this day a remnant survives.

The same tolerance for alien faiths marked Tatar rule in Russia. The Khan of Sarai authorized a Greek church and a bishopric in his capital, exempting the monks from his poll-tax. Khan Usbek in 1313 confirmed the privileges of the Church, and punished with death sacrilege against it. Kublai Khan took part regularly in the Easter services, and allowed the Roman missionaries to establish a school in Shang-tu.

Indeed, reviewing the whole sweep of Asia's religious history, one can hardly escape the deduction that if the greatest race of the greatest continent is idolatrous, it is not the fault of the Mongolians.

The Nestorian missionaries had an unsurpassed opportunity in the fourth century when their faith was new and burning, and the world was at peace. But stigmatized as heretics after a doctrinal dispute which had been settled by the logic of a street fight, in which Cyril's Egyptian bravos defeated the Syrian henchmen of the Patriarch of Constantinople, their mother church was driven out of the Roman Empire into Persia, where, cut off from the support of the main trunk of fellow Christians, their organization withered away as a lopped branch. The chief congregations in Iran and Turan were overwhelmed by the Mohammedans, until at length there were left only the dwindling congregations in Mongolia, and such communities as those on the Malabar coast in India.

To-day one hears of interesting discoveries. Now it is of the old buried Christian strata among Turkomans of Samarcand, of doctrines preserved through the fury of Islam fanaticism by families that have secretly transmitted Christian worship through the centuries. Next it is of Nestorian monks in Asia Minor, startled at being able to read the characters of Ouighour inscriptions, relics of the writings which their predecessors carried to Mongolia. But for all practical purposes the Nestorian labors, once so promising, are as if they had never been.

Another supreme opportunity for Christianity came when Kublai Khan, in 1268, sent west by the Polo brothers for Roman missionaries to teach his people.

"The Great Khan, ... calling to him the two brethren, desired them for his love to go to the Pope of the Romans, to pray him to send an hundred wise men and learned in the Christian religion unto him, who might show his wise men that the faith of the Christians was to be preferred before all other sects, and was the only way of salvation.

"After this the Prince caused letters to the Pope to be written and gave them to the two brothers. Now the contents of the letters were as follows: He begged that the Pope would send as many as an hundred persons of our Christian faith; intelligent men acquainted with the seven arts, well qualified to prove by force of argument to idolaters and other kind of folk, that the law of Christ was best; and if they would prove this, he and all under him would be Christians."

In the advance of Christianity the steps ahead have been made not so much by the conversion of the people as by the winning of their rulers,--Constantine, giving to Rome's legions the standard of the Cross; Clovis; Ethelbert; Vladimir, who drove the whole population of Kiev naked into consecrated water of the Dnieper; Charlemagne, moving against the Saxons with his corps of priests. Where these spoke for a hundred thousand souls, Kublai spoke for a hundred million. He was able to deliver; it was the Pope who

did not rise to the occasion. In all Christendom Gregory could find but two priests to go with the Khan's messengers, and these turned back in the midst of the journey, alarmed by the prospect of its hardships. The Khan, who wished some religion, sent to Tibet, and received the Buddhist missionaries whom he requested. So China, Mongolia, Tibet, and eastern Turkestan are Buddhist to this day.

Yet once again the Christian opportunity came. The way which had been opened into China by Matteo Ricci had been followed by Jesuit missionaries, until at the beginning of the seventeenth century there were two churches in Peking, some three hundred thousand converts in the Empire, and the favor of the Emperor Hang was with the Western faith.

When Christianity was spreading with cumulative rapidity, the Dominicans and Franciscans came in and denounced the Jesuit workers for tolerating the ancestor-cult of the Chinese, and for permitting God to be called "Shang-ti." In vain the Emperor Hang, appealed to by the Jesuits, declared that by "Shang-ti" the Chinese meant "Ruler of the Universe," and that the Confucian rites were family ceremonies and not idolatry. The rival friars persuaded the Pope to proclaim "Tien-chu" the proper Chinese word for God, and to condemn all ancestral ceremonies. Thereupon, the Chinese Emperor, rebuffed and disgusted with all the wrangling fraternities, condemned the Christian religion and killed the friars, save those whom he wanted for the Imperial Observatory.

One cannot but recall an early commentary made by Mangu Khan upon the jarring Christian sects whose rival dogmas have prevented, and do to this day, the common progress.

"We Mongolians believe that there is but one God, through whom we live and die, and we have an upright heart towards Him. That as God hath given unto the hand fingers, so He hath given many ways to men. God hath given the Scriptures to you, and ye Christians keep them not. But He hath given us soothsayers, and we do that which they bid us, and we live in peace."

For some years after Kublai Khan's death, the Mongol Empire held its preëminence by inertia rather than by strength. Each of the khans had his kingdom. Presently the nations that had been subdued began to rise against the numerically small garrisons of Mongolia. In China, the young Bonze, Chu-Yuan-Chang, finally organized a band of Boxers, and succeeded in driving out the last degenerate Mongol khan from Peking. He united the old eighteen provinces and established the Ming Dynasty, the tombs and palaces of whose kings are still the most celebrated structures of China.

In Russia, Dimitri of the Don gathered one hundred and fifty thousand men and defeated the Mongols at Kulikovo.

If the old supreme monarch of the north had lost his sway, in the south the Mongol race was being lifted to its second period of empire under Tamerlane, the Iron Khan. His was the history of the first Mongol conqueror repeated. The ant that Timur watched during his exile, which fell back and returned sixty-nine times before it carried its grain of wheat to the top of the wall, was the symbol of his early career. Constant obscure tribal conflicts, unsuccessful at first, led finally to a gathering of the nomads into a terrible invading army. The Golden Horde was hurled against Dimitri, defeated him, and marched upon Moscow. It was sacked with the horrors of Genghis' days, and all Russia was ravaged to the Don and the Sea of Azov. One of Tamerlane's armies traversed the Pamir into India, and, by the capture of Delhi, opened the way for the Mogul Dynasty of his sons, which was to endure until the Indian Mutiny. His Indian army, returning, swept a swath of desolation through Persia, Mesopotamia, Syria, Georgia, and Armenia. Every city that was taken was sacked, and the event commemorated by a pyramid of skulls embedded in mortar. One hundred and twenty pyramids marked Tamerlane's path through India alone. The Delhi pyramid was made from the skulls of one hundred thousand slain "with the sword of holy war."

Bajazet, Sultan of the Ottoman Turks,--themselves sprung from a nomad Mongol tribe,--was threatened by Tamerlane on the west. In a great battle Bajazet was defeated.

Alhacen, Tamerlane's Arabian secretary, relates that the conquered king was examined by his master.

"Wherefore dost thou use so great cruelty towards men? Dost thou not pardon sex or age?"

Bajazet might logically have responded with a "tu quoque," but his position did not warrant it.

"I am appointed by God to punish tyrants," continued Tamerlane. He had an iron cage made; and locked within it like a linnet, the unfortunate sultan was carried from place to place, because, in the Tatar's naïvely quoted words, "It is necessary that he be made an exemplary punishment to all the cruel of the world, of the just wrath of God against them."

The invasion of China was under way, in 1405, when Tamerlane died, leaving a renewed Mongol Empire, which stretched from the Hoang-ho to the Don, and from Siberia to India.

Here again the descendants of the savage conquerors rose to the requirements of their sovereignty and obeyed the peaceful and humane maxims that each of the two great and warlike and pitiless tyrants had bequeathed to his successors. They ruled with a fair degree of wisdom and a large measure of success. A descendant of Tamerlane was to build at Agra, in 1630, the most splendid monument the world has ever seen, the Taj-Mahal.

In the century after Tamerlane's death the Hordes split up once more, Ivan the Great of Moscow, having consolidated many neighboring princedoms, with the nominal consent of his Tatar overlord, at length seized the opportunity to refuse the payment of tribute. The Mongol Khan had no longer the power to compel it at the sword's point, and without a battle the Tatar supremacy was covertly relinquished. In 1480 the long servitude of Russia to the alien invader was ended. From this time the Mongol nomads appear hardly at all in history. They withdrew gradually to their Asian steppes, leaving in Turkey, in the Crimea, and in India, the kingdoms of their offshoot tribes. Russia and China still felt the raids of the horsemen, for the khans of the Golden Horde were yet not to be despised.

Fernan Hendez Pinto, the shipwrecked Portuguese of the generation after Vasco da Gama, was in China in 1542 when Tatars came down and besieged it. He saw "an emperor called Caran whose seigniorie confineth within the mountains of Gen Halidan, a nation which the naturals call Moscoby, of whom we saw some in this citie [of Tuymican], ruddie, of big stature, with shoes and furred clothes, having some Latin words, but seeming rather, for aught we observed, idolaters than Christians.

"To the ambassador of that Prince Caran, better entertainment was given than to all the rest. He brought with him one hundred and twenty men of his guard, with arrows and gilded quivers, all clothed in chamois-skins, murrie and green. After whom followed twelve men of high giantlike stature, leading great greyhounds, in chains and collars of silver."

When Yermak cleared the way to Sibir, and opened the path that was to lead to the Pacific, the Mongols were pushed south. Russians still had Tatars all along their frontier, but these were pressed steadily back as the Slavic race advanced eastward. The Tatar domains were restricted soon to the steppe country and Mongolia.

After Yermak's time the Mongol power sank. It fell further when the Manchus established their dynasty in Peking in 1644. So low had its estate become that even the old fighting instinct was gone,--all the passionate desire for independence that has been the Mongols' birthright since the dawn of history. How had it vanished? Christianity had not come. Buddhism had come, and it was the tolling of the knell for freedom.

The sum of national energy and the heat of the new dispensation were diverted into theocracy. The meaning of life, its value and its duty, these basic ideas which determine the ultimate activities of every race, were revolutionized by the new faith. To the Pagan the world was good despite its evils; struggle against environment measured the worth of manhood and freedom was the supreme blessing. To the Buddhist, life was an evil in which the soul had become enmeshed. The path to release lay not in overcoming the environment, but in retreating from it within the citadel of the soul. Resignation, self-surrender, the yielding of this world to secure the other world beyond,--such were the forces which transformed the Mongols from the foremost warriors into the priest-ridden, subject, unaspiring people of to-day. The supreme problem in the autonomy of China, and in the subjugation of India, is involved in the point of view of Buddhism and its outgrowth in character.

In 1650 a son of the leader, Tu-she-tu Khan, was made chief of the Mongol _kutukhtus_, or cardinals, with the title of Cheptsun Damba. This monsignor began the Urga hierarchy of Gigins, or god-priests, which has continued until the present time, when the eighth Gigin reigns at the Holy City. As the powerful Tu-she-tu clan lost its vitality, Chinese influence made itself felt. This was directed in general toward the encouragement of the priesthood, whose celibacy and other-worldliness dovetailed with Chinese control.

The Mongol khans, becoming through the years more and more unwarlike, had grown tired of internecine feuds. They were at last won over by China to a nominal allegiance and the payment of a formal tribute, reciprocating which, imperial gifts of tenfold value served as artful bribes. Modestly, diplomatically, came King Stork, leaving to the local Daimios, seemingly undisturbed, their feudal sway. With the coming of the first Manchu governor began the present era of Mongolia.

[Illustration: THE GLORY IS DEPARTED]

As time went on, the Chinese, more astute and cunning, took little by little from the careless hands of the nomad princes the reins of real political power. The native chiefs were wheedled into giving up many ancient rights over the vassals, as well as their general taxing powers. The celibate priests, who were draining the manhood of their idle but powerful hierarchy, were subsidized and directed by the interlopers. They preached to their confiding countrymen obedience and submission. In the Mongol Gigin of Urga, the Chinese raised up a native power superior to all the old feudal lords, whose armies melted away beneath the ecclesiastical dominion. When the Gigin became in turn too great a menace, they caused it to be decreed that each succeeding incarnated Buddha must come from Tibet, and that his main powers must be delegated to a "Council of Lamas."

In the train of the Manchus came the Chinese traders, polite, supple, calling themselves friends of the Mongols, offering their alluring wares on undefined credit terms which tangled the unsuspicious natives in inextricable usury. Peking-brought gewgaws were paid for a hundred times over in the food and clothing which the natives kept giving to the compounding voracity of the debt.

Chinese coolies pressed up the river-valleys, begging land here, intruding themselves there; more followed, and ever more, until the best of the pastures were filched away, and the nomads, in order to exist, were forced to trek to the more distant and barren slopes. Deforesting transformed into deserts whole provinces. The once famed virtue of the Tatar women is forgotten, and every Chinaman has his "friend" whom he leaves behind when he returns to his native land. The big prosperous Mongol families, that early travelers noted, are no more. Two or three children are the most that one sees to a _yurta_, and the population, owing to lama celibacy and the decreased means of subsistence, is declining from year to year.

This is the people and this the land which sent horde after horde through centuries to conquer the world; where in half a dozen generations a little band of blacksmiths like the Turks could breed a nation that would dominate Asia. With narrowing means of subsistence, and aliens draining their small surplus capital, the Mongol race lies prostrate beneath the Yellow Empire. The grim Malthusian tenet that the world cannot give food for all its children falls short here of the grim actuality. The silent invasion of the Chinese has been as ruthless as was the march of Genghis Khan. The economic garroting of a race is what the world has seen in Mongolia.

No longer are there men to lead or men to fight. Obediently and submissively the once fierce, ranging warriors have yielded to the artfully-imposed yoke. The army of unmatched cavalry has become a memory, and a nation of fighters has become a race of timid herders, with little heart or brain. The sons of the old soldiers have learned to shave their heads and croon Tibetan prayers, and the fires of a people's ambition are quenched in the creed that makes abstention from effort a cardinal virtue, and annihilation life's supreme objective. What there was of virtue and of valor lies buried in distant graves. Ringed with the bones of slaughtered captives, rusted swords at their sides, they sleep well, those old forgotten warriors. In poverty and hardship, priest-ridden and debt-ridden, decimated and degenerated, their descendants eke out their sterile days. But there lingers yet among them a half-forgotten memory of the heroic past. The wandering chanter still sings in the twilight the old "Song of Tamerlane"--Tamerlane who will come again, they say, and lead the hordes once more to victory.

When the divine Timur dwelt in our tents, The Mongol Nation was redoubtable and warlike. Its least movements made the earth bend; Its mens' look froze with fear The ten thousand people upon whom the sun shines. O Divine Timur, will thy great soul soon return? Return, return; we await thee, O Timur!

IX

CHINA

Destiny has bequeathed to his once subject-race the heritage of Genghis Khan, but whether its Manchu possessor can or cannot hold even his own birthright is to-day an enigma. The last few years have seen the gathering of the eagles, disputing the mastery of eastern Asia, where China stands against the world. Slav, Saxon, and Frank press in, upon the supine empire. Has this yellow race the manhood and the capacity to rally against them and retrieve its national integrity?

The cession of Formosa after the war of 1895 began the partition. China's defenselessness was then visualized. The revelation of her easy defeat set every predatory nation on the alert. Watchful for an occasion, which two murdered missionaries supplied, Germany, by clumsy but successful unscrupulousness, seized Kiao-chow and two hundred miles of hinterland. Three weeks after the bludgeoned ratification of Admiral Diedrich's grab, Russia procured the signature of the intimidated Emperor to the lease of Port Arthur. France demanded and secured the cession of Kwang-chow-wan, on the mainland opposite the island of Hainan. England acquired the lease of Wei-hai-wei, and continental territory opposite Hong-kong. Italy came to claim as its portion Sanmen Bay; but

this at least China found courage to refuse.

Then followed a period when, backed each by its government, invading cohorts of promoters scooped in franchises and special privileges of every description. The latter part of 1899 saw foreigners pushing in from Manchuria on the north, where Russia with her so-termed railway guards held the strategic route, and from Yun-nan on the south, where France was constructing a similar road of conquest. It showed four European nations so established along the coast that only by courtesy of a foreign government could a Chinese vessel cast anchor in some of the principal ports of China. It saw a Belgian-French railway driving from Peking into the heart of the Empire at Hankow; an American line started north from Canton to the same objective; an English line controlling the territory between the main northern trade-centres, Niu-chwang and Tien-tsin; a French society in possession of a great south-country copper concession; Russians with the exclusive right to all the gold in two _eimucks_ of Mongolia; and an English syndicate deeded the best of the Chinese coal-fields.

The partition was thus far accomplished. The continental nations seemed to be ready for all that they could get. The strength of Great Britain's traditional position, based upon maintaining the integrity of China, was shaken by her lease of Wei-hai-wei, although this lease was to run only so long as Russia should hold Port Arthur. England was on the point of recognizing openly "spheres of influence," as is shown by the inferential claim to special British rights in the Yangtse region set forth in the official transactions of Sir Claude McDonald, and brought out under parliamentary interpellation, when a Secretary of State for Foreign Affairs in the Balfour Ministry spoke of "British rights" to the provinces adjoining the Yangtse River and Ho-nan and Che-kiang.

There was apparently good warrant for the general belief that in expectation of an impending partition a provisional understanding had been reached by the different chancelleries, regarding the share of each nation, England being allotted the mighty domain from the Yellow Sea to Burma and Afghanistan, including all Tibet, as well as six hundred and fifty thousand square miles in China proper. In general, from Shan-tung inland the valley of the Hoang-ho was destined for Germany; the district north of her Anamese possessions for France; all Mongolia and Manchuria for Russia; Corea and the province of Fokien on the mainland opposite Formosa, for Japan. Peking and the surrounding district, whose disposition was embarrassed by jealousy if not by scruples, was alone left for the Chinese.

At this critical juncture, when the day of dismemberment seemed indeed to have arrived, the United States came forward in behalf of the "open-door" doctrine, as a means of preserving the nationality and the integrity of China. In a circular letter to the Powers, our Secretary of State, Mr. John Hay, asked that adhesion be given in writing to three main propositions, appertaining to each country "within its respective sphere, of whatever influence." These points were that no treaty port rights or other vested interests should be interfered with; that the Chinese tariff should be maintained; that no discriminating railway charges or harbor-dues should be imposed.

America's might, thrown into the wavering balance, turned the scale. Great Britain gave ready adhesion. Though the responses of some of the other Powers were evasive, none was at this time willing to bear the onus of an adverse stand: each nation nominally accepted, and the movement toward partition was checked.

To most people Chinese matters seemed settled. The preservation of a nation had been combined with the guaranteeing of a great free market; the orgy of grabbing had ceased. Russia, assenting to the open door, had promised to evacuate Manchuria. The special concessions, though secured by stand-and-deliver methods, it was felt would bring economic improvements and would furnish to the Chinese a demonstration of the beneficent results of Western civilization.

It was recognized that there would be frictions: misunderstandings are inevitable when old ways are faced with new. The extra-territorial rights of foreigners and their converts, absolutely necessary to protect their liberties if not their lives, could not but create occasional unharmonious situations, in which the consuls would have to intervene. The severity of the judicial punishment meted out at times to rioting cities for harm done to the protégés of the Powers was to be deplored, each nation grieving at the atrocities the others had seen fit to perpetrate.

But periodic local and temporary disturbances had been going on from time immemorial. Did not the Chinese realize, we reasoned, that their old corrupt government had been given another undeserved chance to try and march with the rest of the race; that this world is not the place for graft-ridden relics from the fifth century B.C.? The least we felt was that, thanks to the bearer of the "Flowery Banner," the Chinese had been given a last opportunity. A self-denying Occident had guaranteed the nation's existence and had presumably earned its everlasting gratitude. "Let China get up and do something--let it redeem itself."

[Illustration: THE BRIDGE AND TABLETS IN PEI-HAI]

A very small circle of Chinese shared this Western view, and realized at their true value the mights if not the rights. There existed among the literati at Peking and in the coast cities the rudiments of a foreign liberal party. Recognizing that Western methods must come, they had been in favor of accepting foreign improvements even at the cost of railway concessions and the violated dwellings of wind and water spirits. When this party won over the young Emperor, there began the period of foreign concessions. Reforms, too, covering every subject, from queue-cutting to postage-stamps, were inaugurated.

The summer of 1898 saw the important edict which ordered the abolition of the Wen-chang essays and the penmanship posts, with the Emperor's personal comment that the examinations should test "a knowledge of ancient and modern history, and information in regard to the present state of affairs, with special reference to the governments and institutions of the countries of the five great continents, and their arts and sciences." A Bureau of Mines was established, a patent-office, schools, a scheme of army reform.

The climaxing decree was the one abolishing sinecures. For the Emperor's unreconstructed entourage this last was too much. Foreign aggression had embittered to the point of unreason mandarin and coolie alike. The _coup d'état_ planned by the Dowager Empress, and executed by the reactionaries, virtually dethroned the Emperor, exiled his advisers, and ended the foreign-encouragement reform.

Indeed it was not within human nature for it to endure. From the point of view of the party of the second part the aspect of the whole foreign relationship, even after the Hay Note, looked very ugly indeed. The fact of guaranteed integrity was obscured by the _laissez-faire_ of the already consummated grabs. The idea that gripped them was the humiliation of foreign occupation and foreign aggression. It was as if the Russians and the English had just seized rival reservations on Long Island and the Jersey coast, commanding New York City; as if the English had wrenched away Charleston; the Germans, Philadelphia; the French, New Orleans; and Cossacks were garrisoned in strategic points throughout New England. It was as if the New York, New Haven and Hartford Railway were manned and guarded by Slavs, the New York Central by Belgians, the Pennsylvania by Prussians; as if the Pittsburgh mines were handed over _en bloc_ to an English corporation, and the Russians had exclusive mining rights to the gold of Alaska's Yukon region. It was as if America's protective-tariff and contract-labor laws were repealed at foreign dictation, and a flood of foreign machine-made goods and undesired immigrants were poured into the unwilling country. It was as if yellow-robed Buddhist lamas were everywhere haranguing the Yankee farmers, telling them of the fraudulent nature of the Christian creed, and urging upon them an approved canine method for disposing of deceased ancestors, to replace their superstitious funeral services. It was as if astrologers, calling themselves engineers, were to dig up New York cemeteries in order to erect prayer-wheels; as if the apostates whom these yellow priests had drawn into their joss-houses were enabled to dodge part of the taxes, which consequently fell with added oppression on the rest of the people; and as if, when they did something which others would in the normal course of events get punished for, a lama came before the magistrate and got them off. As if the President and the Senate were given a weekly wigging by the diplomatic corps, and were periodically forced to deed away sections of the forest reserve and tracts of particularly desirable territory.

With such an aspect as this, which represents what in an undefined, bewildered way the Chinese saw and felt, it is no wonder that they considered the Confucian dictum obsolete: "Do not unto others, what you would not that they should do unto you"; and joined the patriotic harmonious Fists,--the Boxers.

Chinese sentiment was ungauged in the West because we had never put ourselves in their places. Unforeseen save by a few unheeded Cassandras, and unprepared for, there broke out the planless, leaderless Boxer Rebellion, grim fruitage of the national resentment. A few hastily gathered legation guards were alone available for defense. Spreading from the Shan-tung Province, where the severity of the Germans had goaded the usually peaceable people to madness, the I-Ho-Chuan besieged the legations at Peking. It was the infuriated and ill-directed rush of a patriotism real if futile,--a turning against the spoilers.

The movement was crushed in a torrent of blood, and with a devastation that for long will leave its mark upon the northern provinces. The closing year of the nineteenth century saw the Taku forts stormed, Tien-tsin, the Liverpool of the North, taken over and administered by a foreign board, Manchuria and Mongolia swarming with Cossacks, the Dowager Empress in flight, and her capital looted by foreign armies.

The coming of alien soldiery to the Forbidden Palace left its impress in the fiercer though more carefully smothered hatred of mandarins and people. It was still a blind resentment. They were injured, stung in all their pride and self-sufficiency, but dumb, bewildered, not knowing what to do, which way to turn. The liberals with their solution were gone; with them had passed the hopes

of a progressive policy.

The people, perplexed, looked to their reëstablished reactionary rulers for guidance. But these officials, mostly of advanced age, and steeped in the ideas and ideals of the Confucian classics, were anxious mainly to close the ears and eyes of the masses to the unpleasant realities; to feather their own nests and finish off their lives in tranquility.

The Chinese Minister to the United States, Wu Ting Fang, gives a graphic picture of these Celestial Bourbons:--

"It must be remembered that most of the high officials in Peking are born and bred Chinese of the old school. All the princes and nearly all the ministers of state have spent most of their days within the four walls of the capital. They have never visited even other parts of the empire, not to say foreign lands; nor can they speak any other language besides their own. They have absolutely no knowledge or experience of foreign ways except those who are ministers of the Tsung-li Yamen, and the experience of these men has been confined exclusively to their official intercourse with the foreign representatives at Peking."

Buttressing their hereditary _intransigeance_, these mandarins had, after the Hay Circular, possessed a measure of confidence that their yielding of open-door trade privileges to the greed of the foreigners had enlisted a combined support which would preserve China's remaining national powers.

But so powerless to fulfill their purposes had these paper pledges become, so far was the open-door doctrine from settling the situation, that in China's own territory, where by solemn promises of both parties no special privileges could accrue, the year 1904 saw two Powers in the throes of the greatest war of modern times.

If the realization of the combatants' purpose has signified much to the nations of the West,--perhaps rather to the United States, for the others nursed no illusions,--to China it has meant far more. It has brought for the first time a real and general appreciation of the necessity for modernized, efficient self-defense.

Fifteen years of aggression have been needed to drive home this knowledge. While the defeats of 1895 came as a blow to a few keen-minded Chinese, to most they were a matter of entire indifference. China was not conquered, they reasoned: only two provinces took part while the viceroys of the rest looked idly on. "That Shan-tung man's war" was the general attitude; "Li Hung Chang's boats beaten." When it was over, merely Formosa, the little-valued island of "tame barbarians," had been lost. The traditional policy of playing off the jealous powers one against the other had apparently succeeded; it had cleared the Japanese from Corea and Port Arthur. China as a nation was hardly touched, and multitudes of people never knew there had been a war.

The seizures of 1897-1899, coming close upon each other, exasperated, but taught no lesson. The mass of Chinese, and even those in high official circles, believed that a little effort would drive the foreign devils into the sea. The march of the Allies to Peking stunned them. It was their first facing of the fact.

[Illustration: HSUEN-WU GATE, PEKING]

The Russo-Japanese War, and the partition of the province that had cradled their Emperor's dynasty, dissipated their fool's paradise. It was seen then, clearly, by all, that China's only hope of maintaining her integrity lay in her defensive power. With the object, not of securing the blessings of civilization (which the overwhelming majority of Chinamen desire no more than we do the Holy Inquisition), but of beating away the spoilsmen, the Peking rulers turned at length to the survey of their actual military condition. As this concerns intimately the Chinese internal situation, a summary of it may be pertinent.

The Hwai-lien regulars, to the number of twenty-five thousand, are well-drilled, and well-armed with Chinese-made Mausers. They are stationed in the northern provinces, including the Taku and Peht'ang forts, the Tien-tsin station, and the neighborhood of Peking. These make up the only national force of modern troops at the disposal of the Chinese Government, but the private armies of various viceroys bring up the total somewhat as follows: The camps of foreign-drilled troops, formerly Yuan Shi Kai's, probably the best in China, number roundly twenty thousand. From the Shen-ki Ying, or artillery force, from the camps of the Manchu Banners, which the Government is making an effort to whip into some kind of shape, from the Imperial body-guard, and other scattered and less important troops, ten thousand effectives might be culled. In the south the Viceroy of Nanking has, all told, some twenty thousand more men holding the Wusung forts, who may be classed as efficient and well-armed; some of these are German- and Japanese- drilled. This total of seventy-five thousand represents China's numerical military strength in effective modern troops.

The old hereditary organization of twenty-four Banners, adds some two hundred thousand Manchus, Mongols, and Chinese,--of the privileged soldier caste, which through two hundred and fifty years has drawn an annual subsidy of eight million taels from the

Peking treasury. Billeted as the nominal wardens of the provincial cities and garrisoned around Peking, these Tatars have become as a rule so degenerated by immemorial idleness as to be useless save for picturesque parades. The one positive element is that they are men under pay, subject to order, and available for initial experiments.

The Green Banner, or militia, under the command of a general for each province, is theoretically composed of a large number of native Chinese. The army is made up mainly of officers. The higher officials of the Green Banner acquire the pay, commissary, and weapon-allotments of their nominal armies, and pad the rolls with the names of coolies who come out for the annual review in return for the small portion of their nominal wage which must be spent to keep face.

To expect these men to get out and fight is obviously more than they bargained for. The Green Banner can deliver about the same relative number of actual soldiers per unit of population that a Mississippi backwoods county polls for the Republican party. The most that can be said for the Green Banner is that it has a list of men's names from which a certain number of real recruits might be obtained.

The military organization of even the best regular troops is feeble. Constant word reaches the press of soldiers revolting for lack of pay. In one such instance nine hundred men near the Manchuria border mutinied and were put down with difficulty, tying up the caravans for some time. Aside from questions of discipline, and considering number only, it is doubtful if, in the whole empire of four hundred million people, one hundred thousand decently armed and drilled troops could be gathered, in an extremity, for defensive purposes.

Drilled and armed men in whatever numbers are, however, but one element of a country's defensive power. Organization, transportation, commissary, and supply are factors of hardly less importance. The troops that get there are the ones which count, and even a Chinese army marches on its belly. Russia's defective transport, to mention but one case, undoubtedly decided both the Crimean and the Japanese wars. The question of territorial defense is one of several dimensions, first of which is how soon could a given force, with its necessary commissary and ammunition-supply, be disposed along the various lines of possible attack.

Making the round of the Chinese Empire, it is apparent that Tibet and Mongolia, for all the resistance that could be made, might be taken by England and Russia respectively whenever they were minded to cross the border. The Chinese could throw out barring columns no further westward than Sze-chuan, no further northward than the Great Wall.

On the frontier of Corea, the Yalu River formerly defined the first line of defense. But this frontier has been moved westward by the Japanese, so that it would be a political impossibility to put men there even were it practically possible. The present line would of necessity be between Shan-hai-kwan and Yung-ping. Perhaps withdrawals from the northern provinces, the viceroys permitting, might admit massing here fifty thousand troops. But this, as well as any other possible line, is entirely unfortified, giving hardly more advantages to the repelling than to the attacking forces. There would be no second line of defense, nothing to fall back upon but the old Tatar Wall of Peking. Beyond this fifty thousand any quota brought from the south would consume a very considerable time, probably a month, even allowing that their semi-independent viceroys did not discreetly hold off altogether.

Further east, at Shan-tung, Germany's railway pierces to the heart of the Confucian province; while from the Chinese military centre in Chi-li there is no corresponding railroad, Chinese-manned, giving them access, were it necessary to repel aggression. The Anamese railways afford the French means of bringing up troops, where China could assemble an army only after weeks of marching. The Burmese frontier of Britain's dominion is similarly vantaged.

The German _Land-Wehr_, while the first armies go to the front, may be called out and mobilized, until the whole manhood of the nation is in arms. Such a body is nonexistent in the Celestial Empire. Like her own lichee nut, once the frail shell of her resistance is broken, the meat is ready for the eating. Considered solely from the military standpoint, aside from reform as such, China is as supine as a huge helpless jelly-fish, with disconnected nerve-ganglia, and not even the rudiments of a backbone.

For the first requirements of national defense, what is necessary? For the north there should be a thoroughly drilled and equipped regular army of at least one hundred and fifty thousand men, with capacity for rapid concentration in the neighborhood of Peking. For the south a standing army of at least fifty thousand men. An intermediate army of fifty thousand more should be available near Hankow, capable of being thrown either way. The Peking-Hankow railway line must have strategic branches to Canton, Shanghai, Yun-nan, and Shan-tung. These must be controlled not by foreigners but by Chinese. There must exist a reserve of, say, five hundred thousand men, at least partially drilled, from which to draw reinforcements. There must be arsenals able to make all the weapons and ammunition for these forces, since foreign nations will continue to command the sea. The sums needed to realize

such a programme must be available, and China must possess the organization and fiscal system for the conduct of a war. From this summary it may be seen that adequate defense requires a measure of increase in her efficiency that is revolutionary. The demand which such measures would make upon any nation is stupendous. How much more would it exact of China, where for its accomplishment every single factor must overthrow the ideas, the principles, the very morals evolved through centuries in the most conservative race of the globe!

At the outset, for the personnel of such a regular army, two hundred and fifty thousand adults must be transformed from stolid, superstitious field-tillers and coolies, never of combative spirit, into courageous, disciplined fighting men. Can this be done? Some, eminently qualified to judge, answer that it can; but Chinese history has not for several thousand years furnished many glorious annals. Where a stark fight is recorded, as at Albazin, or against the Mongol khans in the sixteenth century, the warriors have been Manchus rather than Chinese. Whenever an aggressive nation, be it Hiung-nu or Khitan, Mongol or Manchu, British or Japanese, has gone against the genuine Chinaman, the latter has invariably submitted. It is only when his subjugators, absorbed into the swarming mass of conquered, have degenerated, that the native has been able to rise and drive out his enfeebled oppressor. The Chinese have conquered by time and their birth-rate.

[Illustration: PEKING Where the Allies' main assault was made]

On the other hand, the Chinaman has qualities which, translated into military virtues, should theoretically give him a great initial advantage over any other race. He is comparatively without nerves; he can hold a gun without a tremor for what to a Westerner is an inconceivably long time; he has good eyes and a strong sight; he can be victualed on a few handfuls of rice; he is entirely indifferent as to where or how he lodges; he is sober and reliable; he is a big-bodied man, stronger even, perhaps, than the Japanese; he is docile, obedient, and susceptible to discipline. Indeed, in all that concerns his physical qualities and certain moral superiorities, one could not ask for better raw material. When well led he has at times done very creditably. A generation of such leadership as Yuan Shi Kai's would do not a little toward bringing out what there is latent in this people.

If in the army organization the gap between what is and what should be is so great, how much wider is it in the government organization needed to finance reform. The revenues of China are some $100,000,000. About $36,000,000 are allotted to military purposes. When from this has been deducted the eighteen million-odd which go to the generals of the Red and Green Banners, there is left, theoretically, about $18,000,000 for the real army. Actually there is efficiently applied probably not over $10,000,000. The regular army of Japan--two hundred and twenty-five thousand--takes $40,000,000 effectively expended. China must begin from the very bottom, whereas Japan is simply carrying along. A judicious total expenditure of at least $50,000,000 is needed for China's army. With the additional railway and arsenal programme, and other concomitant work, the demands over and above present outlays would reach around $110,000,000. Add this to the present budget, less the well-spent ten millions, and there is to be reckoned a total budget of at least $200,000,000.

Could China raise such a defense-fund on top of her present hundred-million-dollar budget? Could she cut down on present expenses to help it out? The latter might be considered. Theoretically the wasted army money of the present budget might be saved and applied. Practically the vested interests in the graft are so important as to make it of infinite difficulty. The mere beginning of sinecure-cutting cost the Emperor the actuality of his throne and nearly his head.

The list shows other items of expenditure which cannot be materially economized. The large and growing sum which goes to repay interest, foreign loans, and indemnities, cannot be touched, nor can the $16,000,000 sent to the provinces for their local expenditures. The $8,000,000 for the Peking salaries and palace expenses is a fixture. The modest and well-administered $3,000,000 of the customs expenditures, covering about all the public works that China undertakes,--the lighthouse and coast-patrol allowances, the mails, the interpreters' school,--this cannot be pared. The needed money must come if at all by increase of the receipts. One is driven irresistibly back to the Government's taxing capacity.

The physical possibility of such taxation undoubtedly exists. The per capita revenue which the Government receives from its four hundred million subjects is but twenty-five cents. The American per capita revenue is eight dollars, the Japanese five dollars, the Russian twelve dollars, the Indian--perhaps in conditions the closest parallel to the Chinese--one dollar and a quarter. An extra twenty-five cents would raise the Chinese Government well above all financial difficulties, and still leave the rate far below that of the other great nations of the world.

Looking at the actual mechanism for revenue collection, one is met by difficulties which have rooted themselves deeply into the system. One cannot squeeze any larger proportion of the needed sum than the present $25,000,000 from the Imperial Maritime

Customs. Tariff-rates are fixed by treaty, and the collections, under English direction, are as efficient as they can become. The likin duties on freight during inland transit are such a plague to commerce that, far from being increased, they should be swept away altogether as one of the earliest of reform measures. This $14,000,000 is produced at so heavy a price of fettered and thwarted commerce that added tariff would but aggravate the strangulation without materially increasing income. The opium revenue of $5,000,000 is likewise an item which, for the best interests of China, should disappear from a reformed budget, and the "foreign dirt" from the Celestial domain. In any event opium cannot be made much more productive.

After these eliminations there are left items which bring in $56,000,000. The sources consist principally of the land-tax, the grain-tribute, native customs, and the salt gabelle. The returns from these factors would require to be nearly trebled, if they were relied upon to make up the bulk of the needed total.

The method of collection is a further check to greater income. The existing machinery of fiscal administration operates, roughly, as follows: When the funds begin to run short for the usual expense-accounts, the various executive boards apply to the Board of Revenue. The latter makes a glorified guess at the sum which, considering harvests, rebellions, and other elements, each province might be able to pay. It is thereupon put to the provincial officials, consisting usually of a viceroy, a governor, a treasurer, and a judge, to supply something approximating this sum. The provincial syndicate, through the medium of various intermediate officials, such as the _tao-tai_ and the _fu_-prefect, whose powers are nebulous and overlapping, call upon the eighty-odd county magistrates for an estimated share. The magistrates, _shien-kwan_, called colloquially "father and mother officials," whose varied functions include rendering justice, keeping the jail, leading the religious processions, and collecting the taxes, send out each his hundred henchmen to get the actual money or grain. Of this hierarchy of officials not one has a salary which would keep his establishment going for a month. Of necessity the laborer must draw his own hire first from the harvest.

Under such a satrap system, by the grace of human nature, each official takes what the traffic will bear, letting pass to the man higher up enough to conciliate his claim and to keep face with Peking. If the penalties which follow deficient generosity to a superior define the maximum contribution, the minimum is fixed by the famine or the rebellion point. With this method in vogue, it is not unreasonable to assume that the amounts gathered in the first instance are about as great as can be wrung from the people. An increase of the Government's receipts would have to come through shaking down the office-holders for a larger share of their pickings. Such a revenue as a real reform would demand must despoil of vested rights in his livelihood every mandarin, viceroy, _tao-tai_, _fu_-prefect, magistrate, and petty publican in the empire. It might be practicable to commute the likin, or inland octroi dues, for fixed sums by agreement with the _hongs_, or merchant associations. This was done in Li Hung Chang's province, Kwang-tung, where $2,750,000 was paid in order to get rid of likin dues which netted only $670,000. Enough might be raised by this means to pay the officials at just rates. Then honest collections might reasonably be demanded, and a beginning be made of fiscal reform. But it is apparent from these outlines how long a way China has to travel before her capacity for self-defense is a reality.

The facts are now being comprehended by all classes. From the coast cities, a growing number of young Chinese have been sent to study abroad, mainly in Japan--as many as fifteen thousand in 1907. Returning, these so-called "students" have become the leaders in the boycotts against the United States and Japan. They have engaged actively in propaganda of a patriotic nature, and, more constructively, have translated into their mother tongue hundreds of books on history, economics, and law, including the whole Japanese code, Herbert Spencer, Huxley, Voltaire, Montesquieu, the "Contrat Social" of Rousseau, the works of Henry George and Karl Marx, and many others of the same general nature.

These movements show a widespread public opinion friendly to Chinese regeneration. Various administrative measures have been inaugurated which are yet more promising.

The old method of dividing the Peking Bureau into provincial departments, and letting each of these care for every sort of business from its special province, has been altered. Instead of a bureau having general charge over the salt-tax, the customs, and the appointments of each province, there have been organized ten departments, dealing each with its specialty throughout the entire realm. The five recently-created bureaus--Agriculture, Works and Commerce, Police and Constabulary, Post-Office and Education--tell by their names the centralizing purpose of the new régime. Formerly five hundred clerks attended a department, with office-hours from eleven A.M. to two P.M. including lunch, smoking-time, and due intervals for examining peddlers' wares. Now a much reduced force is employed, with actual working-hours generally from nine A.M. to four P.M. The foot-binding of children has been prohibited; pressure has been put upon the officials who smoke opium to abandon it, under penalty of dismissal from the service; classical essays as a civil-service examination subject are being given up, and the education of the Chinese youths abroad

is being encouraged. A large number of Japanese officers have been engaged to train the khaki-clad and well-armed Chinese regulars, who have shown excellent aptitude. The Government has bought back practically all foreign railroad concessions, and all the valuable mining concessions except the Kai-ping coal-fields.

Even representative government is well under way. The Dowager Empress's edict of August 27, 1908, by which a nine-year period was set for the devolution of legislative powers to provincial assemblies and a national senate has been justified by remarkable success. The local legislatures, elected under carefully restricted suffrage qualifications, have grappled earnestly with the economic problems of the districts. The senate, of thirty-two members, selected by the Prince Regent from an elected body, has not yet had time to show results, but the calibre of the men in it is encouraging.

China is making a real effort to get abreast of the times. But never was a nation brought more directly before the judgment-bar on the plain test of character. Upon the capacity of the race for private sacrifice and public honesty rests primarily her salvation. Whether China can or cannot rise to the task depends upon her own manhood, and no one can be prophet of the issue; for all estimate of Chinese character is perplexed by that curious Eastern subtlety of contradictions which baffle understanding.

The inability of the Chinese to keep fingers out of the public till is proverbial; yet the very high standard of business integrity is universally conceded.

[Illustration: SUMMER PALACE OF THE EMPEROR]

The quality of Chinese honesty is attributed by some to the local idea of good form, and the obvious mercantile maxim that future credit depends upon present performance. Bourse operators may be scrupulously exact as to obligations which the mere lifting of a finger imposes, while engaged in campaigns diverting to their private speculations the funds of a chain of banks, or looting the values from the minority owners of a street-railway.

Chinese business integrity is said to be due to the fact that her merchants are of the upper class; cowardice in war, to the fact that her soldiers are of the lowest caste. In Japan the condition is exactly reversed: hence the prowess of her Samurai, and the peccability of her clerks--such that Japanese bankers employ Chinamen to handle their money.

Since the Japanese have built up an effective public administration, it is fair to give the Chinese the benefit of faith, and to assume that in time they too will rally to the task, and make a modern state.

With this should come the Trans-Mongolia Railway: opening to the plainsmen of Central Asia a prospect of civilization and advance.

Equally or more important, looking at things broadly, it would give to the world the best of the great Asian trade-routes. Examine a globe and see what, in the shortening of distance, this land-route to Peking signifies. Note the enormous circumnavigations that must be made in going around by India and Suez, and measure then the direct overland route by the Urga Post-Road and the Trans-Siberian Railway.

The bulky freight from the Asian Coast to western Europe will still pay tribute to the sea. To compete with vessel-transportation, which carries a ton from Shanghai to London for seven dollars, the railroads over the 7283 miles from Vladivostok to Paris would have to make a rail-rate of one tenth of a cent per ton-mile; this is impossible when one remembers the average American rate of eight tenths of a cent. But North China, all North Asia, and Europe west of Moscow, are within the railway radius of an Urga-Peking line.

From interior China may be drawn the goods for half a continent. The tea-freight which Russia receives over the long sea-trip to Odessa, or by the trans-shipped Vladivostok route, can be loaded then at Kalgan on the car that goes to Moscow. By it the silks of the Tien-tsin merchants may be rolled through into the freight-yards of St. Petersburg, and the timberless cities of interior China may build with the wood of the Yakutski Oblast forests. By it the dwellers in the valley of the Hoang-ho, "China's Sorrow," may be nourished in their need with the wheat of the Angara Valley; the Manchu mandarins may be clad in the furs from the Yenesei; the ploughshares tempered in Petrovski Zavod break the ancient soil of the Chi-li Province; the silver of the Altai Mountains make the bangles that deck the anklets of the purdah women.

For America the road will open a commercial highway into the very heart of a new and expanding empire. American rails may carry American cars,--those ever moving shuttles which weave the woof of trade. American woolens and felts may protect the Siberians against their Arctic cold, American machinery mine and refine their gold. New England cottons, utilizing the Panama Canal, may

clothe the myriad coolies of interior China. Here is the mail-route of ten days from Paris to Peking, against the thirty-five days needed by the fastest ships. Here is the quickest passenger-route from London to Yokohama. All these potentialities lie as the fallow heritage of the Urga Road, if beyond Kalgan it is given its avenues to China and the sea. It is civilization that must profit when the equilibrium of the East is restored, and over the old Urga Road China is relinked to the West by the trains of the great Asian Railway.

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[Illustration: ASIA]

Transcriber's Notes:

Italics are shown thus: _sloping_.

Variations in spelling and hyphenation are retained.

Perceived typographical errors have been changed.

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